WIRELESS CHARGING

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CHAPTER 1

AN OVERVIEW OF WIRELESS CHARGING

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ABSTRACT:

A method known as wireless charging allows electricity to be sent to electrical equipment for energy recharging across an air gap. The introduction of commercial goods and subsequent advancements in wireless charging technologies have offered a viable alternative approach to the energy shortage experienced by typically portable battery-powered electronics. Yet integrating wireless charging into the current wireless communication networks also introduces a number of complex problems with respect to scheduling, implementation, and power management. In this post, we provide a thorough review of wireless charging methods, technical standard advancements, and their most current breakthroughs in network applications. We examine the static charger scheduling algorithms, mobile charger dispatch strategies, and wireless charger deployment strategies specifically with relation to network applications. We also talk about the problems and difficulties in deploying wireless charging technology. Lastly, we consider several realistic wireless charging uses for networks in the future.

KEYWORDS:

Charging, Electricity, Mobile,Networks Wireless Charging.

INTRODUCTION

The technology of wireless charging, sometimes referred to as wireless power transfer, allows a power source to communicate electromagnetic energy to an electrical load over an air gap without the need of cables. Due to its simplicity and improved user experience, this technology is attracting a broad variety of applications, from low-power toothbrushes to high-power electric automobiles. Nowadays, wireless charging is quickly moving from ideas to commonplace features on manufactured goods, particularly portable smart gadgets and cell phones. Several top smartphone producers, including Samsung, Apple, and Huawei, started releasing new models in 2014 that had built-in wireless charging. By 2016, IMS Research predicted that the market for wireless charging will be worth 4.5 billion. According to Pike Research, the market for wireless powered items will quadruple to $15 billion by 2020 [1].

As compared to conventional corded charging, wireless charging offers the following advantages.

1. Firstly, it improves user-friendliness as the hassle from connecting cables is removed. Different brands and different models of devices can also use the same charger.
2. Secondly, it renders the design and fabrication of much smaller devices without the attachment of batteries.
3. Thirdly, it provides better product durability (e.g., water- proof and dustproof) for contact-free devices.

4. Fourthly, it enhances flexibility, especially for the devices for which replacing their batteries or connecting cables for charging is costly, hazardous, or infeasible.
5. Fifthly, wireless charging can provide power requested by charging devices in an on-demand fashion and thus are more flexible and energy-efficient.

Nevertheless, compared to wired charging, wireless charging often has greater implementation costs. The regular charging cable must be replaced with a wireless charger first. A wireless power receiver must be implanted inside a mobile device, second. Also, as wireless chargers often emit more heat than conventional chargers do, extra costs for crafting supplies may be required.

Radiative wireless charging (also known as RF-based wireless charging) and non-radiative wireless charging are the two main ways in which wireless charging technologies are moving (or coupling-based wire- less charging). Electro- magnetic waves, most often RF waves or microwaves, are used in radiant wireless charging as a channel to provide energy in the form of radiation. The electromagnetic wave's radiative electric field provides the basis for the energy transfer. Radiative wireless charging typically functions in a low power zone because of the safety concerns posed by RF exposure . Omni-directional RF radiation, for instance, is only appropriate for sensor node applications with 10mW or less of power consumption. Instead, then using radiation to transmit energy, non-radiative wireless charging relies on the coupling of the magnetic field between two coils inside the coils' dimension. The power transmission distance is significantly constrained because the magnetic field of an electromagnetic wave attenuates considerably more quickly than the electric field. Non-radiative wireless charging has been embraced by a large number of our everyday gadgets, ranging from toothbrushes to electric car chargers, due to safety implementation[2].

Wireless network that harvests RF energy

Study of RF energy harvesting foundations and circuit design, resource allocation plans and communication protocols for various RF-powered wireless network types, as well as real-world difficulties and future prospects. Energy transfer and cooperation as an emerging paradigm that can happen separately or in tandem with information transfer, as well as energy consumption models for energy harvesting communication systems, all affect the performance of wireless networks with energy harvesting information-theoretic physical layer performance limits to transmission scheduling policies and medium access control protocols. Sensor node that can collect energy Study of designs, power and storage sources, and applications for sensor nodes that gather energy. Devices that capture ambient energy use a range of energy harvesting methods, numerous energy harvesting models, as well as power management and networking features [2].

Basics and designs of RF/microwave energy harvesting circuits, as well as the effectiveness of energy conversion in current RF energy harvesting circuit implementations of emerging wireless charging systems with regard to foundational technologies, global standards, and applications in wireless communication networks In our earlier work, we reviewed research topics in RF-powered wireless networks with an emphasis on receiver-side (also known as energy harvester) devices. As compared to , this survey is different in the following ways: Inductive coupling, magnetic resonance coupling, and RF/microwave radiation are the three major wireless charging techniques covered in this survey. It also reviews current international standards, commercialization, and implementations. Finally, it focuses on transmitter-side (i.e., wireless charger) strategy designs for various network applications. From the perspectives of information theory, signal processing, and wireless networking, a new review offers an overview of self-sustaining wireless communications using various energy harvesting approaches. In contrast, the emphasis of this study is on wireless charging techniques for communication networks that can also include wireless energy harvesting, or wireless powered communication networks (WPCNs)[3].

Also, pertinent viewpoints in energy harvesting research were addressed in existing literature, primarily from the standpoint of device-level methods and hardware implementations. The authors provided an overview of the various energy harvesting methods used by sensor nodes in. Reference focused on methods for obtaining energy from ambient light. In their study, the authors looked into RF/microwave energy harvesting circuit design and examined how energy-efficient the most recent implementations were. The major design concerns for wireless charging systems and summarises the primary contributions and breadth of the relevant available survey articles. We begin by giving a succinct overview of the evolution of wireless power transmission, including its theoretical underpinnings, technological innovations, and most recent commercialization developments. The introduction of models for magnetic-field propagation follows the presentation of an overview of current wireless charging technologies and their applications in Section III. We also examine how various wireless charging solutions are implemented in hardware. The specs of the top worldwide wireless charging standards are then thoroughly explained in Part IV. These standards' actual implementations are also described. Next, in Sections V, VI, and VII, respectively, we explore network applications such as static charger scheduling techniques, mobile wireless charger dispatch strategies, and wireless charger deployment strategies. In Section VIII, we also discuss several unexplored avenues for further study into the use of wire-free charging systems. We also see some potential network uses in the future. Part VIII brings the survey to a close[4].

Electric current creates a magnetic field everywhere around it, as H. C. Oersted found. Then, in order to represent certain basic characteristics of magnetic fields, Ampere's Law, Biot-Law, Savart's and Faraday's Law were developed. The Maxwell's equations, which were first presented in 1864 to describe how electric and magnetic fields are produced and changed by one another, are then followed. The study of electricity and magnetism was later brought under one umbrella in 1873 with the release of J. C. Maxwell's book A Treatise on Electricity and Magnetism . Since then, it has been shown that the same force controls both magnetic and electricity. The theoretical underpinnings of electromagnetism were built by these revolutionary developments.

Together with two key study areas on the electric field and magnetic field, history has seen a number of significant technological advancements. In order to transport electricity across a small gap, H. R. Herts employed an oscillator coupled to induction coils in 1888. This was the first-time electromagnetic radiation was experimentally verified to exist. The pioneer of alternating current electricity, Nikola Tesla, was the first to test wireless power transmission using microwave technology. In 1896, he discovered the transmission of microwave signals over a distance of around 48 kilometres while concentrating on long-distance wireless power transfer. Another significant development was the transmission of 108 volts of high-frequency electric power across a distance of 25 miles in 1899, which was used to power an electric motor and 200 light bulbs. Tesla's technique, nevertheless, had to be put on hold since generating such high voltages in electric arcs would have fatal effects on nearby people and electrical equipment [5].

By developing the renowned "Tesla coil" at this time, Tesla also made a significant contribution to the advancement of the magnetic field. Tesla built the Wardenclyffe Tower, seen in Figure 3b, in 1901 to transmit electrical electricity via the ionosphere cordlessly. Nevertheless, the concept has not been extensively further developed and marketed owing to technological limitations such as poor system efficiency caused by a large-scale electric field. Later, in the 1920s and 1930s, magnetrons were developed to transform energy into microwaves, enabling long-distance wireless power transmission. Microwaves could not, however, be converted back to electricity. As a result, efforts to produce wireless charging were given up.

W. C. Brown, who is credited with being the primary engineer behind practical wireless charging, didn't comprehend the conversion of microwaves to energy through a rectenna until 1964 By using a miniature helicopter to show the viability of microwave power transmission, Brown stimulated further research on microwave-powered aircraft in Japan and Canada in the 1980s and 1990s. In 1975, Brown used the Venus Site of JPL's Goldstone Facility to beam 30kW across a distance of 1 mile at 84%, as shown in Figure 3d. Another catalyst for long-distance microwave power transmission is the 1968-launched Sun Power Satellite (SPS). The idea is to put a large SPS in geostationary Earth orbit to gather solar energy and return it to the planet through an electromagnetic beam. Throughout the 1970s and 1980s, NASA's SPS Reference System project stimulated a wealth of technological advancements in large-scale microwave transmission. Coupling-based technologies also had modest development at this time. While inductive coupling was effective and extensively used in the 1960s for low-power medical applications, there were few technological advances.

The market need for portable electronic devices was principally responsible for the recent increase in interest in wireless charging research. Due to the increasing growth of portable electronic gadgets in the 1990s, commercialised wireless charging products started to appear. Progress is being made in both near-field and far-field based wireless charging methods. Mid-range non-radiative wireless charging was shown to be efficient and practicable via testing with the Witri city technology that Kurs et al. presented in 2007. Moreover, marketed radiative wireless charging technologies include the Cota system, PRIMOVE, and Powercast wireless rechargeable sensor system.

Several organisations have more recently been formed to provide global standards for wireless charging, such the Wireless Power Consortium (WPC), Power Matters Alliance (PMA), and Alliance for Wireless Power (A4WP). Several electrical goods on the market today, including wireless chargers and smart phones, have followed these standards. A ground-breaking innovation called magnetic MIMO (MagMIMO), shown in Figure 3h, was developed at the end of 2014 and is based on magnetic waves to accomplish multi-antenna beam formation. This method has created a new field of study for magnetic-field beam formation. The development of wireless charging continues after that. The reader might consult for a more thorough history of development.

The fundamentals of charging approaches, current wireless charging applications, and charging system designs in terms of architectures, hardware designs, and implementations are covered in this part as well as some basic understanding of wireless charging. For non-radiative charging systems, we also offer the wireless power propagation models. Radiative RF-based charging and non-radiative coupling-based charging are two major categories for wireless charging methods. The latter may be further divided into directive RF power beamforming and non-directive RF power transfer, while the former comprises of three techniques: inductive coupling, magnetic resonance coupling, and capacitive coupling. The possible coupling capacitance in capacitive coupling depends on the device's accessible area. A difficult design restriction is imposed since it is difficult to create enough power density for charging a typical-sized portable electronic gadget. The restriction of directional RF power beam formation is that the charger must be aware of the precise position of the energy receiver. Wireless charging is often accomplished through the other three approaches, namely magnetic inductive coupling, magnetic resonance coupling, and non-directive RF radiation, because to the apparent limitations of the first two methods.

As the created electromagnetic field predominates in the area immediately around the transmitter or scattering object, the magnetic inductive and magnetic resonance coupling operate in the near field. According to the cube of the reciprocal of the charging distance, the near-field power is attenuated. As an alternative, microwave radiation operates on a further field. According to the square of the charging distance's reciprocal, the far-field strength diminishes. Also, the transmitter is unaffected by radiation absorption in the far-field approach. In contrast, the load on the transmitter is affected by the radiation absorption for near-field approaches. This is due to the fact that the far-field approach does not connect a transmitting and receiving antenna. For the near-field approaches, a transmitting coil and a receiving coil are connected.

Coupling Inductively: Magnetic field induction provides electrical energy between two coils via inductive connection. When a main coil of an energy transmitter creates a primarily changing magnetic field across a secondary coil of an energy receiver within the field, often shorter than a wavelength, this is known as inductive power transfer (IPT). The secondary coil of the energy receiver within the field then induces voltage/current due to the near-field magnetic power. At this voltage, a wireless gadget or storage system may be charged. Inductive coupling generally operates at frequencies in the kilo Hertz region. To improve charging efficiency, the secondary coil should be adjusted at the working frequency. Since the transmitted power rapidly diminishes for greater quality values, the quality factor is often specified in modest values, such as below 10. Since high quality variables are not compensated, the effective charging distance is often less than 20 cm. Radio frequency identification (RFID) that is inductively linked is one example that extends the charging distance limit to tens of centimetres at the expense of decreased efficiency with received power in the micro watt range. Despite the short communication distance, extremely high charging powers may still be achieved (e.g., kilowatt level for electric vehicle re-charging)[6].

The simplicity of installation, convenience of use, high efficiency at close ranges (usually less than a coil diameter), and safety assurance are all benefits of magnetic inductive coupling. It is thus appropriate for and widely used on mobile devices. MagMIMO is a unique wireless charging technique that MIT researchers recently revealed the development of. It can charge a wireless device from up to 30cm away. MagMIMO is said to be able to identify and direct a cone of energy towards a phone even when it is tucked away in a pocket. Resonance Magnetic Coupling: Evanescent-wave coupling, which creates and transmits electrical energy between two resonant coils via fluctuating or oscillating magnetic fields, is the foundation of magnetic resonance coupling. Strong coupling between two resonant coils that are running at the same resonant frequency allows for great energy transfer efficiency with little leakage to non-resonant externalities. For instance, it was shown that a modern prototype could transmit electricity at a maximum efficiency of 92.6% across a distance of 0.3 cm. Magnetic resonance coupling also benefits from immunity to the surrounding environment and a necessity for line-of-sight transmission due to the resonance feature. Earlier experiments using magnetically linked resonators have shown their capacity to transmit power more efficiently and across greater distances than inductive coupling or RF radiation. One transmitting resonator and several receiving resonators may also be coupled via magnetic resonance. As a result, it permits the simultaneous charging of many devices[7].

The quality factors are often high since magnetic resonance coupling typically works in the megahertz frequency range. The high quality factor works to reduce the steep decline in coupling co efficiency and, therefore, charging efficiency as charging distance increases. As a result, it is feasible to increase the effective power transmission distance to the metre range. Witricity, a very effective mid-range wireless power transmission system put out by MIT researchers in 2007, is based on tightly coupled magnetic resonance. According to reports, wireless power transfer has a transmission efficiency of roughly 40% and can illuminate a 60W bulb across a distance of more than two metres. When the transmission distance is one metre, efficiency rose to 90%. A Witricity receiver, however, cannot be made smaller since it needs a spread capacitive coil to function. This is a significant obstacle for the integration of Witricity technology into portable devices. By adjusting linked resonators of several receiving coils, magnetic resonance coupling may charge multiple devices simultaneously. It has been shown that doing this increases efficiency all around. Proper tuning is necessary because mutual coupling of receiving coils might cause interference.

DISCUSSION

RF Radiation: To transmit radiant energy, RF radiation uses dispersed RF/microwave. Line-of-sight RF/microwave transmissions often travel across space at the speed of light. RF and microwave frequencies typically fall between 300MHz and 300GHz. Other electromagnetic waves, such infrared and X-rays, may be used for the energy transmission. They are not often utilised, nevertheless, because of the safety concern. A microwave power transmission system's design. The AC-to-DC conversion is the first step in the power transmission process. The transmitter side then does a DC-to-RF conversion. The RF/microwave that was sent across the air is caught by the receiving antenna and converted back into electricity using a process known as RF-to-DC conversion.

The capture power density at the receive antenna, the accuracy of the impedance matching between the antenna and the voltage multiplier, and the power efficiency of the voltage multiplier that converts the received RF signals to DC voltage all have a significant impact on the RF-to-DC conversion efficiency. The RF-to-DC conversion efficiency was shown to be reached at 62% and 84% for a total -10dBm and 5.8dBm input power, respectively, using a state-of-the-art implementation. You may find a more thorough analysis of the conversion effectiveness of RF energy harvester implementations in. Moreover, a closed-form mathematical characterisation of the maximum output power and energy-conversion efficiency for an energy-harvesting circuit has been offered from the standpoint of the theoretical analysis[8].

With beamforming, the RF/microwave radiation may be directed either isotropically or in a specific direction. For broadcast purposes, the former is more appropriate. Energy beamforming, which transmits electromagnetic waves for point-to-point transmission, may increase the effectiveness of power transmission. An antenna array or aperture antenna may produce a beam. With more transmit antennas, energy beamforming becomes more precise. Sharpness may be improved by using large antenna arrays. Commercial items have also entered the market as a result of the current development. Examples of devices that support 1W or 3W isotropic wireless power transmission include the Powercaster transmitter and Powerharvester receiver.

In addition to a larger transmission range, microwave radiation has the benefit of being compatible with current communications systems. It has been suggested that using microwaves would allow for simultaneous energy and information delivery. Although microwave's radiation and vibration are utilised to transmit energy, its amplitude and phase are employed to alter information. Simultaneous wireless in- formation and power transmission is the name given to this idea (SWIPT). Advanced smart antenna technologies used at the receiver side have been developed to handle SWIPT and provide a good trade-off between system performance and complexity. On the other hand, given of its affordability and applicability, the deployment of dedicated power beacons layered with current communication systems has also been suggested as an option. Nevertheless, because to the health risks associated with RF radiation, the power of beacons should be limited in accordance with RF exposure laws, such as those set out by the Federal Communications Commission (FCC) and the IEEE C95.1-2005 standard, as well as the maximum allowable exposure levels. Hence, to power hand-held cellular mobiles with less power and across a shorter distance, a dense deployment of power beacons is needed. In this paragraph, we present the current uses of wireless charging with relation to near-field and far-field techniques in order to better illustrate the many and potential applications of this technology.

Applications for near-field charging may be accomplished via magnetic resonance coupling and inductive coupling. Most of the applications now in use have predominantly employed inductive coupling due to its simplicity and inexpensive implementation costs. As IPT can enable high power transmission over the kilowatt level, industrial automation uses it extensively. Robot manipulation, autonomous underwater vehicles, induction generators, and induction motors are some of the main uses. High-power IPT has also been used to provide on-demand power for public transportation, including high-speed trains, monorail systems, people-movers, and railway-powered electric vehicles. Kilowatts to thousands of kilowatts of electricity may be transported. For instance, a 100kW output power with 80% power efficiency is achieved across a 26cm air gap using the online electric vehicle system.

Powering the battery of electric vehicles (EVs), especially plug-in hybrid electric cars, is another commonly used high-power charging application (PHEVs). Since the 1990s, inductive coupling has been used to charge EVs. Vehicle-to-grid electricity has been made possible by the development of inductive chargers that can operate in both unidirectional and bidirectional directions. Generally, 1–10kW of power delivered through a 4–10mm gap results in a charging efficiency of over 90%. You may read an overview of the current developments in EV inductive charging in. Magnetic resonance coupling-based charging solutions for electric vehicles have also recently been tested and shown to work. Magnetic resonance coupling-based EV chargers provide longer charging distances while also being more efficient than inductive chargers. For instance, over 95% efficiency is achieved in the testing in over a 22.5 cm air gap.

The medium-power near-field charging, which has an operating power of several to 10 watts, has mostly been used with medical equipment and household appliances. Inductive coupling-based biomedical implant concepts have been shown in. Across a 10mm air gap, the most recent implementation may reach a charging efficiency that is over 50% overall. For biomedical implants, magnetic resonance coupling-based charging demonstrates stronger penetrating ability. Magnetic resonance coupling permits reduced implanted device size with a typical charging range since the charging distance is much greater than the coil dimension. As shown in, a charging efficiency of more than 60% may be achieved at a distance of 20 cm when using a 3 cm transmit coil and a 2 cm receive coil. In surroundings with biotissue, the most advanced implementation may provide charging efficiencies of above 70%.

The majority of uses for everyday appliance powering are for portable and home electronics. Examples of domestic appliances include an inductive toothbrush, a TV, illumination, a wall switch, and a heating system. Variant standard conforming wireless chargers for portable devices, such as Avower's Qi charger, Verizon Qi charger, Duracell Power mat, Energizer Qi charger, ZENS Qi charging pad, and Airpulse charging pad, have been created and made available for purchase. Oil well, offshore energy harvesting, coal mines, electric bikes, sensors, wearable technology, implantable systems, light-emitting diode (LED) displays, power line communication, and smart grid are further current near-field charging uses.

Long-range Charging: Either directional RF beamforming or non-directive RF radiation may be used to implement far-field charging devices. Without a direct line of sight, non-directive RF radiation may be transmitted and is less sensitive to the location and orientation in relation to the transmit antenna. Unfortunately, the charging efficiency that was achieved was not very high. The most extensively used applications for non-directive charging are low-power wireless systems like RFID systems and wireless renewable sensor networks (WRSNs). Low duty cycle WRSNs may operate continuously with typical RF power levels in the 20–200 W/cm2 range. For instance, the authors of created a far-field charging ultra-low power sensor platform. To obtain a data rate of 500kbps, the constructed sensor transmitter and receiver need 1.79mW and 0.683mW of power, respectively. Both sensors with batteries and sensors without batteries have been claimed to use similar system designs with a specialised wireless charger. Wireless charging devices based on ambient energy gathering have also been developed as an alternative to specialised wireless chargers. The creation of self-recharging sensing platforms that capture RF signals from satellite, cellular base stations, WiFi routers, amplitude modulated (AM) radio broadcast, TV broadcast, and radio has been documented in the literature.

Other contexts, such as wireless body area networks (WBANs), also use RF-powered sensors (e.g., for health-care monitoring). Wearable and implantable WBANs, which are placed on or within the human body, may be broadly categorised into these two categories. Wearable WBAN concepts and implementations without batteries have been documented. The power consumption of body sensors is often in the tens of milliwatts, and the charging efficiency is in the range of a few percent. In contrast, implanted sensors that are firmly embedded into body organs produce a charge efficiency that is often less than 0.1%. As shown in, conventional implanted sensors may be powered from tens of centimetres distant using a micro-watt level RF power source. Also, the safety concerns related to implant device RF powering have been looked at. Machine-to-machine (M2M), Internet of Things (IoT), smart grid, and other systems have also been equipped with RF-powered sensors[9].

It is possible to support electronic equipment with higher power consumption by using directive RF beamforming. During the 1960s, as microwave technology has advanced, ultra-high power transmission systems capable of transmitting hundreds of kilowatts have been created. It is not uncommon to supply high power across great distances using microwave beamforming methods. For example, the 1975 Goldstone microwave power transfer experiment, which was run at 2.388GHz, was able to transmit 30kW with a 450kW beam power across a distance of 1.54 kilometres. A group of massive wireless charging systems, including SPS, unmanned aerial vehicles, microwave-driven unmanned vehicles, high altitude electric motor powered platforms (HAPP), Raytheon Airborne Microwave Platform (RAMP), and stationary high altitude relay programme, have also been accelerated by far-field microwave beamforming (SHARP)[10].

CONCLUSION

Microwave beamforming has been used more recently to remotely power EVs due to the growing market penetration of EV/PHEVs. A prototype has been developed and studied in which a roadside transmitter is used to recharge an EV. The designed rectenna is shown to correct 10kW power with an RF-DC conversion efficiency of more than 80%. In the last ten years, medium-power directed RF beamforming applications have emerged for recharging portable electronics. One example is the marketed Cota system, which can transmit a power beam up to 30 feet away without a transmission connection that requires line-of-sight. In cellular networks, RF power beacons have also been recommended as a way to power mobile devices. Nevertheless, further experimental testing is need to determine the viability. We have given an overview of the main wireless charging methods and their uses in the two subsections above. The non-radiative propagation model and hardware design for non-radiative charging devices will be discussed in detail in the next two subsections. The reader may consult for additional in-depth details on current developments in radiative charging systems.

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CHAPTER 2

WIRELESS CHARGING SYSTEM

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ABSTRACT:

In this subsection, we present an overview of wireless charging system in the aspects of architectures, hardware designs and implementations. Architecture shows a block diagram of a general non-radioactive wireless charging system. The transmitter side consists of an AC/DC rectifier, which converts alternating current (AC) to direct current (DC); a DC/DC converter, which alters the voltage of a source of DC from one level to another; and a DC/AC inverter, which changes DC to AC. The receiver side is composed of i) an AC/DC rectifier, which converts high-frequency AC into DC, ii) a DC/DC converter, which tunes the voltage of the DC, and a load for charging applications.

KEYWORDS:

Alternating Current (AC), Direct Current (DC), Charging, Electricity, Mobile,Networks Wireless Charging.

INTRODUCTION

The way that wireless charging works is as follows. The AC/DC rectifier must first be activated by a power supply. The charger raises the AC frequency by first converting the AC to DC, then increasing the voltage of DC, and then converting the DC back to high-frequency AC power since the commercial AC used in the globe runs either at 50Hz or 60Hz frequency, which is too low to drive wireless charging. AC is generated at the receive loop coil, which is spaced apart from the transmit coil by an air gap, as the high-frequency AC that flows through the transmit loop coil induces a magnetic field around it. After that, the energy receiver changes the induced AC to DC and reshapes it to the voltage needed by the load. The electronic device's battery may thus be recharged at the load[1].

Systems with inductive coupling typically use one of four fundamental topologies: series-series, series-parallel, parallel-series, and parallel-parallel. The ways in which these topologies use the circuit's compensating capacitance vary. A second series inductor used in parallel-series and parallel-parallel converters regulates the inverter current coming into the parallel resonant circuit, increasing converter size and cost. Additionally, depending on the coupling and quality variables, these two topologies have varying resonant capacitance values. Series-series and series-parallel topologies are thus more often used. You may see a performance comparison between these four compensation topologies in. In contrast, parallel and series pattern circuits are the two primary kinds of magnetic resonance coupling system input ports. To produce a substantially greater value of the induction coil, the series pattern and parallel pattern circuits should be used, respectively, when the system operating efficiency is high and low.

The two-coil system architecture is what inductive coupling systems often use, as seen here. In contrast, magnetic resonance coupling makes use of a wider variety of system designs. The use of magnetic resonance coupling has been expanded to include four-coil systems with impedance matching, relay resonator systems, and domino-resonator systems. In 1998, the four-coil system was originally suggested. Figure 8 depicts the structure's components, which include an excitation coil, a transmit resonator, and a load coil on the receiver side. Two additional mutual coupling coefficients, namely those between the transmit resonator and load coil and the receiving resonator and excitation coil, are required when the excitation coil and load coil are used. The two additional coefficients provide more flexibility in spreading the transmission distance as compared to the two-coil method. Nevertheless, due of the necessity for independence matching, the total transfer efficiency will not be more than 50%. [209] contains a thorough examination of the four-coil system's circuitry as well as optimizations for independent matching and charging power.

Between the transmit coil and receive coil, an additional relay resonator is placed to create the relay resonator system. At 115.6 kHz operating frequencies, optimization and experimental assessments of this system have been carried out. Domino-resonator systems may be created by connecting many nearby resonator relays between the transmit and receive coils in order to significantly increase the transmission range of relay resonator systems. Resonator relay placement is quite versatile and may be done in a variety of domino configurations, where I, N, and r stand for current, number of turns, and radius of transmit coil, respectively[2].

It goes without saying that increasing the transmit coil's radius and turn count will increase intensity. The size of the coil and the number of turns, however, cannot be increased indefinitely since they must be adjusted for the transmission frequency and resistances. The receive coil should be made with a low impedance to best catch the energy that was delivered from the transmit coil. The mutual inductance between two coils, the quality factor Q, and the load matching factor all have a significant role in the efficiency of power transmission in a non-radiative charging system. A coil pair's mutual inductance shows how changes in one coil affect the induced current in the other coil. With the use of a coupling coefficient, the mutual inductance between a pair of coils is proportional to the geometric mean of the self-inductance of the two coils. The alignment, distance, ratio of diameters, and form of the two coils all affect the coupling co-efficiency, which measures how tight the coupling is.

The ratio of the energy stored in the resonator to the energy supplied by a generator is known as the quality factor Q. A lower rate of system energy loss during power transmission is indicated by a higher Q. As a result, the oscillation/resonance reduce gradually in a high Q power system. Self-inductance, resistance, and intrinsic frequency, which mostly rely on the materials used in fabrication, have an impact on the quality factor. The distance is the major determining element for load matching. The load matching factor gauges how closely the resonance frequencies of a coil pair are matched since the resonance frequencies fluctuate as the distance changes. The literature has suggested a number of strategies, including coupling manipulation, frequency matching, impedance matching, and resonator parameter tuning, to adjust the load matching factor for sustaining resonant frequency matching at variable distances.

We display some of the most recent hardware for magnetic resonance coupling systems and IPT systems, respectively, in Tables IV and V. It has been shown that IPT systems can reach 50% to 80% charging efficiency within a few centimetres of a charging distance. With an effectiveness of between 50% and 90%, charging distances for magnetic resonance coupling systems reach several decimeters.

Wireless Power Propagation Models

The models for RF propagation in the distant field are widely established in the literature. The introduction to the characterisation of near-field magnetic wave propagation is the main goal of this subchapter. Starting with the fundamental single-input, single-output (SISO) setup of the magnetic induction model, we proceed. The model is then expanded to include setups for single-input-multiple-output (SIMO), multiple-input-single-output (MISO), and multi-input multi-output (MIMO)[3].

Figure 9a depicts the SISO magnetic induction mechanism. Let rt and rr stand for the corresponding radii of the coils on the transmitter and receiver. d is a measure of the separation between the two coils. The resonance angular frequency at which the two coils are coupling is denoted by the symbol o. Then, Lt and Lr are the respective self-inductances of the two coils at the transmitter and receiver, and o = LtCt = Lr Cr. The mutual inductance is M, and the two resonant capacitors are Ct and Cr. Rt and Rr, respectively, stand for the transmit and receive coil resistances[4]. The letters RS and RL, respectively, stand for the impedances at the source of the transmitter and the load of the receiver. The AC source voltage between the two coils may be represented as follows using Kirchoff's voltage law:

The receive power at the receiver's load may be calculated as follows, simplified from: Moreover, k(x) stands for the coupling coefficient between the two coils. The mutual inductance, represented as M, and the self-inductance of the transmit and receive coils, which may be calculated using the following calculation, determine the coupling coefficient. Let Nr stand for how many coils there are in the energy receivers. Similar to the MISO system, all of the energy receiving coils are connected with the charger's coil at resonant frequency. A fraction of the energy from the charger is captured by the coil in each receiver. The charger's coil m is supplied the receive power at the load of the receiver m 1... Nr, accordingly. The symbol Dm denotes the separation between the receiver's coil and the charger's coil [5].

Then, the total transferred power can be calculated as follows:

- **MISO:**The reference model for point- to-point transmission with MISO channel. Let Nt represent the number of transmit coils. At resonant frequency, each coil of a charger is coupled with that of the energy receiver. The power delivered to the receiver from the charger’s coil n ∈
- **MIMO:** Let kn,m and dn,m denote coupling co- efficiency and distance between the transmit coil n and receive coil m, respectively. In the point-to-point MIMO transmission model, as shown in Figure 9d, the receiver receives the power from each individual transmit coil separately. The crosstalk between the transmit coils and receive coils is small. The receive power at the load of the receive coil m ∈ {1, . . . , Nr} factor, and efficiency of the charger’s coil n, respectively[6], [7].

Several wireless charging protocols have been suggested, where Dn stands for the distance between the charger's coil n and the device being charged. Two of the most popular standards supported by major smartphone makers are Qi and A4WP. An overview of these two standards is provided in this section. The authority that was transferred may be summed up as follows: Figure 10a shows a system model. Between a wireless charger and a charging device, the Qi standard guarantees compatible wireless power transmission and data exchange. Qi enables the charging process to be managed by the charging device. The Qi-compliant charger may modify the transmit power density in response to the charging device's signalling requests[8]–[10].

CONCLUSION

120W of power in the medium-power category is available in the 80–300 kHz frequency range. A Qi wireless charger often features a flat surface known as a charging pad that a mobile device may be placed on top of. As was already noted, a key element in the effectiveness of inductive charging is coupling tightness. A mobile device must be firmly positioned in precise alignment with the charger in order to ensure tight connection. Qi outlines three distinct methods for achieving alignment.

A charging device should be put according to a fixed-positioning charging guide in order to achieve a precise alignment. The Qi standard uses a magnetic attractor to direct the mobile device into a fixed spot. This alignment method is advantageous in that it is straightforward, but it also calls for the incorporation of a piece of material that is attracted to a magnet in the charging device. The magnetic attractor will experience eddy-current-related power loss (and consequent temperature increase). Another one-to-one charging method that may localise the charging device is free-positioning using a moveable main coil. A mechanically moveable primary coil that can adjust its location to make connection with the charging device is needed for this method. Either inductive or capacitive methods may be used to accomplish this. If the charging station is made to fit only one device, then this alignment strategy is easy to execute. Yet, because of the moveable mechanical parts, the systems are often less dependable.

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CHAPTER 3

PRIMARY COILS CAN BE COMPLICATED AND COSTLY

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ABSTRACT:

Free-positioning with coil array, demonstrated in, allows multiple devices to be charged simultaneously irrespective of their positions. The Qi specification endorses the “vertical-flux” approach, which utilizes the whole charger surface for power transfer without any restriction on the orientation of the secondary coil. For example, this free-positioning approach can be applied based on the three-layer coil array structure. Compared with the above two approaches, this alignment approach offers more user-friendliness, at the expense of more costly and complex winding structure and control electronic element. The Qi-compliant wireless charging model supports in- band communication. The data transmission is on the same frequency band as that used for the wireless charging.

KEYWORDS:

Charging, Electricity, Mobile,Networks Wireless Charging.

INTRODUCTION

The Qi wireless charger will change its power output to accommodate the charging device's needs and will stop power transmission once charging is complete. The procedure operates as follows.

1. **Start:** A charger senses the presence of a potential charg- ing device.
2. **Ping:** The charging device informs the charger the re- ceived signal strength, and the charger detects the re- sponse.
3. **Identification and Configuration:** The charging device in- dicates its identifier and required power while the charger configures energy transfer.
4. **Power Transfer:** The charging device feeds back the control data, based on which the charger performs energy transfer.

A4WP seeks to provide wire-less power with spatial mobility. This standard suggests using magnetic resonance coupling to produce a bigger electromagnetic field. The A4WP standard does not need exact alignment and even permits spacing between a charger and charging devices in order to achieve spatial flexibility. A few metres is the maximum charging distance. Moreover, many devices may be charged simultaneously at various power requirements. Foreign items may be put on an active A4WP charger without having any negative effects, which is another benefit of A4WP over Qi. As a result, the A4WP charger may be integrated into any item, increasing deployment flexibility. The A4WP-compliant wireless charging reference model is seen in Figure 10b. Power transmitter unit (PTU) and power receiving unit make up its two halves (PRU). From the PTU to the PRU, which is managed by a charging management protocol, the wireless power is transmitted. To assist manage the charge, the PRU and PTU conduct feedback signalling. The 6.78MHz Industrial Scientific Medical (ISM) frequency spectrum is used to create the wireless power[1].

In contrast to Qi, control signalling uses out-of-band communication that runs on the 2.4GHz ISM band. Resonator and matching circuit components, power conversion components, and signalling and control components are the three major functional parts of an A4WP charger, also known as a PTU. One of the following function states is possible for the PTU: Configuration, during which the PTU performs a self-check; PTU Power Save, during which the PTU routinely monitors changes in the main resonator's impedance; PTU Low Power, during which the PTU creates a data connection with the PRU(s); PTU Power Transfer, which controls the transfer of power; Local Fault Condition, which occurs when any local fault circumstances, such overheating, affect the PTU, and PTU Latching Fault, which occurs when rogue objects are discovered, as well as when a system error or other failures, are reported.

The components for energy receiving and conversion, control, and communication are included in the A4WP PRU. The PRU is functionally in the following states: PRU Boot, when the PRU creates a communication connection with the PTU; PRU On, when the communication is carried out; Null State, when the PRU is under voltage; when there is a warning for an overvoltage, overcurrent, or overtemperature condition, the PRU system is in error; PRU System Error, which causes the power to be turned off when there is an issue[2], [3].

A4WP provides a communication protocol to allow wireless charging functions, much as the Qi standard does. A4WP-compliant systems use a Bluetooth Low Energy (BLE) connection for power level management, valid load detection, and non-compliant device protection. There are three phases in the A4WP communication protocol. Device recognition Ads are sent out by the PRU that has to be charged. Any advertising is met with a connection request from the PTU in return. The PRU pauses ad-vertising when any connection request is received. After that, a link is made between the PTU and PRU.

Information sharing

The following describes how the PTU and PRU exchange static and dynamic parameters. The PTU first receives and reads the status information from the PRU Static Parameters. The PTU then transmits the PTU Static Parameters to the PRU, describing its capabilities. The PTU receives and reads the PRU dynamic parameters, which include the functional status, voltage, current, and temperature of the PRU. The PTU then recommends to manage the charging process in the PRU Control. When PRU Control is selected and the PTU has enough power to satisfy the PRU's demand, charging control is started. Periodically, the PRU Dynamic Parameter is updated to provide the PTU with the most recent data, allowing the PTU to alter PRU Control as necessary. The PRU notifies the PTU of any system errors or complete charging events it has identified. The alert's cause is included in the PRU Dynamic Parameter [4].

Implementations of the International Charging Standards

Research has been done on prototype studies since the publication of these worldwide charging standards. The majority of current implementations are based on the Qi standard due to its simplicity and early introduction. We examine various hardware designs in the section that follows. In, the authors suggested a Qi-compatible charger for medical implants. A Bluetooth low-power communication module included into the charger enables remote management and monitoring of the devices. The technology allowed for remote control of the device's charging cycle, real-time battery monitoring, and system status collection. The prototype was shown to attain its maximum efficiency at roughly 75% when operated at over 3W output power. According to WPC Qi requirements, the authors of this study evaluated the performance of bidirectional wireless charging between portable devices. 70% charging efficiency was attained at a distance of 2mm with an output power of 2.5W both a wireless power receiver and a transmitter. The full-bridge resonant inverter and full-bridge variable voltage regulator form the architecture of the power converter. Discrete components and an integrated circuit were used to implement the prototype systems. According to the testing findings, a charging efficiency of 70% was attained at 5W output power and a 5mm charging distance. The design of a completely integrated Li-ion battery charger in compliance with the Qi standard was given by the authors in. The highest and average charging efficiencies of 83% and 79%, respectively, were attained with a constant current.

The authors presented a concept for a control unit and communication controller for guided positioning single receiver wireless charging platform, focusing on the alignment control. Using a serial communication interface, the control unit configures the reaction time values, the data transmitted between the charger and receiver pair, and the operation frequency. The communication controller's job is to start, watch over, and manage wireless charging. Moreover, in order to make the design adaptable in terms of reaction time and the amount of control data transmission, the authors included more data processing and storage capabilities. The hardware design complexity and internal power consumption of the power transmitter and receiver were proven to be reduced by the implementation. The authors have developed a concept based on a single-layer winding array to allow free-positioning simultaneous charging of several devices. The suggested method used mathematical packing theory to focus the charging flow within the covered charging space, allowing the devices to be placed freely (i.e., secondary coils). The results revealed that any position of the charging device was capable of achieving energy efficiency in the range of 86% to 89% [5], [6].

DISCUSSION

For Qi-compliant wireless power transfer applications, the authors in this study examined four distinct power management methods: voltage control, duty-cycle control, frequency control, and phase-shift control. The investigation showed that, despite the more expensive equivalent circuit, the two phase-shift control strategy beats the others. For 5W wireless charging, a system efficiency of 72% was achieved using phase-shift control. The charging methods for static chargers in WPCNs are covered in this section. Wireless devices in WPCNs can only communicate using energy that has been collected from wireless chargers. Two kinds of wireless chargers are often taken into account in WPCNs. An energy access point, the first kind, is specifically designed to provide wireless charging (E-AP). The second kind, known as a hybrid access point, may also handle data transmission and function as a data assessment point (D-AP) (H-AP). There are two main avenues for the study being done on WPCNs. The first path, which is the emphasis of this section, separates wireless power transfer from wireless information transmission to concentrate on exclusive wireless charging. The second avenue is SWIPT research, which combines wireless information transfer with charging to produce a trade-off. Many SWIPT experiments have been carried out in a variety of settings, including point-to-point channels, broadcast channels, relay channels, OFDMA channels, multi-antenna channels with additive white Gaussian noise (AWGN) or fading AWGN, opportunistic channels, and wiretap channels. Moreover, research on cooperative SWIPT in distributed systems has been conducted. We skip the discussion in this article since our earlier work in has already offered an extensive overview of the subject[7]. According to, there were four different kinds of system models that were taken into consideration in the literature.

1. **WPCN with H-AP:** This system model em- ploys an H-AP to perform downlink wireless charging to and receive information transmission from a user device.
2. **WPCN with dedicated E-AP:** In downlink wireless charging and uplink information reception are conducted separately by an E-AP and a D-AP, respectively.
3. **Relay-based WPCN with H-AP:** This system model has a relay to facilitate the uplink transmission from a device to the H-AP.
4. **WPCN with multi-antenna E-AP:** This system model adopts multiple antennas/coils at the E- AP to improve the charging efficiency by steering the energy beam spatially toward the direction of a device. The energy beamforming strategy is the main focus, while the information transmission is performed separately with

Wireless charging.

It should be noted that in WPCNs, a full-duplex H-AP enables concurrent wireless charging and data transfer in the downlink and uplink directions, respectively. A half-duplex H-AP, in contrast, requires coordination between wireless charging and data transmission of dispersed devices across various time intervals. A full-duplex device also needs out-of-band wireless charging, which is carried out on a separate frequency band from that used for data transmission. In-band wireless charging is supported by half-duplex devices; this frequency range overlaps with that used for data transmission. We examine the charging tactics in the following subsections based on the kinds of WPCNs they apply to.

Charging Strategies for Hybrid Access Point

The main challenge in a WPCN with an H-AP is resource allocation to increase the throughput that wireless powered devices can achieve. Both sought to increase the network's weighted sum-throughput. A harvest-then-transmit protocol was suggested by Reference, which initially planned for network devices to gather energy from wireless charging in the down-link. Next, using time division multiple access, the gathered energy is used to send distinct information to the H-AP in the uplink (TDMA). Based on the channel information and average energy harvesting rates of the users, the authors collaboratively optimised the time allocations for wireless charging and data collection at the half-duplex H-AP using this protocol. The optimum time allocations were determined in closed-form expressions by using convex optimization methods. The technology under consideration, however, showed a double near-far problem: consumers located distant from the H-AP get less energy while also needing greater power for uplink information transfer. The authors developed a performance metric called common-throughput to solve this problem, placing the restriction that all network devices must be allocated with the same throughput regardless of where they are located. Also, a simple bisection search-based iterative method was created to handle the common-throughput maximisation issue. The suggested iterative algorithm's utility in solving the doubly near-far issue is shown, albeit at the expense of sum-throughput deterioration.

Using a full-duplex H-AP as a reference. The authors jointly optimised the power and time allocation at the H-AP in the downlink, as well as the time allocation for the users in the uplink, to handle the maximising issue in the network under consideration. For the scenarios involving perfect and imperfect self-interference cancellation, the issue was shown to be convex and non-convex, respectively. As a result, the authors were able to determine both an optimum and a suboptimal solution for the combined allocation of time and power. It was discovered that customers with inferior channels and/or lower weights should have more power transmitted throughout their time periods. According to the simulation findings, full-duplex H-AP systems perform better than half-duplex ones when self-interference can be efficiently cancelled. Both took into account user devices with precise locations. By using a stochastic geometry technique, the authors in developed a fresh way to analysing the performance of devices that were randomly arranged. The author created a collaborative framework to optimise the uplink transmit power as well as the time partition between downlink energy transfer and uplink information transmission with the goal of maximising the system spatial throughput. The authors defined the likelihood of effective information transfer using the suggested paradigm. Also, the issues with spatial throughput optimization for both battery-free and battery-deployed scenarios were resolved. The effects of battery storage capacity on the system's spatial throughput were clearly shown by numerical data.

Reference examined the performance of cutting-edge greedy and round-robin scheduling algorithms in conjunction with the harvest-then-transmit protocol rather than focusing on multi-user scheduling optimization. For the smallest power outage probability, closed-form formulations were developed. In order to increase the spectral efficiency on a certain uplink channel with a 0% likelihood of a power loss, the authors adjusted the studied schemes next. It was shown that the changed versions performed better than the original ones in terms of user device fairness. The influence of the accumulated RF radiation from other cells was not taken into account since this research only looked at one cell.

The system models in utilised numerous antennas at the H-AP, unlike the previous three studies. By adjusting the energy beamforming weights, the multi-antenna H-AP may regulate the pace at which energy is sent to various devices. Maximizing the minimal throughput of all devices is the goal of. The authors developed a non-convex problem to concurrently optimise time allocation, downlink energy beamforming, uplink transmit power allocation, and receive beamforming in order to handle the doubly near-far dilemma. A two-stage approach might be used to acquire the best downlink energy beamforming and time allocation possible. Nevertheless, two poor designs were added to the suggested algorithm to reduce its high complexity as a result of the two-stage method's high degree of complexity. It was discovered that, in terms of max-min throughput, the performance of the suggested inferior alternatives approaches that of the ideal option[8].

Network driven by wireless technology with a hybrid access point. Network of wirelessly powered communications with independent energy and data access points. Network powered by wireless technology with relay and hybrid access an energy point access point with many antennas for wireless powered communication. With WPCN with a dedicated E-AP, the emphasis is on controlling the E-wireless AP's charging power to meet particular optimization goals.

The investigations' main goal was to get the highest possible throughput. The harvest-then-transmit methodology was taken into account by the writers. Under the constraints of energy, time, and information error rate, an optimization framework to balance the time length between energy harvesting and information transmission was devised. The answer was shown to be the best one. In contrast to the reference system, a full-duplex mode system was investigated. In this system, data transmission and energy harvesting were carried out via two distinct, time-varying channels. The authors suggested an effective technique to achieve optimum power allocation under the assumption that the information of both channels was a priori known and the user's battery capacity was infinite. By using numerical simulation, the performance difference between the system under consideration and a standard system with the same total power and random energy harvesting rate was investigated. The power distribution to several devices, however, remained unresolved since only one device was taken into account in this effort[9].

The system model in expanded that in by taking into account numerous hardware adoptions, including several antennas at an E-AP. The system sum-throughput maximisation issue, which simultaneously optimises time allocation and energy beam formation, was designed with TDMA in mind. The authors demonstrated the tightness and global optimality of the semi-definite relaxation approximation by reformulating a convex problem using the semi-definite relaxation approach. The authors also developed a quick semi-closed form solution, which was numerically shown to significantly lower implementation complexity[10], [11].

Reference presupposed the E-APs and devices opportunistically access the same channel for wireless charging and information transfer, in contrast to situations where wireless charging is deterministic. The system model took into account the power regulation of several E-APs with various wireless powered devices. In order to reduce energy usage while still meeting the necessary distortion level requirement at the D-AP, the authors suggested a power management method for the E-APs. The quantity of information transmitted by the gadget when it is being used relies on the energy usage. The tradeoff between estimate distortion, the number of E-APs, and their power level was described by simulation results.

CONCLUSION

Using incomplete channel state information, the authors of proposed a frame-based transmission technique for a huge MIMO system (CSI). Each time period is split up into many stages according to the procedure. The access point uses channel reciprocity from the pilot signals supplied by equipment during uplink transmission to first estimate the downlink channels. Thereafter, all gadgets are broadcast with RF energy. Finally, the devices simultaneously communicate each of their separate pieces of information to an access point using the energy they just gathered. By allocating time and energy more efficiently, the strategy optimises the minimum rate across all devices. Moreover, a measurement known as the massive MIMO degree-of-rate-gain was established as the asymptotic uplink rate normalised by the logarithm of the access point's antenna count. It was shown that, in relation to the suggested measure, the proposed transmission method is the best one. A common rate for all devices may also be attained asymptotically, which will ensure the greatest amount of fairness.

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CHAPTER 4

CHARGING STRATEGIES FOR MULTI-ANTENNA ENERGY ACCESS POINT

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ABSTRACT:

Charging Strategies for Relay with Hybrid Access Point.The main concern in relay-based WPCN is to design an operation protocol to coordinate data transmission and wireless charging for throughput maximization. The studies in analyzed different coopera- tive strategies for the relay to improve network performance. In the authors designed a harvest-then-cooperate pro- tocol. The protocol schedules the user device and relay to first harvest energy and then perform information transmission in the uplink direction cooperatively. For the case of single relay with delay-limited transmission, the authors derived the approximate expression for the average system throughput under the proposed protocol over a Rayleigh fading channel in closed-form. For the case of multiple relay nodes, the approximate system throughput under the proposed protocol with two different relay selection schemes was derived. It was demonstrated by simulations that the proposed protocol outperforms the harvest-then-transmit protocol in all evaluated cases.

KEYWORDS:

Alternating Current (AC), Direct Current (DC), Mobile,Networks, Wireless Charging.

INTRODUCTION

Reference also suggested two protocols for collaboration: energy cooperation and dual cooperation. With the former, a relay can only work with an H-AP to deliver downlink energy. The latter allows the relay to help the user device for uplink information transmission after first collaborating with the H-AP for downlink energy transfer. By concurrently planning the power allocation and time allocation, the authors were able to outline the challenges of system throughput maximisation. For both issues, the ideal solutions were found. Theoretical investigation showed that the approach is to always allow an H-AP and relay to transmit with the peak power regardless of the ideal time allocation in order to optimise system throughput under the energy cooperation protocol. Moreover, simulation results showed that the energy cooperation protocol outperformed the dual cooperation protocol when the signal-to-noise ratio (SNR) was high.

The construction of a beamforming method and/or CSI feedback system to increase wireless charging efficiency is the major focus of study for a multi-antenna E-AP. The strategies in this area, it should be noted, do not take information transmission-related difficulties into account. With the same goal of maximising the quantity of transmitted energy, investigations have looked into RF-based multi-antenna systems. For a point-to-point MISO system with shoddy CSI input, the authors of devised an adaptive energy beamforming strategy in. The system under consideration uses a frame-based protocol that initially assigns the receiver the task of channel estimation using the preambles sent by the transmitter before feeding the CSI estimation back to the transmitter. Then, beamforming is used to transmit the RF [1]energy from the transmitter. The authors took advantage of the tradeoff between transmit power allocation and transmit power duration as well as channel estimation duration and power transfer time to optimise the energy gathered. They started by calculating the ideal energy beamformers. Finally, for the scenarios with variable and fixed length preambles, respectively, an optimum online preamble length and an offline preamble length were determined. The channel estimate power and the ideal preamble length are used to determine how much transmit power to use.

The authors looked at the best channel acquisition architecture while taking into account a point-to-point MIMO energy beam-forming system. The E-AP determines the channel state based on channel reciprocity using a specialised reverse-link training signal from the user device. The research demonstrated the trade-off between wireless power transmission and training time in the energy beamforming system. Especially, a training period that is too brief reduces the channel state estimation's accuracy and, as a result, the energy beamforming gain. On the other hand, a prolonged training period increases the user device's energy consumption, which reduces the time available for energy transfer. The energy spent for channel training is normalised with the total energy captured to determine the net energy of the user device. The authors presented an ideal training design based on this trade-off to optimise the net energy of the user device. This suggested layout, however, is only appropriate for narrow-band flat-fading channels[2].

Consider more complex wide-band frequency selective fading channels, which, in comparison to their narrow-band equivalent, provide greater frequency-diversity gain for energy transfer efficiency. The authors devised a two-phase channel training technique to accomplish both the diversity and beamforming gain. Via the pilot signals supplied by the user device, the E-AP chooses a selection of sub-bands in the first phase that have the highest antenna sum-power increases. The E-AP then estimates the MISO channels in the second phase using just the extra pilot signals from the chosen sub-bands. The proposed technique is able to balance the possible frequency-diversity and energy-beamforming benefits with energy limited training, according to numerical findings. The quantity of energy gathered at the user device under the suggested two-phase training system was further deduced by the authors and expressed in closed form. This analytical conclusion shows that when the number of sub-bands approaches infinity, the quantity of captured energy is upper limited by a fixed value. This research, however, did not examine the situation with co-related channels; it solely took into account independent channels.

The coupling-based multi-coil system is the focus of the study, in contrast to the studies mentioned above. A near-field charging technology known as MagMIMO was created specifically for this purpose. It beam-forms a non-radioactive magnetic field to accomplish wireless charging. The channel estimate method was developed by the authors of using a measurement of the load that the receiver places on the transmitter circuit. In contrast to traditional communication systems, this one requires a multi-antenna transmitter to get channel information either by feedback or by inferring the reciprocal channels from listening to some signal from the receiver. The authors also developed a protocol that will enable MagMIMO to recognise the device's existence and its immediate load resistance based on the feedback data from the receiver. The results of the experiments showed that the MagMIMO enabled much greater effective charging distances while using less power than other wireless chargers like the Powermat and Energizer Qi.

The wireless charging techniques in four distinct kinds of networks WPCN with H-AP, WPCN with dedicated E-AP, relay-based WPCN with H-AP, and WPCN with multi-antenna

E-AP have been studied in this section. Table VII provides a summary of the research on scheduling techniques for static wireless chargers. Charging schemes for a half-duplex H-AP in SISO channels, MISO channels, and MIMO channels, as well as a full-duplex H-AP in SISO channels, have been discussed for the WPCN with an H-AP. One of the potential future paths is to investigate charging strategies for full-duplex H-AP and multi-antenna WPCNs. Also, the majority of papers already published take into account TDMA-based systems. To coordinate the uplink information transfer of user devices, it is intriguing to examine different multiple access techniques, such as OFDMA.

Existing research has examined single E-AP charging techniques for a single user device and multiple users with deterministic wireless charging for WPCN with dedicated E-AP. Nevertheless, this approach is only useful for networks with a small number of devices and a modest size. It might be wise to investigate charging techniques for coordinating many E-APs in deterministic channels. Moreover, opportunistic channels have been examined for different E-AP charging strategies for numerous user devices. Relay-based potential strategies for opportunistic wireless charging are investigated in order to increase spectrum efficiency. Further study may be done to analyse charging throughput, system capacity, and interference. Network protocols have been proposed for relay-based WPCN to meet the two scenarios of wirelessly powered and connected power connections for the relay. The latter, in contrast to the former, may work even more closely with the H-AP to conduct downlink wireless charging to the user devices. There are two potential routes for relay-based WPCN that should be further investigated: full-duplex relay and multi-antenna relay.

Beam formation techniques for far-field multi-antenna systems with MISO channel and MIMO channel have been studied for WPCN with multi-antenna E-AP. Yet point-to-point charging was the only topic covered in the literature at the time. A significant problem that has to be solved is energy beam formation for several energy receivers. Moreover, a near-field multi-coil device that uses a magnetic field to create energy beam formation has only just been developed. To comprehend the empirical performance under diverse network settings, further analysis and experimentation study is needed.

However, the majority of current research solely use theoretical analyses and computer simulations. It is necessary to create procedures for real-world applications and carry out experimental assessments. Realistic validation was carried out based on previous research and experiments using actual equipment. The needs for wireless communication, however, are not taken into account. A crucial area of study is designing charging protocols in conjunction with communication performance optimization for practical application.

Beginning with this part, we'll go through wireless charging's network applications. The following sections will present each of the three design issues mobile charger dispatching, static charger scheduling, and wireless charger deployment in turn. We begin by providing a brief overview of the mobile charger dispatch issue. The challenge is to arrange for one or more mobile chargers to visit and recharge a number of target devices, such as those having wireless energy harvesting capabilities. The aim is to increase the longevity of the network. This issue is often researched in relation to WRSNs.

While designing charger dispatch concerns, there are often five considerations to take into consideration:

1. In order for wireless charging to be able to reach all of the scattered devices, we need to identify the optimum places for mobile chargers to stop by.

2. Given a number of charging sites that a mobile charger must visit, we must choose the best travel route (sequence) for the charger to visit each station in order to accomplish one or more specific objectives.
3. In order to ensure that none of the devices are undercharged, we must determine the ideal charging time for a mobile charger to spend at each sojourn place.
4. In order to improve the overall data collection performance, the optimal data flow rates and data routing pathways for the devices must be obtained given the number of devices, their locations, and the required data flow.
5. To achieve a certain goal in the context of collaborative energy provisioning with various chargers, we must establish the bare minimum number of chargers that must be placed (e.g., minimum cost).
6. The optimization of charging site, travel route, charging time, data rate, routing path, as well as the number of chargers, are each addressed by the aforementioned five challenges.

We provide two common system models that have been used in the past to plan the dispatch of mobile chargers. Although wireless charging is handled by the mobile charger(s) in the first model, as seen in Figure 13a, data collecting is handled by a data sink (or a base station). As a result, the movement of the charger has no effect on the routing of data flows or the pace at which network devices use energy. Typically, a service station or a data sink sends out a charger. The charger goes back to the gas station after each trip and gets energy there to recharge its battery. Point-to-point charging or point-to-multipoint charging technology may be used by a mobile charger; examples of both are Travel Tour 1 and Travel Tour 2, respectively, in Figure 13a. While using point-to-multipoint charging, the charger may simultaneously transmit energy to many target devices that are within its charging range at a chosen landmark position also known as an anchor point [3].

1. Separated wireless energy provisioning and data gathering
2. Joint wireless energy provisioning and data gathering

Models for wireless power transmission and mobile charger dispatch/forwarding. When the hybrid charger visits a charging station, data may be transferred to it either in a single-hop or multi-hop way, as indicated by Routing Paths. According to the literature review in, mobile data gathering in wireless sensor networks has traditionally been well researched. In contrast, wireless energy provisioning and data collection are concurrently optimised in this second reference model. Due to the position of the time-varying charger, dynamic routing is necessary in this situation[2].

The techniques may be divided into offline and online dispatch planning based on the timeliness of the demand. The methods may also be divided into single-charger and multiple-charger methods. They may be separated into centralised and dispersed techniques depending on the control structure. We discuss the offline and online tactics in the next subsections. We initially provide the works with a single charger inside each category, followed by the works with numerous charges. Also, we provide the tactics in tables and specify whether they are all dispersed or centralised.

Offline Charger Dispatch Strategy

The majority of the already published research concentrate on an offline situation where deterministic and periodic scheduling of energy replenishment is used. Single-Charger Approach the majority of single-charger strategies aim to reduce the total service time of the charger, which includes travel time and charging. Typically, this is done within the constraints of total time for each duty cycle, energy flow, which requires that the charged power and consumed power balance at each charging node, and energy, which requires that the energy level of each node always remain above a predetermined threshold. This goal is comparable to, given the same restrictions, the maximising of the charger's vacation time, the maximisation of the charger's vacation time to cycle time, and the reduction of the charger's energy usage[4].

The notion of renewable energy cycle was first suggested by the authors in where they found that a device's remaining energy level exhibited some periodicity across a time cycle. For a renewable energy cycle to attain an infinite network lifespan, both the essential and sufficient criteria were offered. The shortest Hamiltonian cycle, the authors theorised, is the best travel route for the charger to support the renewable energy cycle (SHC). The well-known Traveling Salesman Problem (TSP) [306], which is often non-deterministic polynomial-time hard (NP-hard), may be used to derive a SHC. The best trip route for a TSP with thousands of points may be swiftly solved, however, even though it is NP-hard, for example, by using the approach or the tool. A non-linear optimization problem for combined charge time and data flow routing was created and shown to be NP-hard based on the resulting ideal trip route. The authors arrived at a workable solution by using a piecewise linear approximation approach, and they confirmed its nearly optimality via both theoretical evidence and numerical findings[5].

The authors in constructed a non-linear programming problem in a manner similar to how the authors in order to jointly optimise the journey route, charge time, and data flow routing. The main distinction is that in contrast to in, dynamic time-varying flow routing was taken into account. The author's reformulated the original issue as a linear programming (LP) model that can be resolved in polynomial time by using linearizing methods. According to simulation findings, the suggested technique delivers a substantially higher objective value and is less difficult than static data routing. Moreover, any static data routing might provide an impractical solution since certain nodes would run out of energy before being recharged in the next cycle.

In contrast to the previous two research, the authors of this one also included the choice of charging places. Although point-to-point charging was taken into account in the research, point-to-multipoint charging was also examined. It was established that the formulated non-linear programming (NLP) issue is NP-hard. The NLP was initially transformed into a mixed-integer NLP (MINLP) and subsequently a mixed-integer linear programming by using discretization and a reformulation-linearizion-technique (MILP). It was established that the proposed approach was almost ideal. A significant performance difference between point-to-point and point-to-multipoint charging situations was also shown by the numerical data[6].

The system models in considered them concurrently, in contrast to which utilised a separate mobile charger and static base station for wireless energy provisioning and data collecting. In these references, a multihop method is used to transmit data produced by devices to a hybrid charger. The data flow routing has to be dynamically adjusted since the charger's position varies over time. The authors in extended by taking into account a hybrid charger and created the time-dependent optimization issue as a result of the dynamic data flow routing. It's interesting to note that the authors took into account the particular scenario that only includes location-dependent variables. The solution space for this particular instance is entirely contained inside that for the original issue and has the same optimum objective value. As a result, a nearly perfect solution to the specific case issue was put out and validated. Unfortunately, this approach made the assumption that the charger's journey route was known in advance.

DISCUSSION

The research in was then expanded upon in by looking at an instance with an unidentified travel route. Yet, the situation becomes far more difficult as a result. The authors started by discussing an ideal scenario in which the charger would not travel at all. The discretization and logic point representation approaches were used to provide a solution that is provably close to optimum for any precision level. The authors further got the travel route of the original issue using this solution by determining the smallest Hamiltonian cycle. All the logical sites with non-zero sojourn times in the best scenario are connected by this cycle [7]. This route of travel helped to enhance the development of a workable solution. The performance difference between the ideal solution and the feasible option was also theoretically defined.

The point-to-multipoint charging model was also used in the route planning tactics suggested in. The shortest Hamiltonian cycle was chosen as the charger travel route based on the findings in the suggested technique, and a dynamic optimization model was employed to concentrate on maximising the charging time at each stop. To optimise the charger's charging position and duration, the authors developed an LP model. It was shown that using the smallest enclosing area and charging power discretization may significantly reduce the searching space for an ideal solution. A heuristic method called Lloyd's algorithm was devised to combine the charger stop sites while keeping the charging time under control in order to further minimise complexity. Lloyd's technique is based on the k-means clustering algorithm. The simulation demonstrated that the heuristic technique beats a set-cover-based strategy that optimises the number of under-charged devices adjacent to each stop and achieves performance that is almost ideal.

In target-oriented WRSNs, wireless charging methodologies and sensor activation for target monitoring were simultaneously improved by the authors. In particular, sensor activation scheduling is necessary to coordinate the sensors so as to prevent duplicate monitoring since each target monitoring triggers the same information regardless of the number of sensors that collected it. The goal of the issue formulation in was to increase the typical number of objectives being monitored. The issue was shown to be NP-complete. In order to balance computation complexity and efficiency, a greedy algorithm and a random method were developed. The simulation demonstrated that while the charger travels slowly, the greedy method performs on par with the random strategy. With an increase in the charger's velocity, it performs better than the random technique. The performance differences between the ideal solution and the suggested methods, however, were not looked into.

The goal of the investigations was to improve the monitoring quality (QoM). The average amount of information obtained from each event seen by sensor networks was called the QoM. In their article, the authors presented a straightforward technique called Joint Periodic Wake-up (JPW), which cooperatively sends a mobile charger to visit and charge neighbouring sensors at places of interest (PoI) within a predetermined charging time. Moreover, the charger has control over the sensors' duty cycle. The usefulness of charging time on QoM performance was shown by the performance assessment, although the performance difference between JPW and the ideal solution was not quantified.

The optimization challenge to maximise QoM was taken into account by the writers. The authors originally suggested a relaxed issue that ignores the charger's journey time since the original formulation of the problem was found to be NP-hard. The first approach was made to accomplish a 1/6 approximation for the relaxed issue by reformulating it as a monotone sub modular function maximisation problem under a particular necessary condition. The second approach was then developed for the original issue based on the outcomes of the approximation algorithm. The two suggested approximation algorithms' order of approximation and temporal complexity were both theoretically developed. With the use of simulations, it was shown that the second approach obtained a significant performance boost when compared to the Joint Periodic Wake-up technique.

Both endeavoured to increase network utility features that define an overall data collection performance. The authors of came up with a two-step solution to the joint design challenge in. In the first stage, a subset of sensors is chosen to serve as an anchor point, and in the second step, data collection is optimised when a mobile charger travels among the anchor points. Also, the authors offered a selection algorithm to look for the most sensors as anchor points with the lowest energy level while limiting the tour duration of the charger to below a certain level. The authors then created a distributed algorithm and an NP-hard flow-level network utility maximisation model to arrive at a system-wide optimum solution. The simulation confirmed the suggested strategy's convergence and its efficacy in various topologies. However the length of time these gadgets took to charge was disregarded. Moreover, the amount of energy used to receive and sense data was not considered[8].

The authors took into account the energy consumption of diverse devices as well as time-varying charging times. This problem's formulation was demonstrated to be non-convex under the conditions of flow conservation, energy balance, link and battery capacity, and charging period restriction. The authors were able to divide the issue into two stages of optimization by using certain auxiliary variables to change the original formulation into a convex one. A distributed cross-layer technique was used to solve the deconstructed optimization by adapting the device's optimum data, routing pathways, immediate energy provisioning status, and charging time to optimise network utility. The NS-2 simulation demonstrated the suggested strategy's quick convergence and resilience to minor node loss. In terms of network utility and longevity, it was shown to exceed the technique suggested in. This approach has the drawback of ignoring the energy limitations of the mobile charger.

All of the single-charger techniques mentioned above were predicated on the idea that a mobile charger would have enough energy, or limitless energy, to visit and charge a whole network, at the very least during each trip. Designing charger dispatch algorithms for a mobile charger with a little capacity, however, is a more practical issue. The authors in considered the energy restriction of the mobile charger as a result. Finding the best route with the longest network lifespan was the goal. The authors created two heuristic techniques to lessen the computational burden and demonstrated the NP-completeness of the proposed charging issue. The first one tries to extend the network lifespan as much as feasible for a particular charger's battery capacity, while the second one enhances the first one by using binary search to discover a target network lifetime that is more appropriate.

Subject to the restriction of the charger's total energy usage for both transportation and charging, another approach proposed in was developed to maximise the number of devices that may be charged. The technique optimises the charging point selection to shorten the route under the assumption of multiple node charging. The authors established that this issue is NP-hard and offered heuristic solutions based on the particle swarm optimization meta-heuristic (PSO). The PSO-based solutions accomplish a tiny gap between the heuristic and the ideal TSP solution, according to simulation data. But, for the heuristic situation, a much higher number of iterations is necessary[9].

The literature that was just mentioned reveals that the bulk of the study focused on mobile charger energy provisioning for static devices (s). The crucial aspect of this situation is the interaction between two crucial variables, namely the travel distance of the charger and the time it takes for devices to charge. Reference, on the other hand, was a ground-breaking study that investigated the dispatch planning for a mobile charger to refuel mobile gadgets. The distinction is that the first two criteria listed could be at odds with one another. Given the trip profiles of all devices, the authors created a tree-based technique to reduce travel distance while preserving charging latency within a reasonable threshold[10].

The scientists also determined an energy threshold that the device needs to transmit energy at, using a queue-based technique. The tree-based technique approaches the ideal solution when speed or required charging time rise, according to both analytical and simulation findings. This strategy's drawback is that it only works when the network devices' paths were planned[11].

CONCLUSION

Multiple-Charger Strategy: Using a single or a network of dispersed service stations, multiple-charger method sends out mobile chargers to visit a group of target devices at once. Multiple-charger dispatch requires more coordination amongst mobile chargers than the single-charger dispatch issue does. As a result, the design of a multiple-charger strategy often involves two steps: reducing the number of chargers necessary to meet a charging coverage need and scheduling the best dispatch method in light of the reduced charger requirement. Most multiple-charger systems take point-to-point charging into account. References looked at a linear WRSN in one dimension (1D) with very little charging time. Both pieces try to reduce the amount of charges needed to keep the networks running. The authors initially offered an optimum method with linear complexity for locating the fewest possible chargers and carrying out the necessary dispatch planning in a situation where all devices are charged at the same rate, or homogenous charging. The authors then created a greedy method for heterogeneous charging with various charging frequencies, which is shown to have a factor of two optimum solutions by both mathematical evidence and simulation.

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CHAPTER 5

ONLINE CHARGING DISPATCH STRATEGY

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ABSTRACT:

However, the chargers were assumed to have infinite battery capacity. Additionally, the proposed solutions were only examined in a small network up to 10 devices. Different from the study in assumed the energy limit on the chargers. The authors first discussed different approaches when each sensor is allowed to be charged by a single charger, and jointly by multiple chargers, as well as when mobile chargers are enabled to charge each other. Then, an optimal solution to minimize the number of chargers was proposed for the case that allows inter- charger charging. This solution was also shown to achieve the maximum ratio of energy consumed for charging and that for traveling. However, the proposed strategies were restricted for linear and ring topologies.

KEYWORDS:

Charging, Electricity, Mobile,Networks,Two-Dimensional (2D), Wireless Charging.

INTRODUCTION

References examined two-dimensional (2D) WRSNs with energy-constrained chargers as contrasted to the two experiments mentioned above. It was established that the formulation to reduce the number of charges in a 2D network was NP-hard. In order to address this issue, an approximation approach was first put up for a looser interpretation of the original issue, namely by eliminating a linear restriction. The authors then created two approximation algorithms for the original issue and determined the order of approximation for both methods based on the outcomes from the relaxed problem. The two approximation algorithms outperformed a baseline approach, according to simulation data, although they still fall short of the ideal answer in terms of performance. The fact that this research only applies in the scenario when all gadgets have the same rate of energy consumption is another drawback[1].

We sought to reduce the total distance that all charges travelled. This may be expressed as a q-root TSP, which seeks to identify q closed tours that cover every place while minimising the sum of their individual lengths. The authors suggested an approximation technique with a proven 2-approximation ratio on the presumption that the energy consumption rates of all devices are constant due to the NP-hardness of this issue. The primary concept is to locate the q-root trees that are the closest together and then convert each tree into a closed tour that is no longer than twice as long as the matching tree. A heuristic method was then created for the scenario of diverse energy consumption rates. The simulation proved that the suggested approach outperformed a basic greedy algorithm. The performance difference in comparison to the ideal solution was, once again, unknown.

We created a q-root TSP to schedule numerous chargers in a similar setting, with the goal of deploying the fewest number of chargers possible. A two-step design was used to tackle the issue under consideration. To discover q closed tours, the authors first devised a tree decomposition technique with a proved 5-approximation ratio, similar to that in. Then, a suggested approximation technique that invokes the first approach was made in order to reduce the quantity of charges by limiting the overall distance of each trip. As compared to the best solution in networks with linear and random distributions of energy consumption rate, the suggested technique outperformed it by 40%. The disadvantage of this technique is that as more gadgets need to be charged, the more complicated it becomes [2].

Reference took into account a time limit for the distance that each charger had to go. A multiple TSP with deadlines was developed with the goal of reducing the overall trip cost while causing no node outage, and it was shown to be NP-hard. The authors developed a heuristic approach that chooses the nodes to recharge based on the weighted sum of journey time and remaining lifespan of sensor nodes in order to decrease computational overhead. The heuristic algorithm's complexity was also determined. While the simulation results overlooked the performance difference from the ideal solution, they proved the usefulness of the suggested approach.

The authors made an effort to provide suggestions for large-scale WISPs' cooperative energy replenishment and data collection. In the first strategy, data is initially temporarily stored in RFID tags before being subsequently gathered and sent to the data sink through readers. The second method involves providing readers with data in real time. Both strategies start by clustering the WISP nodes according to the system's energy restrictions, and they then optimise the movement path for the involved RFID readers while taking the WISP nodes' energy and time limits into account. It is shown that the suggested procedures always ensure a workable answer. The second strategy also provides superior delay performance.

Although all of the multiple-charger techniques mentioned above used centralised control, the investigation of distributed control using local information is the main objective. The objective was to investigate how the charging performance and the quantity of information supplied trade off. Two distributed techniques were presented by the authors, in which each charger decides which route to take depending on knowledge about the condition of its nearby chargers. The first technique makes no assumptions about network information, but the second one relies on local knowledge to function. Simulation results showed that the first distributed technique performed on par with its centralised equivalent, but the second distributed strategy performed worse. This algorithm-related finding prompted the authors to the conclusion that, in situations where network information is restricted, the coordination of mobile chargers may not be as important as the design of the journey route [3].

Online Charging Dispatch Strategy

The assumption that the mobile charger acts with complete global knowledge is the basis of the majority of the material mentioned in the preceding subsection. But, in reality, acquiring global information involves significant power consumption and high communication costs. Also, since they are dependent on assumptions, offline techniques are susceptible to changes in network conditions. Thus, offline charger dispatch techniques lack flexibility and suffer from significant performance deterioration in actual systems where fluctuation and uncertainty in network demand are typical. A real-time charging online method may be created to solve this problem. In other words, a mobile charger may get new charging requests at any moment, and the online strategy develops and modifies the charger's trip route as needed. The online charger dispatch techniques are discussed in the section that follows.

The single-charger dispatch systems, which operate in a centralised manner, were the subject of most study on online strategy. The goal was to increase the network charge rate per trip itinerary. An offline approximation approach was used to tackle the NP-hardness of the problem's offline formulation on the presumption that all billing requests were known in advance. Next, a naïve technique was put out to re-plan the journey path iteratively for the online version with one charging request arriving at a time by always providing the request with the shortest processing time, which is the total of the charging time and the travelling time. Also, an analysis of the point-to-multipoint charging instance was conducted. A method based on clusters was presented by the authors. The programme divides the requesting sensors into several clusters based on where they are located. The charger then assesses each cluster using a newly created parameter known as a charging gain and selects the cluster with the greatest charging gain to service. Nevertheless, both of the suggested algorithms have a strong location bias, which gives distant devices little possibility of energy transmission.

In order to cut down on both travel time and charging delay, the authors developed the energy synchronised charging (Sync) protocol. A collection of nested TSP tours is built by only include the devices with low residual energy when on-demand energy provisioning is taken into account. The notion of energy synchronisation is used to coordinate the order in which the gadgets charge in order to better optimise the journey. The creation of the journey itinerary is constantly changed depending on the order of requests in order to synchronise the devices throughout each charging loop. Both experiment and simulation were used to confirm that Sync is effective in cutting down on both travel time and charging delays.

With a focus on the design of distributed techniques, as opposed to the authors. In the reference, energy provisioning for a ring-shaped network with randomly dispersed devices was taken into account. The authors presented a distributed and adaptable technique that only needs local information, in contrast to the centralised online solutions mentioned above. Assuming that all sensors operate at the same data rate, the charger attempts to choose a route that would cause its battery to drain the quickest. This decision is obviously impacted by the data routing protocol that has been implemented. A partial charging system that chooses how much energy to send was also shown to have the highest number of functional devices. In principle, a global information-based algorithm should perform better than a local information-based algorithm. The simulation results in this study's suggested technique sometimes even outperforming other strategies that depend on global knowledge. However, in this investigation, the charging time was disregarded.

The approach used was the nearest-job-next with preemption discipline, which takes into account the geographical and temporal characteristics of the incoming charge requests. The fundamental concept is to cause the re-selection of the next node to be charged to occur either when a device's charging is complete or when a new charging request arrives. The charger then decides to service the asking node that is geographically nearest to it. Analysis was done on the throughput and charging delay performance limits. The suggested technique outperforms the first-come, first-served discipline, according to numerical and system-level simulations. Unfortunately, the suggested technique is also location-biased, which unfairly affects the distribution of wireless power. The fact that the suggested technique was solely assessed in terms of charging throughput and latency is another disadvantage. We did not assess how it performed in other criteria, such as charge coverage and performance difference between best solutions.

Reference investigated the use of several chargers online. The authors demonstrated that this issue is NP-complete when attempting to optimise charging coverage with on-demand scheduling in an event monitoring WRSN. The two measures were then shown. Incremental effective coverage (IEC), which was used as the initial measure, was defined to reflect the group of points of interest. The second statistic is trail covering utility (TCU), which represents the average utility of coverage throughout the sensor's charging period. On the basis of maximum IEC, maximum average TCU, and maximum average TCU with multiple chargers, three greedy heuristic algorithms that serve to-be-charged devices were presented. In order to attain equivalent performance in terms of charge coverage, the first two algorithms were assessed. With the third method, simulation identified the trade-off between the quantity of distributed chargers and the charging coverage. The third method, on the other hand, is missing effective charger coordination mechanisms.

When device charging is complete, each charger just broadcasts the information to all the other chargers, which might cause the other chargers' trip distances to be incorrect. We provide a summary of the offline dispatch techniques examined. The number of chargers used, the charger(s)' energy constraints, optimization variables in suggested strategies, charging patterns (point-to-point or point-to-multipoint charging), control methods (centralised or distributed), and assessment techniques are contrasted in the reviewed literature. There are four common ways to assessment methods: numerical simulation, system-level simulation, theoretical analysis, and experiment. As we can see, the majority of the currently used tasks schedule mobile chargers using centralised management. Particularly for multiple-charger dispatch schemes, distributed algorithms have not received as much attention. Moreover, point-to-point charging is used in every single multiple-charger dispatch strategy now in use. The overview of the online dispatch tactics may be presented in future work in order to shorten the journey tours for numerous chargers. We specifically compare the goals, number of chargers used, and energy limitation of the charger, charging patterns, control techniques, and assessment methods in the associated literature. The answer to numerous fees has only been offered in references. Unfortunately, as was already indicated, there is a lack of effective charger coordination. It may be difficult to coordinate charging for online strategy, particularly with dispersed control. Moreover, point-to-multipoint charging may be a future route for online algorithms to handle many charging requests [4].

WIRELESS CHARGER DEPLOYMENT STRATEGIES

Planning the location of wireless chargers is necessary for a wireless network to operate sustainably. The placement of stationary chargers and the use of mobile chargers represent the two categories of deployment issues. As indicated, the installation of static chargers is only appropriate and practicable in limited areas since the effective coverage range for coupling-based wireless chargers is just a few metres and tens of metres for RF-based chargers. A full-coverage static charger deployment in a big network is expensive and has a lot of overhead. The literature now available discusses four possible deployment scenarios for wireless chargers.

1. Point Provisioning deals with the placement of static chargers to support static devices with wireless power.
2. Path provisioning aims to deploy static chargers to charge mobile devices (e.g., wearable or implanted sensors by human) in their travel paths.
3. Multichip provisioning determines the locations to place static chargers in a static network, where the devices are also enabled with wireless power transfer function and can share energy with each other.
4. Landmark provisioning involves two steps: selection of landmarks for the mobile chargers to visit by turns, and clustering landmarks as groups to deploy mobile chargers. The landmarks are the locations to park the charger to provide concurrent charging for multiple static devices in the vicinity.

The distribution of static chargers is the focus of the first three scenarios, while the deployment of mobile chargers is necessary for the last scenario. We go into the tactics in these circumstances in the next two subsections.

DISCUSSION

Static Wireless Charger Deployment

The deployment issue for point provisioning scenarios was the main focus of the bulk of the previous efforts. The research examined a WRSN in which wireless chargers are positioned at preset heights depending on grid points. Each wireless charger has a cone-shaped charging area known as a charging cone and 3D RF-based beam shaping. The authors developed the node based greedy cone choosing (NB-GCS) and node pair based greedy cone selecting (PB-GCS) algorithms to reduce the number of charges. The former produced charging cones node by node, whereas the latter produced charging cones pair by pair. Simulations shown that PB-GCS outperforms NB-GCS in terms of the quantity of charges. With more sensor nodes, their performance disparity widens. Nevertheless, NB-GCS is much less difficult, particularly when there are a lot of nodes. Reference further investigated the charger deployment issue when randomly dispersed base stations coexist, as opposed to the system paradigm in which just a wireless charger serves as the energy source. The authors investigated the scenarios in which BSs performed SWIPT in the first instance and information-only transmission in the second case using ILP. According to the simulation, the first instance uses fewer charges and transfers power far more effectively than the second example[5], [6].

The issue under investigation included placing a limited number of wireless chargers near to an equal number of bottleneck sensors in order to increase the network's flow rate. To establish the route and the group of bottleneck sensors that needed to be charged, the authors first created a MILP. Then, a heuristic charger deployment technique was suggested, and it was shown to provide, on average, 85.9% of the MLIP's optimum solution. Reference addressed the issue of providing charging coverage for a group of sensors using the least amount of wire-less chargers possible. The authors developed an approximation approach based on a network partition technique to choose the deployment sites for wireless chargers in order to lessen the complexity of the optimization issue. Also, on the assumption that all of the target sensors are uniformly distributed, the order of approximation has been theoretically described. In order to demonstrate the performance lower limit of the suggested partition method, the authors additionally presented a shifting approach. The performance of the simulation was not evaluated, however.

Studying a secure wireless charging method under electromagnetic radiation control was the main goal of the project. The point provisioning problem's counterpart was studied by the authors. That is, how to choose which chargers to switch on from a group of deployed chargers such that no area of the planar field is exposed to electromagnetic radiation that is too high. The radiation limit imposes an endless number of restrictions since it is universally applicable. The authors showed that it is generally NP-hard to find the best activation set of chargers to maximise charging throughput given the stated limitations. The authors demonstrated how the original issue may be split into two conventional problems, namely the multidimensional 0/1 knapsack problem and the Fermat-Weber problem, by using constraint conversion and constraint reduction methods[7].

Then, as a solution, an approximation method with proved near optimality was put forward, and it was shown to perform around 35% better than a PSO-based heuristic approach. The suggested system is mainly centralised, however, and as the number of chargers rises, this leads to significant complexity. The research used a variable transmit power model for the chargers as opposed to an on/off switch. The goal was to increase the utility of charging, which is related to overall charging power. This issue imposed limitless limitations, similar to. The authors used an area demonetization approach to first reformulate the optimization issue as a standard LP problem. A distributed redundant constraint reduction strategy was proposed to decrease the number of constraints in order to simplify the LP issue. To overcome the optimization challenge, the authors also created a distributed approximation technique. An experiment using a Powercaster testbed showed that the suggested distributed method may yield an average performance boost of around 40% over the centralised approach.

Reference examined the provisioning issues for wireless identification and sensing platforms on both the point and route levels (WISP). RFID readers wirelessly recharge RFID tags on this platform. The goal of both issues is to use the fewest possible charges. The authors determined the minimum number of readers needed for both situations by assuming that the recharging power from multiple RFID readers is cumulative. Simulated results demonstrate that the suggested strategy for point provisioning led to a significant decrease in the number of chargers as compared to the typical triangle deployment approach in the sensing disc model. Moreover, it was shown that the suggested strategy for point provisioning obtained near-optimal performance whereas the proposed approach for route provisioning produced performance that was practically close to ideal. A full-coverage method, which is only appropriate for a small network, was the subject of the research. It can have too much expense and overhead in a big network[8].

Based on the fact that human activity has a certain degree of regularity, reference used the concept of partial coverage in a route provisioning scenario to build a cost-effective charger deployment in big networks. Designing a mobility-aware deployment technique that maintains a good survival rate with a constrained supply of chargers is the goal. The authors created a grid-based map and the mobility-aware charger deployment (MACD) issue for the highest survival rate, where the grid points represent prospective charger placement areas. The NP-hardness of the MACD issue has been established. The authors then developed a simple MACD algorithm based on a greedy strategy. The simulation shown that the suggested MACD algorithm manages to attain the same survival rate with much fewer charges than the full-coverage system in by effectively using the end-devices' mobility regularity[9].

The studies mentioned above only took into account one-hop wireless charging systems, in which all wireless power is sent straight from chargers. Reference proposed a multi-hop provisioning method in which each node may additionally communicate energy with its neighbours. In this situation, the authors created a MILP for the issue of reducing the number of chargers with fixed capacities. The maximum number of energy transfer hops is limited. By simulating the suggested method in comparison to a single-hop charging strategy, it was shown that fewer chargers are needed, particularly when the charger capacity is high. There is a trade-off between charging effectiveness and the amount of hops for multi-hop charging, however. In this paper, the examination of this tradeoff was lacking [10].

CONCLUSION

The deployment issue for several mobile wireless chargers in a WRSN was addressed by the authors in using a three-step strategy they named SuReSense. The number of landmarks was first reduced using an integer linear programming (ILP) problem based on the sensors' location and power requirements. The locations are then grouped according to how close they are to docking stations where new mobile charges may be purchased. The last visit to the landmark is made by each mobile charger after the shortest Hamiltonian cycle. The simulation results shown that SuReSense is possible to achieve lower route length in comparison to the plan where the wireless charger visits each sensor separately based on the shortest Hamiltonian cycle, particularly when the power demand is low.

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CHAPTER 6

OPEN RESEARCH ISSUES AND FUTURE DIRECTIONS

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ABSTRACT:

The following works focused on the landmark selection for different objectives. Reference considered the profit maximization problem in a WRSN with mission assignment. The authors developed an ILP model, called mission-aware placement of wireless power transmitters (MAPIT), to optimize the number of devices charged from each landmark. It was demonstrated by simulation that the profit can be improved by confining the number of the landmarks. Moreover, the profit decreases with the increase of number of missions, because to complete more missions, the nodes require to be charged from more landmark locations.Both only considered the case that all the sensors are identical in priority. However, this may not be the general case in some environments. For example, the sensors in critical areas need to perform more precise monitoring and thus require more robust power previsioning. To address this concern, the study in proposed the strategy, called differentiated RF power transmission (DRIFT), to extend by considering different priorities of the sensor nodes. The ILP model was developed with the objective to maximize the power delivered to the high priority nodes from each landmark. The simulation demonstrated that DRIFT allows the high priority node to receive significant higher power. However, SuReSense generates lower path length for the mobile charger. Furthermore, the authors demonstrated that there exists a tradeoff between power reception efficiency and the path length.

KEYWORDS:

Charging, Electricity, Mobile,Networks Wireless Charging.

INTRODUCTION

The deployment plans for wireless chargers as of right now are shown in Table X. Multi-hop provisioning has obviously received less research, only in. Studying a system where each device may get energy from a number of transmitters is also crucial. Regarding deployment situations, none of the works now in existence take mobile charger placement in mobile networks into account. It is possible to research mobile device deployment options based on their movement patterns.Moreover, we note that the formulation of the deployment challenges is primarily that of an optimization problem with various constraints and goals. Hence, all solutions need global data such as device location, battery capacity, and even hardware specification characteristics and velocity. These data collection activities include significant communication overhead. While several of the suggested solutions claimed to be simple and scalable for big networks, it is necessary to assess their viability and practicability before implementing them in actual systems. Decentralized strategies built on local data, which loosen the connection need, might be one of the key future paths. Moreover, numerical simulation was used to analyse the majority of the suggestions. System-level simulation has only been shown in references. Future study will need to conduct further evaluations using system-level simulations and actual experiments in order to comprehend the empirical performance[1].

In this part, we first list several unresolved problems relating to data transfer in wireless charging systems and wireless charging technologies. Later, with the development of wireless charging technologies, we see a number of unique paradigms emerge. This section outlines several communication difficulties after first addressing certain technical problems with wire-free charging. Wireless Charging Open Issues: Inductive Coupling There are a number of technical concerns caused by the growth in wireless charging power density, including temperature, electromagnetic compatibility, and electromagnetic field issues. In order to decrease power loss at an energy receiver and battery modules with good ventilation design, high-efficiency power conversion methods are required.

Magnetic resonance coupling: Methods based on magnetic resonance coupling, such Witritiy and MagMIMO, have a wider charging surface and may charge several devices at once. In contrast to inductive charging, they have a lower efficiency and produce more electromagnetic interference. The comparatively high size of a transmitter is another drawback of magnetic resonance coupling. The wireless charging range is often inversely correlated with transmitter diameter. Hence, a large receiver size is often needed for wireless charging over extended distances.Near-field beamforming: For multi-antenna near-field beam-forming, knowledge of the magnetic pathways to the receivers is crucial for computing a magnetic-beamforming vector on the transmission side. It is crucial to carefully consider the channel estimation and feedback systems. The charging performance suffers greatly from inaccurate channel estimate or a lack of feedback. Also, a hardware restriction means that the impedance matching may only be used at its best within a certain range[2].

Energy beamforming for RF-based localization: As was already said, energy beamforming may improve the effectiveness of power transmission. To direct the energy beam, the energy transmitter must, however, be aware of the position of the energy receiver. Real-time spatial estimates for two key factors, namely angle and distance, are required for localization. For mobile WPCNs in particular, self-detection and localisation of to-be-charger devices is difficult. Channel estimate is also essential for the construction of beamforming vectors, much as near-field beamforming.

When placed next to any wireless charger, a metallic or ferromagnetic object may absorb part of the near-field energy. The material's induced voltage or current may result in an increase in temperature. Due to the fact that electrical gadgets must have metallic components, the resulting temperature increase reduces charging efficiency and may lead to a poor user experience. System power loss is nevertheless unavoidable and may be significant even if both Qi and A4WP have the safeguards to prevent safety problems like extreme overheating. This is particularly true if the device is big in size. Foreign items might also contribute to power outages. It's difficult to figure out how to reduce the heating impact so that less electricity is lost [3].

1. **Energy conversion efficiency:** Wireless charging requires electricity energy to be transformed from AC to electromagnetic waves and then to DC. Each conversion adds the loss in overall energy, which leads to a normally wireless charging efficiency hovering between 50% and 70%. Efforts toward hardware improvement of energy conversion efficiency are instrumental to achieve highly efficient wireless charging.
2. **Open Issues in Data Communication:** To improve the usability and efficiency of the wireless charger, their data communication capability can be enhanced.

3. **Duplex communication and multiple access:** The current communication protocols support simplex communication e.g., from a charging device to charger. However, there are some important procedures which require duplex communication. For example, the charging device can request for a certain charging power, while the charger may request for battery status of the charging device. Moreover, the current protocols support one-to-one communication. However, multiple device charging can be implemented with multiple access for data transmission among charging devices and a charger has to be developed and implemented.

The protocols in use today allow for straightforward communication between a charger and a charging device. They are vulnerable to man-in-the-middle attacks, eavesdropping attacks, and jamming attacks, which may all be used to disrupt communication between the charger and the charging device (e.g., malicious device manipulates or falsifies charging status). Unique aspects of wireless charging, such as in-band communication in Qi, must be taken into consideration when developing security features for communication protocols. Only communication between a charger and a charging device is supported by the protocols (i.e., intra-charger). Information from various chargers and charging devices may be transferred when they are linked (i.e., inter-charger). Even if the idea of wireless charger networking has been put out in, there are some enhancements that might be made. To offer both data communication and energy transfer services, wireless chargers may be connected with a wireless access point, known as a hybrid access point.

We cover numerous new paradigms that are predicted in wireless powered communication networks in this area. Network for wireless chargers: A wireless charger network may be created to provide scattered users with energy provisioning services, much to wireless comma-inaction networks that provide data service. In order to schedule the chargers, a wireless charger network that connects a number of dispersed chargers through wired or wireless connections enables the interchange of information (such as availability, location, charging state, and cost of various chargers). Such scheduling may be done either centralizedly or decentralizedly to achieve certain goals (e.g., system energy efficiency, total charging cost). To meet the needs of heterogeneous charging and coverage, a wireless charger network may be a hybrid system based on a number of charging methodologies. For instance, the system might use short-range near-field chargers (like those based on induction) to charge stationary objects with high power requirements, mid-range near-field chargers (like those based on resonance) to charge objects without a line-of-sight charging link, and loosen the coil alignment requirement. Additionally, distant devices with minimal power requirements and certain local mobility requirements may be covered by a far-field charger (like Powercaster and the Cota system) (e.g., wearable devices, MP3, watches, Google glasses, and sensors in smart building).

Providing green wireless energy with the widespread use of wireless powered devices, the question of how to provide large-scale networks with wireless energy in an environmentally acceptable manner is starting to surface. As mentioned above, scheduling techniques for static and mobile chargers have been developed for power replenishment. If the power sources and charging methods for wireless chargers are not properly used, these tactics might result in increased pollution and energy consumption. For instance, a car that has wireless chargers for mobile energy provisioning would emit a significant quantity of CO2. A static RF-based charger supplied by the electric grid may also result in increased usage of environmentally harmful traditional fuels like coal owing to propagation loss and poor transfer efficiency. How to execute green wireless energy provisioning is still up for debate and has mostly been disregarded in present research. Equipping wireless chargers with sustainable energy sources, like solar, is one viable alternative. Renewable energy sources, however, may be erratic, making it challenging for chargers to provide dependable wireless charging services. In this manner, significant pertinent concerns may be investigated.

Recycling Self-energy in Full-Duplex Information Transmitter: Full-duplex based wireless information transmitters are able to send and receive energy concurrently in the same frequency range by using multiple antennas. A full-duplex system often experiences self-interference since the transmitter receives some of the RF signals that are being broadcast. Since self-interference weakens the targeted information transmission, it is undesirable. Self-interference, however, may help with energy conservation due to its capacity for RF energy collecting. In particular, the reception antenna may catch some of the energy utilised for information transmission and store it for later use, a process known as self-energy recycling. Both energy and spectrum efficiency are benefited by this approach. Moreover, a multi-antenna base station, access point, relay node, and user devices may all benefit from its widespread use.

Millimeter-wave Improved Wireless Powered Cellular Network: The development of millimeter-wave cellular communications, which use frequencies between 30 and 300 GHz, has opened up new possibilities for next-generation wireless technologies. Millimeter-wave cellular communication is a natural technology to enable wireless energy beam formation due to high frequencies. The frequency may be raised to improve the beam formation effectiveness of a multi-antenna transmitter. A rectenna-based microwave power conversion system's physical dimensions is also significantly influenced by frequency. The system has a compact form factor since the needed size of the antennas is tiny at high frequency ranges.

The ability to arrange more antennas in an array thanks to a tiny form factor further advances beam formation and reduces the attenuation of charging power. As a result, a millimeter-wave RF transmitter is preferred for use with SWIPT and RF-based wireless charging. SWIPT near-field system: SWIPT has been extensively studied in RF-based wireless communication systems, as previously stated. Magnetic induction communication may be added to a near-field charging system to induce SWIPT as coupling-based chargers become more common. As compared to RF-based communication, near-field communication based on magnetic fields may increase its capacity significantly. An inductive coupling-based device was stated to be capable of delivering 11 Gbps over a 15 m distance in 180 nm complementary metal-oxide semiconductor hardware, according to a hardware design and implementation (CMOS). Hence, high-speed data offloading in next-generation communications has huge potential for SWIPT-compliant near-field chargers. SWIPT-compliant near-field chargers may be connected into cellular networks for smooth data service while charging since they are backhaulled with high-speed Internet connections.

The final remaining chord connections needed to recharge portable electronics might be eliminated thanks to wireless power technology. This intriguing technology has made considerable strides in recent years and now offers a variety of applications that are user-friendly. We have provided a thorough analysis of the paradigm for wireless charging-compliant communication networks in this paper. Beginning with the development history, we went on to describe the fundamentals, global standards, and network applications of wireless charging in that order. We then spoke about any unresolved challenges and imagined potential future uses. Resource allocation is made more difficult and opens up new options as a result of the integration of wireless charging with current communication networks. This study has shown the current methods for delivering smooth wireless power transmission via the deployment of wireless chargers, the dispatch of mobile chargers, and the scheduling of static chargers. Among those studies, a number of new issues, such as distributed wireless charger deployment strategies, multiple access control for wireless power communication networks, near-field energy beamforming schemes, energy provisioning for mobile networks, and online mobile charger dispatch strategies are less explored and need further research. The unresolved problems and practical difficulties covered in Section VIII may also be seen as the key topics for further study. One effective international plan to reduce carbon emissions in the transportation industry is the shift to electric mobility. The goal of the international effort, which seeks to have at least 30% of new car sales be electric by 2030, is supported by a small number of nations, including India[4].

To complete this ambitious change, a reliable and accessible network of EV charging infrastructure is a necessary prerequisite. The development of the network of charging infrastructure has been encouraged by a number of enabling laws implemented by the Indian government. It is necessary to adapt this new infrastructure type to the distinctive Indian transport ecosystem and increase stakeholder capacity to support its on-the-ground growth, nevertheless, given the innovative qualities of this new infrastructure type. To guarantee that EV charging infrastructure is implemented effectively and on schedule, as well as to ensure that it complies with local regulations and is well integrated into transportation and electrical supply networks, a contextual approach is required. A methodical approach is provided by the Handbook for Electric Vehicle Charging Infrastructure Implementation Version 1 to assist implementing authorities and stakeholders with the design, approval, and implementation of EV charging infrastructure. Together with a step-by-step process for developing the implementation roadmap, it provides an overview of the technical, legislative, and governance frameworks and structures required to support EV charging. Although the manual concentrates on the current requirements for developing charging infrastructure, it also touches on factors for long-term planning.

DISCUSSION

The primary target audience for this handbook is composed of public and private sector participants who are in charge of implementing the charging infrastructure, including electricity distribution companies, municipal corporations, urban development authorities, and providers and operators of charge point solutions. The regulatory authorities in state and federal government organisations charged with developing an enabling governance structure to assist implementation are the secondary audience. The manual is anticipated to be a live resource that will be periodically updated in response to changes in the demands and characteristics of the dynamic EV market. The manual offers a step-by-step process for developing the roadmap for EV charging infrastructure, starting with an evaluation of EV charging needs and continuing on to site planning, arranging energy supplies, and models of on-ground implementation.

Introduces the reader to the technical terms of electric vehicle supply equipment, AC and DC charging, power ratings, and charging standards. Orients the reader to EV charging infrastructure. Defines the duties of charge station operators and e-mobility service providers, and identifies the regulatory and executive government bodies participating in the deployment of the charging infrastructure to lay out the governance structure of the EV charging ecosystem. Introduces the planning process, outlines a technique for estimating energy demand for public EV charging, and provides an overview of the access- and demand-based methodologies for establishing objectives (for the necessary number of public chargers). By outlining location planning concepts and illustrating a mechanism for allocating charging demand spatially, this article covers the location and site planning components for

EV charging. It also defines the necessary procedures and regulations to include public charging in urban design[5].

focuses on the provision of energy for infrastructure for EV charging, familiarising readers with the rules that govern electricity supply for EV charging, the function of DISCOMs in providing EV charging connections, and the three ways to set up power supply for charging infrastructure. Focuses on the need for smart charging to reduce the negative effects of EV charging loads on the grid by zooming out from site-level concerns for power supply to analyse grid-level implications. Describes the usual responsibilities in an EV charging infrastructure implementation model and defines three types in India: the consumer-driven model, the government-driven model, and the charge station operator-driven model.

Depending on the situation and need, there are several methods to charge electric vehicles (EV). As a result, there are several kinds of charging infrastructure for EVs that are created for various uses. Electric vehicle supply equipment (EVSE), also known as EV charger specifications and standards, differ from one nation to the next depending on the types of EVs that are sold there and the power grid's features. In addition to highlighting the necessity for a contextual approach to local development and implementation of EV charging networks, this chapter presents the basic ideas of electric vehicle charging infrastructure.

The fundamental component of an EV charging infrastructure is electric vehicle supply equipment (EVSE). The EVSE uses a connected connection and a control system to securely charge EVs by drawing power from the local power grid. A control system for an EVSE may perform a number of tasks, including user identification, charging authorisation, information recording and exchange for network management, as well as data privacy and security. For all charging needs, it is advised to utilise EVSEs having at least fundamental control and management features. The most popular charging technique is conductive charging, often known as plug-in (wired) charging. The amount of EVSE needed for conductive charging depends on a number of variables, including the kind of vehicle, the battery capacity, the charging techniques, and the power ratings[6], [7].

In India, light electric vehicles (LEVs), which include two-wheelers (scooters, motorbikes) and three-wheelers, are anticipated to be the primary force behind transport electrification during the next ten years (passenger and cargo). The two important vehicle sectors that are being electrified include autos and light commercial vehicles (LCVs), in addition to these. There will also be a lot more electric buses, although these are beyond the purview of this manual. The parameters of EV batteries affect the charging needs for EVs since electricity must be delivered to the battery at the proper voltage and current levels to enable charging. The typical EV battery size and voltage varies depending on the EV sector; low-voltage batteries power E-2Ws and e-3Ws. Low-voltage batteries are also used to power the initial generation of e-cars. Nonetheless, even if they persist in certain use cases like taxis, they will probably be phased away in the future. The forthcoming e-car models of the second generation of e-cars are powered by high-voltage batteries. Depending on their ability to carry a load, electric LCVs will be made up of both low-voltage and high-voltage vehicles.

Direct current (DC) must be supplied to the battery pack in order for an EV to charge. A converter is needed to deliver DC power to the battery since electrical distribution networks only offer alternating current (AC) power. AC or DC conductive charging is both possible. In the case of an AC EVSE, the onboard charger of the EV receives the AC power and converts it to DC. Bypassing the onboard charger, a DC EVSE externally transforms the electricity and delivers DC power straight to the battery. The four charging modes for AC and DC charging are further divided into AC charging (Modes 1-3) and DC charging (Mode 4).

An electric vehicle (EV) may be connected to a regular socket outlet using a cable and plug in either mode 1 or mode 2. It is not advised to utilise mode 1, commonly known as dumb charging, since it prevents communication between the EV and EVSE. The portable cable used in Mode 2 is designed for home charging and contains built-in safety and control features. The upgraded control systems of modes 3 and 4, which provide a separate charger device to power the EV, are utilised for commercial or public charging. The input power requirements for charging infrastructure are determined by the power ratings or levels of the EVSEs, which vary depending on the charging needs. Normal power charging is limited to 22kW, while high-power charging is limited to 200kW. EVSEs with power ratings of up to 500kW are readily accessible across the world, however they are mostly used for big vehicles like buses and trucks.

For e-2W, e-3W, and e-car charging, standard AC power is sufficient. Because to the high incidence of LEVs and the usage of low-voltage batteries in e-cars, normal power DC charging is unique to India. For LEVs and vehicles with single phase on-board chargers, single-phase AC chargers with a maximum power rating of 7kW are sufficient. For electric automobiles with bigger on-board chargers, three-phase AC chargers with a power rating up to 22kW are needed. The conventional electricity distribution network may offer input power supply for regular power charging. High-power DC charging of 50kW is utilised for high-voltage e-cars with battery capacity between 30 and 80 kWh. The market offers DC chargers with power outputs between 25kW and 60kW. But, more powerful DC chargers will soon be accessible. High-power DC charging needs more infrastructure and greater electrical supply, although it is faster for e-cars. So, most charging needs, even slow or overnight charging of e-cars, may be met by normal power charging outlets.

Battery swapping, which involves removing the vehicle's exhausted EV battery and replacing it with a fully charged one, is an alternate battery charging technique that is gaining interest on a worldwide scale. The technology is being tested for usage in e-2Ws, e-3Ws, e-cars, and even e-buses, among other EV categories. Batteries are manually inserted and withdrawn from the separate slots in the battery switching station, which is a stand-alone machine. Manual changing stations are modular and take up very little room. They are utilised in applications requiring 2W and 3W batteries since they have smaller battery packs and can be lifted by one or two people.

These battery replacement facilities use a robotic arm, and the procedure is partially or entirely automated. For 4W and e-bus applications, robotic switching is employed since the bigger and heavier battery packs there need mechanical help. Furthermore more costly and requiring more area are these exchanging stations. Although battery swapping provides several unique benefits over plug-in charging, there are also a number of obstacles in the way of its widespread adoption as a charging method.

Advantages Barriers:

1. EV recharging
2. is completed in minutes
3. Lack of standardization among EV batteries
4. Batteries can be charged away from swapping point, allowing more freedom in setting up swap facilities
5. Unsuitable battery pack design to enable ease of swapping. Reduction in upfront cost of EV, as battery ownership is replaced by battery leasing
6. Greater number of batteries needed to power same number of EVs.Increased predictability of battery life due to controlled charging conditions

7. Shorter commercial life of battery packs due to customer preference for new batteries with higher range
8. Slow adoption of charging method by OEMs
9. Higher costs of battery leasing over the life of the EV
10. Higher GST on separate battery (18%) vs battery sold with EV (5%).

In the e-2W and e-3W sectors, battery swapping is currently seen to be a workable option for commercial EV fleets. The Ministry of Road Transport and Highways (MoRTH) has permitted the sale and registration of electric vehicles (EVs) without batteries, which gives battery swapping technologies a big boost. Also, major investments are being made by industry players in the ecosystem for battery switching. This suggests that in the next years, battery swapping will become a distinctive feature of EV charging networks in India.

Standards guarantee the compatibility and interoperability of every EVSE with every EV. India's national standards organisation, the Bureau of Indian Standards (BIS), is in charge of creating the nation's EV charging regulations. The International Electrotechnical Commission (IEC), a worldwide organisation that is creating reference standards to guarantee interoperability and reduce trade barriers for electric cars and their components, is a member of the BIS. Although Indian EV charging requirements are consistent with international norms, local climatic factors and the variety of car types available in the nation need adaptations that are unique to India[8].

The primary EV charging standard in India is IS 17017, which has three parts and six sections. All EV charging systems include the fundamental characteristics listed in IS-17017-Part-1. This standard, as well as certain AC connection specifications in the IS-17017-Part-2, must be followed by an AC EVSE. Technically speaking, AC and DC EVSE must both meet IS-17017-Parts 21 and 22. For usage in parking lots, further Indian standards for AC EVSEs have been established for light EVs and e-cars (in the form of inexpensive charging stations). IS-17017-Part-23 outlines the specifications for DC charging stations with power output ranging from 50kW to 200kW. In addition, in order to accommodate buses and other big vehicles, high power charging requirements are needed. The IS-17017-Part-25, which is designed for delivering low DC power of less than 7kW for light EVs, was just completed by the BIS. IS-17017-Part 24 specifies data communication standards since digital communications between the DC EVSE and the EV are necessary. Communications will follow the IS-15118 series after the Combined Charging System (CCS) standard is implemented, which can provide both AC and DC charging [9], [10].

CONCLUSION

The development of battery switching standards for buses and LEVs has been split into several initiatives. The battery pack form factor, interoperable connection technologies, communication between the battery management system (BMS) and the EV and charging station, and network management will all be covered in two sets of standards papers. Any EV may use a battery pack that complies with these requirements. Both AC and DC charging methods may be used to recharge the detachable battery packs. The BIS has not yet created Indian standards for EV roaming and management tasks involving the grid. High-power EVSEs with numerous charging guns and often operating in Mode 3 or Mode 4 are referred to as charging stations. EVSEs with standard electricity are referred to as charging stations and may be reached using a portable charging cable. Although charging stations were the primary focus of the original public charging infrastructure deployment in India, it is becoming clearer that the majority of public charging requirements can be met by a densely dispersed network of charging points. It is better to have an extensive network of low-power charging stations for EVs than a sparse network of high-power charging stations. With EVs, every parking space where the car is parked still and where there is a charging station for EVs presents a chance to recharge the battery. As contrast to "on-the-go charging," which involves cars quickly topping up their battery charge to continue to their destinations, this is also referred to as destination charging. Consequently, rather than creating additional spaces for EV charging stations, EV charging infrastructure should be supplied in areas where cars are often parked.

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CHAPTER 7

COST-EFFICIENCY OF CHARGING INFRASTRUCTURE

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ABSTRACT:

This approach to charging infrastructure implementation promotes a distributed network of EV charging points for users to plug into at various locations - at residences, apartment buildings, office campuses, shopping malls, metro and railway stations, bus depots, etc. Such a distributed network approach has multiple advantages for users and operators, ranging from ease of access to financial viability. By providing EV charging points at locations where vehicles tend to park, EV users can charge their vehicles while they are parked, thereby saving time, and eliminating the distance one must travel to access public charging. A dense network of normal-power EV charging points reduces the need for high power and ultra-high power charging points, which are more expensive and can be detrimental to EV battery health if over-used. Normal power charging points are not only less expensive, but they also require less electricity and less space, which further reduces capital costs. They can be connected to low-voltage single- and three- phase distribution networks, which are widely available in buildings and public spaces.

KEYWORDS:

Cost, Electricity, Mobile,Networks, two-dimensional (2D), Wireless Charging.

INTRODUCTION

Government subsidies may be cut down by lowering the initial costs of installing charging infrastructure, which also increases the profitability of private sector involvement in charging operations. Increasing the availability of charging stations is more important than anything else for an effective deployment of EV infrastructure in a developing EV market. It is possible to guarantee that EV charging demands are effectively addressed by distributing the availability of several conventional power charging points together with a limited number of high-power charging stations. The availability of land and supply of power for EV charging, the specification and installation of EV charging equipment, daily operations and maintenance of EV charging facilities, and services enabling EV owners to access charging facilities are all included in the EV charging ecosystem. This underscores the necessity for collaboration between stakeholder groups for thorough development and execution of charging networks and defines the public and commercial parties accountable for the governance of EV charging. In general, ownership and usage determine how EV charging infrastructure is governed. Generally speaking, there are three types of EV charging infrastructure: public, semi-public, and private[1].

PRIVATE CHARGING

1. Usage: Dedicated charging for personal EV or EV fleet owned by one entity
2. Locations: Independent homes, dedicated parking spots in apartments/offices; for fleets any location with land availability
3. Ownership: Individual EV owners, EV fleet owners/ operators
4. Operation: Self-operated or CPO-managed (for EV fleet charging)

1. Usage: Shared charging for a restricted set of EV users Locations: Apartment complexes, office campuses, gated communities, shopping malls, hospitals, universities, government buildings, etc.
2. Ownership: Host properties, Orginal Equipment Manufacturers (OEMs) & Charge Point Operators (CPOs) Operation: CPO-managed
3. Usage: Open for all EV users
4. Locations: Public parking lots, on-street parking, charging plazas, petrol pumps, highways, metro stations
5. Ownership: Municipal authorities, PSUs, CPOs, host properties
6. Operation: CPO-managed

These are not rigid classifications, and some charging stations could exhibit hybrid traits. As an example, charging infrastructure controlled by EV fleet owners and operators for captive use is regarded as private, but it may be made available to the general public as a paid charging service while fleets are in operation. Depending on whether they are accessible to all EV users or just transit users, the EV charging infrastructure at bus depots or metro station parking may be semi-public or public. Across categories, there are significant differences in the level of regulatory monitoring and the complexity of governance structures. As we shall see throughout the manual, private billing often includes fewer parties and requires less regulatory compliances. The management of EV charging is under the control of several central, state, and municipal government entities. These organisations' functions may be divided into two categories: executive or executing functions and policy-making and regulatory functions.

These governmental entities are in charge of creating laws, rules, and standards and requirements for EV charging infrastructure. A crucial need for the development of charging infrastructure is the availability of energy. Due to the fact that electricity is a topic on the Concurrent List of the Constitution, organisations at the federal and state levels are active in regulating the availability of power for EV charging. Public charging infrastructure guidelines and standards were published by the Ministry of Electricity (MoP) and provided a framework for their implementation. The MoP stated that the operation of EV charging services did not need licence under the Electricity Act 2003 in its function as a legislative body. Technical specifications and rules for EV charging are set by the Central Electricity Authority (CEA).

The EV tariff and other rules governing the supply of power for EV charging are established by the State Electricity Regulatory Commissions (SERCs). The availability of land or parking spots to place charging stations is another crucial input factor for setting up EV charging. State governments are responsible for land use and urban planning, with municipal corporations handling urban planning in many areas. The Model Building Byelaws 2016 and the Urban and Regional Development Plans Formulation and Implementation Guidelines 2014 (URDPFI) were updated by the Ministry of Housing and Urban Affairs (MoHUA) to incorporate provisions for EV charging. States are advised to make these changes. The state-level urban development departments are in charge of implementing the MoHUA's recommendations for changes to the building bylaws and other urban planning frameworks. Urban development agencies (UDAs) or municipal corporations, when power is further delegated, are in charge of amending building byelaws and urban planning frameworks to incorporate arrangements for EV charging. The Bureau of Indian Standards (BIS), the nation's standard-setting authority, establishes EV charging criteria in addition to those relating to land and electrical supply. A thorough summary of the notices, policies, and rules regarding EV charging infrastructure is provided in Annexure A. The administration of EV charging infrastructure, which includes the tasks of planning, obtaining permits, and assisting with execution, is the responsibility of government entities with executive powers.

The Bureau of Energy Efficiency (BEE) has been recognised by the MoP as the central nodal agency (CNA) for the deployment of EV public charging infrastructure throughout the nation. The Department of Heavy Industries (DHI) is the other primary organisation charged for putting public charges into action. It is in charge of overseeing the FAME-II programme, which provides financial aid for public EV charging infrastructure. States have designated state nodal agencies (SNAs) to oversee the implementation of public charging under the MoP's instruction. SNAs are required to choose the implementing organisations that will set up, run, and maintain the state's public charging stations and battery swapping/charging facilities. State energy distribution companies (DISCOMs), unless the state specifies differently, are the SNAs by definition[2].

Urban local bodies (ULBs) and DISCOMs are in charge of planning, obtaining the necessary permits, approvals, and certifications at the local level for EV charging infrastructure. Municipal corporations, municipal councils, and any other legally mandated governing entities at the city level are all considered ULBs. They are in charge of maintaining public parking, granting construction permits, and sometimes working with UDAs to enforce building bylaws prime location for public EV charging).

In addition to providing electricity connections for EV charging, DISCOMs are in charge of managing the distribution network, upgrading the grid based on load growth, including that from EV charging, and enforcing the EV tariff set by SERCs. They also have to make sure that the EV charging infrastructure is connected and functioning properly. The SNAs and ULBs may get assistance from unified metropolitan transport authorities (UMTAs) in cities where they are in operation with developing strategies for public charging infrastructure. In addition to this, government entities that possess property are often asked to contribute land parcels for the construction of public EV charging stations. Moreover, as they have access to information on changes in EV penetration in the city or area via car registration data, the state and regional transport authorities (RTAs) are significant players in the planning for public charging infrastructure.

The effective implementation of public charging infrastructure is the result of collaboration between several state and municipal governmental entities. Nevertheless, there is currently no system in place for the many agencies to work together. The essential collaboration between various government entities may be facilitated by a working group for EV charging infrastructure. All relevant nodal and executing agencies, including SNAs, DISCOMs, municipal corporations, and urban development authorities, would be represented by such a working group. Moreover, the transport authorities and SERCs could be represented. To guarantee the required interdepartmental cooperation, the working group might be led by a Chief Secretary and should include senior officials from the energy or urban development ministries. The working group formed in Delhi for this aim is described in Box B. It is recommended that big cities and metropolitan areas form city committees for EV charging, under the direction of the municipal corporation commissioners or the heads of the operating

DISCOMs. To oversee the implementation procedures, ULBs and DISCOMs should deploy nodal officers for EV charging. Building the capacity of local authorities will be crucial to raising awareness of and understanding of the needs for EV charging infrastructure.

The Department of Power of the Government of National Capital Territory of Delhi (GNCTD) established the "Working Group for Accelerated Rollout of Charging Infrastructure in Delhi" in 2019 to support prompt coordination between various government agencies in carrying out the strategy for installing charging infrastructure for EVs in Delhi.

High-level representatives from the power and transport departments, the three municipal corporations, the New Delhi Municipal Council, the three power distribution companies operating in the area, and Energy Efficiency Services Limited make up the working group, which is headed by the vice-chairman of the Dialogue and Development Commission of Delhi (DDC) (EESL.) Special invitees are permitted to participate in working group discussions with the Chairman's agreement.

The main functions of the working group include the following:

1. To take a holistic view of opportunities and challenges for rollout of EV charging infrastructure and recommend strategies to accelerate progress towards the same, in keeping with the Delhi EV Policy.
2. To identify and address coordination issues between various departments and agencies of GNCTD, DISCOMs, local authorities, and the Government of India.
3. To monitor the progress of rollout of charging infrastructure in Delhi at various stages of implementation.
4. Any other policy or coordination issues to accelerate the rollout of EV charging infrastructure in Delhi.

For semi-public and public charging facilities, charge point operators (CPOs) and e-mobility service providers (e-MSPs) oversee and facilitate daily operations of the EV charging infrastructure. The framework architecture, protocols, and procedures that allow centralised administration of charging facilities and their connection with the DISCOMs as well as guarantee effective access to EV charging services for customers are set up by CPOs and e-MSPs. Networks of EV charging stations are installed, maintained, and operated by charge point operators for semi-public or public usage. They can be the charge station owners' agents or they might be the proprietors of the EV chargers. CPOs can handle a combination of client-owned and self-owned charge point networks at once and can accommodate various configurations[3].

In order to build the best EV charging installations, consider the available space and power needs for EV charging at each location. Get in touch with nodal and executing authorities to arrange for the necessary EV charging facility connections, permits, certificates, and licences. Purchase EVSE hardware that complies with the necessary standards, taking into account charging demand, charging patterns, and necessary charging functions. For backend network administration, including user registration and rights management, EV charger categorization (by location and charger type), and remote monitoring, install a centralised system management programme. Handle operational tasks such as planning charging availability, revenue collecting, monitoring charger use in real time, load balancing, performance analysis, etc.

DISCUSSION

Establish service fees for EV charging that are in accordance with legal requirements or market standards. As required by law, provide the DISCOMs and other governmental organisations with the appropriate data. A commercial company or a public utility may serve as the CPO. Because to their advantage in managing the energy infrastructure, public energy utilities are playing a leadership role in the installation and management of public charging infrastructure in various areas of the globe. The majority of CPOs in India today are now private organisations working to develop the public charging industry. By linking EV consumers with various CPO-operated EV charging networks, e-mobility service providers provide charging services. Users of EVs may find and complete transactions at EV charging locations with the use of E-MSPs. Moreover, they allow EV users who are subscribers to one CPO to "roam" (as appropriate) and utilise the charging infrastructure of another CPO. CPOs sometimes take on the role of e-MSPs[4].

Stakeholders must take into account prospective charging demand as well as physical and power supply restrictions when developing EV charging infrastructure. Information on EV charging infrastructure planning will be included in the following three chapters. Assessing the demand for EV charging is the first stage in the planning process and is based on the actual or anticipated number of EVs on the road. In addition, having access to EV charging infrastructure is necessary to meet EV adoption goals. Hence, regulatory agencies could also establish goals for EV charging infrastructure. This chapter provides an overview of the goals that guide the availability of EV charging stations as well as a technique for determining the approximate number of EV chargers needed in a city or area. Given the levels of vehicle ownership and anticipated trends towards electrification in transportation, targets for EV charging availability differ from one location to the next. Along with changing over time, EV penetration will also change. The MoP and MoHUA have established goals for the availability of public charging stations and the availability of EV charging in buildings, respectively (see Box C). These recommended objectives may be adopted by state and municipal planning organisations, or they may impose more challenging goals for their areas. The Ministry of Power (MoP) stipulates the following minimal criteria for the placement of public charging stations in its Charging Infrastructure Guidelines and Standards.

- At least one charging station should be available in a grid of 3km x 3km.
- One charging station to be set up every 25km on both sides of highways/roads.

Public charging stations may have one, multiple, or any combination of chargers from a list of approved EVSE and connection types, in accordance with MoP requirements. Any charger may be installed in e-2W and e-3W charging stations as long as it complies with the technical and safety requirements established by the Central Electricity Administration (CEA)[5]. The availability of EV charging in buildings was added to the Model Building Byelaws (MBBL) 2016 by the Ministry of Housing and Urban Affairs (MoHUA). Section 10.4 of the MBBL-2016's Chapter 10 (Sustainability and Green Provisions), titled "Electric Vehicle Charging Infrastructure," has been included as an amendment.”

- Charging infrastructure shall be provided for EVs at 20% of all ‘vehicle holding capacity’/’parking capacity’ at the premises.
- The building premises will have to have an additional power load, equivalent to the power required for all charging points to be operated simultaneously, with a safety factor.

Except for individual dwellings, all structures are subject to the changes. Additional slow charger (SC) supply standards are offered by segment and are depending on the quantity of EVs to be serviced. Fast charger (FC) standards are optional. Goals for public charging infrastructure are often determined by factors such as demand for EV charging or accessibility.

ACCESS-BASED TARGETS

Aim to provide the least amount of coverage possible across a city or area, and are sometimes assessed in terms of "number of charging points/unit area." Because to the low demand for EV charging in the early phases of EV adoption, they are more suited.

DEMAND-BASED TARGETS

With more EVs on the road, adequate public charging infrastructure is needed, which is the goal of this project. These are based on EV penetration rates and the distance covered by electric vehicles. For a planned expansion of the public charging network in accordance with anticipated EV growth, demand-based objectives are helpful. The method of EV charging demand evaluation for target-setting is covered in the next section. In jurisdictions where a working group for public charging infrastructure has been created, urban or regional objectives for public EV charging should preferably be set by such group. The SNA, urban development agencies, municipal corporations, or other local entities participating in EV charging infrastructure planning may establish objectives in its absence[6]. According to the MoHUA's proposed changes to the construction byelaws, 20% of parking spots in all new buildings must include charging infrastructure. The only jurisdiction with the authority to do so via municipal corporations or urban development bodies is a state. States are advised to implement the EV charging infrastructure adjustments as soon as possible to guarantee that all new structures are EV-ready since buildings generally have a lifetime of 50 years or more.

Amendments to building bylaws mandating an EV charging infrastructure provision also have an impact on the management of parking spots in various building types and electrical power supply connections. The next chapters will go into further depth on them. Building bylaws only apply to new structures, however existing structures should also provide EV charging as a convenience for residents and guests. Based on the demand for EV charging and the available power capacity of the electrical connection, the number of chargers that will need to be placed may be determined. Governments may sometimes issue directives requiring the installation of EV charging infrastructure at commercial and institutional buildings. The Delhi Government ordered all businesses and institutions with a parking capacity of more than 100 cars to reserve 5% of their parking spots for EV charging beginning in March 2020. This covers places like retail centres, clinics, hotels, workplaces, schools, and movie theatres. According to the Delhi EV Policy, properties will be obliged to install slow EV chargers at a least at the designated parking spaces and would be eligible to get a subsidy of INR 6,000 per charging station.

An evaluation of the demand for EV charging may be used to inform many planning steps for the infrastructure. As we shall explore in this chapter, it may be utilised as input data to send objectives for the number of public EV chargers. As we shall see in subsequent chapters, it may also be used to examine grid capacity and the need for improvements as well as to design the locations for public charging infrastructure. Urban and regional EV charging demand is influenced by per capita car ownership rates, EV penetration levels, and driving habits. Such an evaluation need to be carried out or commissioned by government planning bodies in charge of the infrastructure for charging as it is often utilised for public planning procedures.

An evaluation of the demand for public charging for various car segments should be the main focus of an assessment of the infrastructure needs for EV charging. In order to establish yearly objectives for public charging infrastructure, this may be used to determine the necessary number of public chargers. The following list of steps includes estimates for the charging infrastructure and demand for EV charging. Estimate EV sales for various car categories for the horizon years 2025 and 2030 based on desired EV penetration rates. Based on data from city development plans or information from transport planning, segments may be classified into 2Ws, passenger and freight 3Ws, personal and commercial automobiles, and other LCVs to determine the daily kilometres travelled by each vehicle segment. Determine the daily energy consumption for EV charging based on the average battery capacity and driving range of each car category[7].

Assign the proportion of charging to be completed via public charging infrastructure for various car segments based on current research or through polls of current EV customers. Personal 2Ws and automobiles, for instance, may complete the majority of their charging needs in homes or places of business, and may only need public charging for 10% of their charging requirements. Calculate the daily EV charging demand at public charging infrastructure for various car segments using the information from steps 3 and 4[8].

Indicate the charger types that will serve the various EV sectors based on the numerous kinds of chargers that are on the market, grouped by voltage level and power rating. Calculate the number of various kinds of chargers required for the public charging infrastructure based on the estimated charger use (for instance, 25%). The number and kind of public charging stations needed are determined by forecasts of EV penetration in various car segments, the demand for charging, and the percentage of charging to be handled by[9] public charging stations. In order to set up an EVSE and park the EV while it charges, there must be room available. This location is designated for private and semi-public charging in the parking lots of independent residences, apartment complexes, or business and institutional structures. Therefore, it is vital to arrange for a network of chargers that are conveniently positioned and evenly spread around a city or area if public charging is to be implemented [10].

CONCLUSION

In order to design the placement of public charging infrastructure, this chapter provides a paradigm that combines top-down spatial analysis with bottom-up site selection. It also emphasises the institutional setups and legislative changes required to expand public charging. Planning the placement of public charging infrastructure enables the selection of the best sites for their installation. It may be done on many sizes, from a city-level exercise to one that takes place in a neighbourhood. To guarantee a well-planned public charging network, SNAs or ULBs may carry out or commission a site planning study as part of their mandate. CPOs may also do site planning when establishing charge point networks to find the ideal areas with high charging demand.

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CHAPTER 8

A LOCATION PLANNING FRAMEWORK

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ABSTRACT:

Accessibility may be understood as the ease of finding and getting to public charging facilities from any location. This includes areas of low estimated charging demand, which still need a minimum provision of charging infrastructure. Network planning and site selection play a role in improving EV charging accessibility. A greater number of distributed charging points in an area reduces the average distance EV users must travel to access public charging. Further, visibility of charging facilities, ease of entry and egress at charging sites, and their proximity to major roads can also influence their accessibility.

KEYWORDS:

Electricity, Location, Mobile,Networks Wireless Charging.

INTRODUCTION

To achieve maximum use, public charging infrastructure should be placed where there is a need for charging. The demand for public charging at a particular location will depend on a number of factors, such as the population and employment densities, parking accessibility, traffic volumes, and the presence of tourist attractions, transit stations, and other commercial establishments and other points of interest. It also depends on if there are any additional private or partially public charging stations nearby. The price of EVSEs, the price of the land, and the price of the power supply are the three main determinants of the cost of public charging infrastructure. By using a dispersed charging network of regular power charging stations instead, which are less costly, take up less room, and use less energy overall, all three may be greatly decreased[1].

Utilization

Indicators: Population and employment densities, traffic volumes, point of interest, transit stations

Cost

Cost of EVSE, land, and power supply connection are indicators. , Depending on the scope of the planning and the quality of the geospatial data at hand, location planning for public charging infrastructure may be carried out via a digital geospatial analysis or as a physical activity. It is advised to use a hybrid approach to site planning at the urban or regional scale. To determine prospective charging demand and the ensuing public charging needs at a unit area level, a macro-level geospatial analysis may be done. Site selection for the installation of public charges may be done locally, in conjunction with local government officials and landowners. Here, using a geographical analytic approach, we will map the prospective EV charging demand's geographic distribution. The relative EV charging demand at various sites may be mapped with the use of geospatial analysis. This may then be used to disperse public charging infrastructure according to the charging demand across various locations. Such a study is often helpful to determine how charging demand is distributed within a city or area. The effectiveness of a geospatial study for smaller regions, such as neighbourhoods, would rely on the accessibility of highly disaggregated spatial data. Depending on the scope of the exercise and the level of data disaggregation used, divide the region to be planned into cells of 1 sq km size (hexagonal or square).

Find the parameters that, as stated in the preceding part, indicate a prospective charging requirement and gather spatialized data for those metrics from various sources. The grid cells should be mapped to the data values. It is possible for parameters like places of interest or existing charging stations to have impact zones that may be allocated to specific grid cells nearby. Calculate the necessary number of charging points in each cell as a proportional part of the overall number of public charging points for the planning area based on the charging demand for each cell. Make sure accessibility goals are satisfied with a minimal charger allocation as needed in cells with extremely low charging demand.

An area-level need for public charging stations is determined at the conclusion of this procedure. Instead, municipal authorities may use geospatial analysis, as in the case of FAME-II charging stations, to evaluate the relative desirability of certain public areas for EV charging. Depending on how they may affect future demand, give certain parameters and their values distinct weights. Combining all of the cell parameters' values, classify the cells according to the prospective demand, from high to low.

The location of public charging infrastructure should maximise the facilities' visibility, accessibility, and use. A distributed planning technique may be used to choose several charging locations with various configurations of the number of chargers and power levels as needed for a particular charging demand in the region. This may make network deployment more efficient by lowering the amount of space and power needed at each location. Locations for public charging may be found in areas reserved for transit station parking, on-street parking spaces, or any other place with enough room and accessibility for all EV users. Site ownership may vary, and numerous agreements may be necessary for restricted charging usage.

Each EV charging station must have enough room for parking and moving about, setting up charge points, installing barriers and signs, and setting up any necessary upstream electrical equipment. A automobile parking bay typically requires an area of 5 x 2.5 metres. Depending on whether it is open parking or underground parking, the Equivalent Car Space (ECS) for automobile parking ranges from 23 to 32 square metres, including the vehicle circulation area. This may be used as a general guideline to calculate the necessary number of charges. Wall-mounted or pedestal-mounted chargers may be used, which would increase the amount of space needed in the parking area, depending on the parking position and the charger specs.

Exclusive distribution transformers (DTs) are not always necessary and are normally only needed when there are many high-power charging outlets on high-tension (HT) electrical connections. Planning the energy supply for EV charging and figuring out if upstream electrical infrastructure is necessary are both topics covered in Chapter 5. The approximate amount of area needed on site for DT installations is given.

Including EV charging in parking lots requires careful site design. It depends on the kind of parking lot and how many different kinds of EV charging stations will need to be installed there. For instance, wall mounting regular power chargers is a more affordable and space-efficient solution. This option is available for charging installations in residential and commercial structures. Pedestal-mounted charging equipment allows for improved movement and can house numerous charging stations in a single EVSE for high-powered chargers in public off-street parking areas.

The following planning recommendations should be kept in mind while preparing for EV charging integration at a specific location:

1. Allocate space that is easily accessible and clearly visible from the site entrance.
2. Select the charging location to minimize civil work and wiring requirements, where possible.
3. Follow all safety provisions for EV charging planning as defined by the CEA Measures relating to Safety and Electric Supply.
4. Clearly demarcate the parking spaces reserved for EV charging with appropriate signage and markings.
5. Provide ample space for vehicle circulation i.e. to enter and exit the charging bays.
6. Ensure that the charging area is secured against theft and vandalism.

In order to follow the planning criteria, CPOs should collaborate with site owners. The following page offers indicative site designs for two different kinds of charging stations. A dense network of standard power charging stations that is connected with public parking is the goal of a distributed approach to public charging infrastructure. Even a single parking space or a huge parking lot’s numerous space may enable EV charging. Because of this, a network needs more than one location even if each site may only need a tiny amount of space. Nonetheless, CPOs often do not own the land needed to install the infrastructure for charging, and therefore, there may be difficulties installing public charging stations in highly trafficked, accessible sites for a number of reasons.

1. **Lack of Clarity on Land Ownership:**It is sometimes unclear who really owns the land parcel where EV charging is to be put. For instance, while though businesses and other establishments often control the street parking in front of their locations, this property is frequently publicly held and may be taken back at any moment for objectives like road expansion or other similar ones.
2. **Poor Planning and Regulation of Parking:**Several regularly used on-street or off-street parking spots are prohibited. While parking is OK, related activities like EV charging are prohibited. In addition, there is a lack of anticipated public parking in a number of locations, which leaves no room for the installation of charging stations.
3. **High Cost of Urban Land:**The price of urban property may be exorbitant, even in cases where ownership is obvious and when parking is permitted. Contractors that run public parking lots often don't want to charge EVs at below-market prices. Due to the absence of guaranteed demand for public charging during the early phases of EV adoption, this presents a high entrance hurdle for CPOs. This also applies to government-owned property, such as municipal parking, parking at metro stations, and other open spaces.

These issues may be resolved by SNAs and local planning organisations, which will promote a quicker expansion of the public charging infrastructure. Although more fundamental legislative changes are required to include EV charging in planning procedures, immediate action may be taken to free up land for EV charging.

DISCUSSION

By Memorandums of Understanding (MoU) with CPOs, land-owning organisations like municipal corporations, urban development authority, and other local government entities may provide access to attractive parking spaces. The MoUs would grant the usage of certain locations for EV charging for a predetermined amount of time. Without affecting the financial sustainability of developing EV charging services, revenue-sharing methods with the CPO or a separate allocation of advertising rights at charging sites might bring in money for the government authority.

This method works well for vacant lots and impromptu parking areas outside of stores and other structures. The traffic police should inspect chosen locations to make sure that traffic flow is not impeded. To reduce the cost of civil construction, site selection should assure close access to electrical supply locations. Innovative technologies like light EV charge stations, streetlight chargers, and other inexpensive EVSE solutions are offering practical solutions for the infrastructure of charging. By allowing connection with street furniture like lamps and bollards, as demonstrated in the example in Box F, ULBs may collaborate with EVSE manufacturers and CPOs to incorporate these inexpensive charging stations into existing parking lots.

This is acceptable for both on-street and off-street parking locations that are officially classified as public parking. ULBs and CPOs may split the expenses and income from the charging infrastructure since the costs of implementation are so drastically lowered. To include public charging in parking spots, communities must alter their parking policies. This will not only arrange street parking in cities, but it will also guarantee that EV charging stations are allocated for all present and future public parking. This makes public charging infrastructure more accessible and may even assist its spread in residential or institutional areas where on-street parking is available. Local government bodies might order that a portion of currently available public parking spots be set aside for EV charging in the near future. For planned urban development and expansion, techniques like town planning programmes and land pooling programmes are used. They take into account parking needs for projected growth. Integrated into urban and transportation planning procedures should be reserved parking and auxiliary infrastructure for public EV charging. To construct integrated and multimodal transportation networks, EV charging might also be included at transit hubs.

A suitable charging infrastructure provider requires inexpensive, accessible, and dependable power. Whenever possible, the widespread low-tension (LT) electricity distribution infrastructure should be used to offer electrical connections for EV charging in order to create a quickly scalable EV charging network. Most charging stations may be linked to the LT electrical network thanks to a distributed charging infrastructure that mostly consists of normal-power charging points. This chapter examines the governance and regulatory frameworks that affect EV charging connections and presents three options for setting up the power supply to either private or public charging stations. In India, the market for electricity is heavily controlled, with both federal and state laws in place. A collection of rules and criteria, some general and others created expressly for charging facilities, govern the provision of power connections for EV charging.

The CEA has announced changes to the law that will make it easier for charging infrastructure to connect to the grid. Here are highlighted important regulatory regulations for EV charging.

- Defines “charging stations” and “charging points”
- Recognizes EVs as an energy generation resource
- Introduces standards for charging stations connected or seeking connectivity to the electricity supply system

outlines the necessary safety precautions for the charging infrastructure, such as general safety for EV charging stations, earth protection systems, fire safety, testing of charging stations, inspection and periodic assessment, record-keeping, and safety requirements in accordance with international standards. According to the Indian Constitution, the distribution and supply of electricity is a state responsibility, hence state laws govern the conditions for connection and delivery. The primary legislative framework controlling the provision of electricity connection and supply by DISCOMs is the State Electricity Supply Code & Performance Standards Regulation, which falls under the jurisdiction of SERCs. Planning or putting up charging facilities should take into account the proper state rules since this regulatory framework varies from state to state. The following rules of the state supply code have a particular bearing on electrical connections for EV charging[2].

The required sanctioned load determines the type of connection, which can be single-phase LT, three-phase LT, or high-tension (HT). This decision also determines the tariffs, the time it takes to get a connection, and whether or not ancillary upstream infrastructure like distribution transformers is required (DTs). An HT connection requires the applicant to build up auxiliary electrical equipment, incurs greater installation and monthly demand fees, and takes longer to energise. States have vastly different sanctioned load limitations for LT and HT connections. Commissioning an EV charging connection may be more expensive and time-consuming depending on the regulations controlling the delivery of electricity from the current network. It is simpler and more cost-effective to connect to an existing network (without the need for expansion) than it is to extend the distribution system. In addition to taking time, network expansion may also require the applicant to contribute financially.

When the capacity usage of the closest feeder is anticipated to surpass the permissible level (often 70%) upon award of a new connection, such as a charging infrastructure link, a system upgrade is suggested. The distribution network may be expanded, although doing so can be costly and time-consuming. With fewer authorised loads and charging stations per location, a dispersed public charging network may reduce the time and expenses involved in obtaining power connections for EV charging. When more charging stations are needed or mandated by building bylaws or other governmental regulations, this might increase capital and operating expenses and deter the construction of EV charging stations. The supply code has to be modified by SERCs and DISCOMs to provide a cost-effective and dependable energy supply for charging infrastructure. EV charging is a new kind of consumer need that is unique from current consumer categories. State governments have access to electricity tariffs as a crucial fiscal and regulatory instrument, and different states have different tariff structures. A DISCOM's consumer basket now includes EV charging, and by classifying it as a separate consumer category in the tariff schedule, electricity connections for EV charging may be made easier.

Many advantages come from implementing an EV-specific power pricing. Tariffs may be created to regulate the load profiles of EV charging as well as to clearly communicate pricing signals to EV consumers. The economic case for public EV charging may be impacted by electricity costs, which are a significant operational expense for CPOs who provide charging services. The fixed or demand charge for an electricity connection is assessed on the sanctioned load for the connection or the maximum power demand registered during the billing period, and it must be paid regardless of the actual power usage. Additionally, a separate tariff category for EV charging will allow state governments to offer "EV-only" incentives in order to promote adoption. Demand fee exemptions for EV charging connections might strengthen the financial case for installing charging stations given the low demand for charging during the early stages of EV adoption. Energy costs, which are based on the total amount of energy or electricity utilised during the billing period, are the variable portion of an electricity tariff. Both CPOs, who may cut their operating expenses as a result of cheaper energy prices for EV charging, and EV consumers gain from lower charging rates.

21 states and Union Territories have already passed unique EV charging rates with decreased energy costs and/or demand charge exemptions as of March 2020. In Annexure C, state EV tariff information is supplied. Electricity connections for EV charging facilities must be provided by DISCOMs. They deal with various kinds of energy users while enforcing and carrying out the laws and regulations governing the power supply on the ground.

New customer classes for DISCOMs include EV owners and CPOs, who have different power connection needs than previous consumer classes. DISCOMs will need to put in place regulatory measures like EV pricing categories, create standard operating procedures, and learn how to design and provide power connections for EV charging infrastructure in order to meet these needs. DISCOMs may speed up the process of supplying energy connections for charging infrastructure since they serve as the link between the electricity network and CPOs or EV consumers. All DISCOMs should be required by SERCs to conduct the following actions:

Establish a single-window system for processing applications and provide explicit public standards for the metered connection application procedure for EV charging. In order for CPOs to determine the viability and projected cost of obtaining the necessary sanctioned load for a proposed charging facility at a specific site, prescribe a technical pre-feasibility check for public charging connections. Establish upper limits for the rapid examination, certification, and award of EV charging connections. Provide CPOs with a simplified version of the standards and demands for various kinds of connections and related fees. Clearly define the criteria and procedures for applying for metered EV connections so that owners of private charging (such as those in homes and workplaces) may take advantage of any advantages like EV-specific prices and specialised EV charging programmers.

Create a special internal team, similar to a "e-mobility cell," to handle inquiries, work with potential candidates, and conduct site visits for EV charging connections. The energy connection for an EV charging station or facility may be set up in a number of ways by an EV owner or CPO (with multiple points). CPOs or EV owners should decide which option is best for them depending on their needs. Estimating the necessary power consumption in kilowatts is the first stage in setting up the energy supply for EV charging (kW). This is the same as adding up all of the charging points' rated input needs that are going to be installed at a certain location. This would be similar to the electricity necessary to concurrently charge all of the batteries that are contained in a battery charging system. An EV owner or CPO may choose one of three ways to provide energy for the EV charging infrastructure after the necessary power demand is known: use a power source that is already connected Plan a new electrical connection. Use a system that generates renewable energy on-site.

Where semi-public or public EV charging is built within a host facility, the CPO may choose to draw electricity from the existing power connection provided the host establishment owner permits it. For private charging, where a single charging point is being installed in a home or office, EV owners can draw the electricity from the existing power connection. The following procedures must be taken in order to connect the EV charging infrastructure to an existing power connection. Verify the kind of connection offered by the host business and if the sanctioned load can sustain the expected power consumption of the charging infrastructure. A standard operating process for determining if the sanctioned load is sufficient to meet the demand for electricity for EV charging should be made available by DISCOMs[3].

The owner of the host facility must submit an application to the DISCOM for an increase in the sanctioned load if the current connection's sanctioned load is insufficient. It can cost more and take longer to get up and running. The owner of the host establishment must submit an application for a three-phase LT connection or an HT connection if the existing connection type is single phase LT or three phase LT and the increase in sanctioned load exceeds the permitted power demand threshold for the category (as specified in the state supply code). This entails replacing the metre, for which the applicant will be responsible for paying various expenses such Service Line Cumulative Development (SLD) fees and metre change fees, among others[4].

It is necessary to evaluate the serving DT's capacity before upgrading to a three-phase LT connection. The DISCOM may need to put up a new DT together with the required 33/11 kV wires if it turns out that the DT is loaded near to its capacity threshold. To minimise delays in grid augmentation, the owner of the host facility may choose to construct an exclusive DT on their property at their own cost. The applicant will have to build their own DT and 33/11 kV lines if an HT connection is required, which will be expensive and time-consuming. This method is often used when the sanctioned load of the current connection has surplus capacity or when competitive EV charging costs are not a concern. It works best for private and semi-public charging, which the host institution provides as a perk for customers and guests. The CPO or EV owner must apply for a separate metered connection a pre-paid connection is also a possibility specifically for EV charging in accordance with the requirements of the relevant SERC in order to take advantage of special EV pricing [5].

CONCLUSION

CPOs or EV owners may submit an application for an exclusive power connection for EV charging at a host location or at a separate location with charging stations. Same procedures apply when setting up a new electrical connection. Determine if the anticipated power demand falls within the single-phase LT, three-phase LT, or HT categories, then apply for a new connection in accordance with the DISCOM's stated process. If the state where the charging station will be located has a distinct EV pricing category, the DISCOM should have distinct application requirements. The CPO must set up its own DT and 33/11kV wires for an HT connection. When deciding where to establish the charging infrastructure and how much power would be needed, the CPO for an LT connection should consider the adjacent DT's hosting capacity. This may lessen the need for costly grid improvements.

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CHAPTER-9

OPEN CHARGE POINT PROTOCOL (OCPP)

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ABSTRACT:

If a new DT needs to be installed to serve the new connection, the DISCOM may undertake this as part of their planned grid upgrades. Alternatively, the CPO may need to pay for the installation of a new DT, especially if it is for the exclusive use of the charging facility. This will depend on the provisions of the state supply code and may vary between states. In case the charging facility is housed within a host establishment, the CPO may not be able to apply for an exclusive connection if it does not have the ownership of the charging space. However, the CPO can apply for a separate pre-paid EV metered connection for the charging facility up to a certain load, provided there is a formal rent or lease agreement for the space with the owner and that such pre-paid connections are permitted by the SERC concerned.

KEYWORDS:

Charging, Electricity, Mobile,Networks, Open Charge Point Protocol (OCPP).

INTRODUCTION

DISCOMs may allow further actions to make EV connections available inside of already-existing host businesses. Less metering and separate EV connections without demand fees are examples of measures. The preferable places for EV charging stations are major commercial and institutional enterprises like malls, big office buildings, amusement parks, etc. These venues often have unique DTs, their own HT connections, and a high sanctioned load. In these situations, it is practical to create a separate LT metered connection from the current HT line for EV charging. The provision of "minus metering," in which an exclusive electricity connection for EV charging is taken from the host establishment's current HT connection and the energy usage for EV charging is monitored using a sensor, is something that DISCOMs may take into consideration. The energy used to charge EVs will thereafter be invoiced in accordance with the relevant EV tariff. A new LT connection for the charging stations is more expensive and difficult to implement than such a setup[1].

The appropriate demand/fixed costs must be paid individually for an additional EV connection at a host business. This is the case even if the current energy connection has a sufficient sanctioned load to cover the power demand from EV charging. If the aggregate peak demand from both connections always stays lower than the authorised load of the original connection, DISCOMs may consider suspending demand costs for separate EV connections in such circumstances. The EV connection has to be associated with the same customer profile as the current connection in order to qualify for this demand fee waiver. By installing charging stations, such agreements clearly benefit host enterprises like shopping centres, office buildings, entertainment venues, etc. Also, they justify the authorised load requirements for new EV connections, which may be quite large if demand costs are completely cancelled. Smart chargers and central management systems may be used by host establishments to regulate the EV charging load so that the total load does not go beyond the authorised load[2].

A Delhi-based family intends to buy an electric four-wheeler with a 45 kWh battery capacity. As compared to using the current household energy connection, it is determining if an EV metered connection is more cost-effective. The family's sanctioned load has headroom to accommodate an extra load of around 3 kW, and its typical monthly power use from April to September is about 380 units. According to the usage slabs in the table above, a residential home connection in Delhi is subject to energy costs. The energy fee for Delhi's EV pricing is 4.50 per unit, and there is no demand charge.

The EV must be charged every five days from 20% to 100% state of charge to meet the demands of the family. Hence, the estimated 216 unit monthly power usage for EV charging. A set cost of 4.50 cents per unit will be applied to the power used to charge EVs, making a monthly total energy fee of 972 cents. The household will therefore pay a total monthly energy fee. The anticipated average monthly power usage is 596 units (380 + 216). The relevant monthly energy price is anticipated to be $2,774 per month based on the current rates. At this amount of EV use, the family would be better off taking advantage of a separate EV metered connection. Moreover, if the regulator decides to include EV charging within the ToD price system, it will profit from any upcoming Time of Day (ToD) rates[3].

CPOs may decide to use captive electricity production to partially or entirely satisfy the energy demand for EV charging. Yet, it is necessary to evaluate this option's viability on a case-by-case basis. Solar photovoltaic (PV) or solar-wind hybrid systems are often used to provide captive electricity for EV charging, with stationary energy storage providing a stable power source. A crucial factor in determining viability is the surface area available for installing the generating system as well as the site's solar insolation and wind profile. A typical installation space for a 1 kWp solar PV system is 10 sq m. To make the most of the available space, the system may be built as a roof over the charging facility, or it can be installed, if necessary, on the host establishment's roof.

To assess the site's capability for power production and needed storage, a technical feasibility study must be conducted. The CPO must assess the portion of the installation's needed power consumption that can be met by captive generation based on the feasibility study. The CPO will need to make arrangements for a backup source of energy supply, either via an existing grid connection or through a new metered connection, in cases where on-site electricity production and storage can only partially meet the power demand.

CPOs will need to compare the capital expenses of installing the energy generating and storage system, including the ongoing maintenance of storage batteries, against the economic advantages of captive power generation. A captive generating system may make sense for CPOs to install in areas where the DISCOM's power supply quality is a significant problem. Electricity generated on-site using renewable energy may be subtracted from the overall amount of power used during a billing period thanks to net metering or net billing. A "prosumer" is a person or entity who uses energy from the grid and has the ability to provide power to the grid, thus this lowers their electricity cost. At the conclusion of the billing cycle, the prosumer may choose to pay the DISCOM for any excess units or pay the difference in units.

The rules allowing customers to participate by installing renewable energy generating equipment on their properties have been specified in several states' Net Metering Rules, which have been made public. DISCOMs should encourage CPOs and host businesses to use the rules for net metering. Owners of EVs that use captive renewable energy production to charge their vehicles may also be eligible for subsidies from SERCs[4].

A CPO wishes to build two 50 kW chargers, three 7 kW chargers, and a 9-unit stack battery charging system at a place where a freestanding charging facility will be built. Upon consultation with the DISCOM, it is discovered that the neighbouring DT has the potential to accommodate an extra load of 48 kW before needing to be expanded. Also, for single-phase LT and three-phase LT power connections, the supply code specifies maximum sanctioned load restrictions of 7 kW and 65 kW, respectively.

What is the best form of connection for a battery charging system? If parking is available, you may also adjust the layout to seven 7-kW chargers stacked one above the other. The overall power need for the requested configuration is 133 kW, exceeding the three-phase LT connection restrictions as well as the closest DT's hosting capability. There are three primary ways for the CPO to access the energy supply on the property. The chosen configuration is determined by the site's billing needs. Unfortunately, this is in excess of the surrounding DT's capacity, necessitating an upgrade. The DISCOM may accept the CPO's application for a new DT as part of its routine grid enhancements. The CPO won't incur any further costs for the DT in this situation. This is subject to the DISCOM's judgement and the relevant rules outlined in the state supply code laws. Implementing such plans might take a long period, which would put off the charging facility's inauguration[5], [6].

With this choice, the CPO is free to make accommodations for the charging station as intended. Nevertheless, it is responsible for paying for the DT and the related 33/11 Kw wires, which may cost up to 2.5 lakhs. The supplementary electrical infrastructure will need more room at the chosen location, according to the CPO. Also, there are additional fees involved with applying for an HT connection, such as SLD fees, and the CPO may be required to pay higher demand fees on its power bills. The CPO may either keep one 50 kW charger and the stack with a maximum sanctioned load of 65 kW.

Electricity connections may be granted more quickly and easily if the entire power consumption is reduced to fit within the adjacent DT's hosting capability. The charging infrastructure can accept five 7-kW charging ports in addition to the stack battery charging system for a total load of 48 kW. There is no imminent need for capacity expansion since the adjacent, current DT is capable of supporting this load. Any additional charging requirements may be met at a nearby location with enough load capacity. With a 33% EV adoption rate by 2030, it is anticipated that the total power consumption for EVs would be 37 TWh. By 2030, fewer than 2% of the nation's entire power consumption will be met by this. Consequently, it is not anticipated that India would have a problem fulfilling the entire energy demand for EVs.

Yet, EVs' large charging capabilities and geographic concentration might cause their power need to fluctuate greatly. This may create obstacles to the smooth supply of EV charging connections and have an effect on grid stability for all energy users when coupled with localised limitations in distribution capacity. The approaches to increase grid infrastructure usage and include EV charging loads into electrical network design and growth are highlighted in this chapter. Measures to improve power connections for EV charging at the site level were covered in the preceding chapter. Energy management strategies and distributed charging network design at the feeder and network level may maximise grid consumption and considerably lessen the urgent need for expensive upgrades[1]. The amount of load needed for EV charging rises when charging stations, particularly high-power chargers, are concentrated in one area. When a feeder's acceptable use limit is reached, this may then call for infrastructure changes. Thus, it is advised to construct charging infrastructure in a dispersed way to reduce the power consumption for charging at any place.

DISCUSSION

Passive EV charging management comprises modifying EV customers' charging habits using tools with specifically created power tariffs. In order to prevent the electrical system from being overloaded, Time-of-Day (ToD) tariffs are created so that EV charging is more costly during peak times. ToD tariffs manage EV charging loads efficiently and without placing an undue financial strain on EV owners or CPOs. Remotely managed EV charging is known as active charging management, and it reacts to events such as changes in tariff, energy consumption, etc. EV charging sessions may start or stop, and charging levels can ramp up or down automatically, depending on the inputs. For active EV charging, specialised "smart chargers" are required. As well as more dynamic regimes like Time-of-Use (ToU) tariffs, where power rates are altered in real time depending on demand, smart chargers can handle passive management tools like ToD pricing[2], [3].

Beyond maximising grid consumption, using passive and/or active EV charging management may provide a number of system-wide advantages. Reduced consumer power prices, better renewable energy integration into the electrical supply, and more dependable and robust grid services are a few of these. Growing EV adoption poses concerns at several levels, from the DISCOM's service region to the feeder level, as a result of increasing charging demands. On the one hand, as shown in the modelling of the EV charging load in California, USA, aggregated charging demand may worsen the peak demand in a DISCOM's service region or produce additional demand (secondary) peaks.

On the other side, periodic surges in EV charging demands might be bad for the distribution network, especially in places where the hosting capacity of the power feeders is limited. Unmanaged EV charging, also known as simple or dumb charging, may impair the efficient functioning of the electrical distribution system by resulting in voltage instabilities, harmonic distortions, power losses, and a decline in dependability indices. When EV charging stations utilise an existing connection to get power, dumb charging might lead to voltage instability in the host establishment's electrical circuit[7], [8].

The expected state-wide aggregated EV charging demand for California, USA, on a typical workday in 2025 is shown in the image above. The expected load from Level 1 charging, which utilises a typical residential plug, is shown by the blue band (single-phase 120V). These chargers vary in output power from 1.3 kW to 2.4 kW, and they normally lack any load management features. Residential charging drives the diurnal peak in EV charging demand, which peaks at the same time as the traditional evening high in home power consumption. Residential charging loads should be controlled by passive and active demand management to reduce the need for grid upgrades and spread out charging demand throughout various times of the day.

Smart charging, on the other hand, employs both passive and active energy management techniques in order to balance charging demand more evenly and to reduce the adverse effects of EV charging loads on the distribution system. Pilot programmes throughout the globe have shown that smart charging, when used in conjunction with passive management strategies, may successfully move a substantial portion of the EV charging load to off-peak hours while still meeting consumer demand. Moreover, controlled EV charging may be used to increase the amount of renewable energy used by coordinating the best times for vehicle charging with the times when renewable energy is generated at its highest rates.

Smart charging is helpful in charging scenarios where EVs utilise an existing power connection to get their energy. In order to prevent exceeding the permitted load, smart chargers with the necessary capabilities may adjust charging power levels in response to overall power consumption. In order to offer frequency response services and load balancing services, smart charging devices react to signals at the feeder level or within a DISCOM service area to manage the rate of charging. A variety of capabilities and features are included in smart charging. An EVSE with minimal features is sufficient for private charging when configured according to ToD rates. A greater variety of functions are required for more sophisticated systems at commercial charging facilities or quick charging hubs in order to offer dynamic load management, react to ToU pricing signals, and run various subscription plans for efficient charging transactions. To enable interactions between the various levels of the system, such as between EVSEs and charging networks (or central management systems), between various charging networks, and between the Central Management System (CMS) and Distributed Energy Resources Management System (DERMS) hosted by the DISCOM or a third-party aggregator, smart charging at scale requires a uniform communication architecture.

EVSE-CMS COMMUNICATION

An EVSE and a CMS, commonly referred to as a charging station network, may communicate thanks to the open-source, free-to-use Open Charge Point Protocol (OCPP). Users may transition between charging networks because it enables interchange between various charging networks, software systems, and equipment. It provides capabilities for managing devices, managing transactions, maintaining security, smart charging, etc.

In addition, a smart charging system comprises the following features:

1. An intelligent back-end solution that enables real- time data sharing between the EV, EVSE, and CPO, known as the Central Management System (CMS). This is the backbone of smart charging.
2. A uniform communication layer for all the charging devices within the CPO network. For DISCOMs, a standard communication layer needs to encompass all charging networks of different CPOs in their service area, for charging load management at the grid level. See Box H forbore details.

EV charging will first be done using time-based tariffs like ToD utilising ToD metres; subsequently, more flexible time-of-use (ToU) prices may be used. Commercial charging facilities are where smart charging is often implemented, and for semi, smart chargers with backend communication capabilities should be utilised. In order to facilitate automatic roaming across charging networks for EV owners, the Open Charge Point Interface protocol (OCPI) enables information sharing between e-mobility service providers (e-MSPs) and charge station operators. Charge station details, charging session authorisation, prices, reservations, roaming, and smart charging are supported features[4].

Demand response signals between DISCOMs and EV consumers are facilitated through the Open Automated Demand Response (OpenADR) protocol. Electric cars are among the distributed energy resource (DER) assets that DISCOMs may manage with the use of the DERMS platform. Using demand response signals and EVSE power reduction during peak public and public charging hours, OpenADR offers energy demand management for EV charging. Private charging is typically Mode 2 charging and does not support smart charging when done at home or for personal usage. This makes managing home charging loads challenging, as seen by the California example previously given.

It is recommended that a market be developed for inexpensive chargers that can be configured to correspond with ToD rates in order to partially alleviate this problem. This will make it possible to passively regulate private charging occasions, which may help to balance off the grid's surplus demand during peak use. EV owners may update their chargers at that time, when DISCOMs need smart charging capabilities for private charging. Table 5 lists many stakeholders and their respective roles and duties in order to establish a controlled charging system [9].

Private EV user

- Apply for separate EV connection with ToD meter
- Use programmable EV chargers with pre-set charging functions
- Charge EV in accordance with ToD tariffs, where applicable

CPO

- Install charging equipment compliant with OCPP1.6 or higher version
- Adopt OpenADR or equivalent communication, when notified by the concerned authority

DISCOM

- Enable passive management measures by designing appropriate ToD tariffs
- Develop guidelines on minimum data sharing requirements by CPOs
- Offer bundled services to private EV owners, with EV metered connections and programmable EV chargers
- Tie up with charger manufacturers to certify charging devices that meet the minimum criteria for managed charging

SERC

- Stipulate installation of ToD meter for EV charging, including for private charging and battery charging for swapping
- Introduce time-varying rates for EV charging based on the availability of grid-tied renewable energy
- Structure demand charge to minimize financial burden to LT-charging points while also discouraging unmanaged EV charging

CEA

- Mandate DISCOMs to adopt OpenADR and create a Distributed Energy Resources Management System (DERMS) at the back end
- Make installation of ARAI-approved charging equipment compliant with OCPP1.6 or a higher version mandatory for all charging use-cases
- Stipulate CPOs to adopt a uniform CMS template that is:
  - Based on OCPP for network communication
  - In sync with OpenADR for communication with DERMS of the serving DISCOM[10]

SNA

- Promote smart charging to avoid lock-in with unmanageable dumb chargers
- Provide a platform to the EV charging service market for bulk procurement of smart chargers

CONCLUSION

To ensure a quick and widespread transition to EVs, the energy infrastructure must be prepared to meet EV charging demand. Without the requirement for grid improvements, the use of smart charging techniques may assist control EV charging demands to some extent. But, coming future, DISCOM's planning procedures for network improvements and grid upgrades will need to take EV charging demands into consideration. In order to analyse EV charging at the grid and feeder levels for various EV penetration scenarios, DISCOMs need also take into consideration additional elements of relevance, such as the geographical concentration of EVs, different EV charging patterns, and the simulated effects of ToD measures. As a result, DISCOMs will be better able to plan their load management strategies, create plans for grid upgrades, and prepare for necessary increases in power purchase agreements (PPAs). DISCOMs should then create EV preparation plans based on the effects of the charging demand on the grid infrastructure.

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CHAPTER-10

CHARGING INFRASTRUCTURE IMPLEMENTATION

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ABSTRACT:

National and state regulators are advised to direct DISCOMs to undertake impact assessments and prepare EV readiness plans. Box I provides an example of an impact assessment study undertaken by DISCOMs in Delhi. The study "EV – A New Entrant To India's Electricity Consumer-Basket" (by Alliance for an Energy Efficient Economy) evaluates the seasonal impact of charging requirements for 10,100 EVs (comprising 7,100 e-2Ws, 1,550 e-3Ws, 1,350 e-4Ws and 100 e-buses) on the peak power demand of each of the four DISCOMs in Delhi.

KEYWORDS:

Electricity, Load, Mobile,Networks, State Load Dispatch Centre (SLDC), Wireless Charging.

INTRODUCTION

According to the research, the demand for quick EV charging accounts for a very small portion of the overall demand in a DISCOM's service region. Yet, based on EV charging trends, even at this time, EV charging might either aggravate peak loads or fill out the off-peak hours for power consumption. Moreover, more than 23,000 EVs were registered in Delhi in 2019, although the research only took into account around 10,000 EVs in a DISCOM service region in Delhi. By 2030, this number is anticipated to increase to over 200,000 annual EV registrations. The demand for EV charging as a percentage of overall power consumption in a DISCOM service region is anticipated to increase quickly at the current pace. Impact analyses of localised charging loads on grid infrastructure at the feeder level may be used to forecast that the effect of EV charging will be more evident at the distribution transformer (DT) level. Less than 2,000 charge stations have been installed nationwide as of March 2020, making India's EV infrastructure sector a fledgling one. Nevertheless, given that the market is anticipated to grow quickly over the next years, businesses from a variety of industries are joining at various stages of the value chain [1].

Based on the following input data, the research created an Excel-based model to assess the change in a DISCOM's load profile caused by EV charging:

1. Load data for the DISCOM for different seasons from the State Load Dispatch Centre (SLDC)
2. EV population scenario based on publicly available projected data
3. Vehicle and charger specifications for different EV categories
4. Charging requirements and time-based charging patterns for different EV segments

Driven by financial considerations or legal constraints, several parties are investigating business plans and implementation alliances to set up EV charging. This chapter explains the usual implementation approaches used in India and lists the normal stakeholder responsibilities in the development of charging infrastructure. Several responsibilities are often involved in the deployment of charging infrastructure, which may be carried out by a single stakeholder or in collaboration with other stakeholders. In addition to setting up the infrastructure for charging, additional responsibilities include providing land, energy, EVSEs, charging software solutions, and customer services[2].

Infrastructure for charging:

The stakeholder who purchases the infrastructure for charging is the driving force behind deployment. The principal user of the charging infrastructure, the company that provides the charging services, or the body in charge of setting up the charging infrastructure may all engage in procurement. The EV chargers are often owned by the procurer as well, however this is not a requirement. Land provision: The procurement stakeholder may own the space needed for EV charging, or may obtain it via a lease or other means (revenue sharing, for example). Public charging stations may be constructed on either public or private land, whereas private and semi-public ones are often located on private property.

Energy supply:

The DISCOMs in charge of power distribution in the area where the charging station is situated provide energy for all EV charging facilities[3].

EVSE supply, installation, and maintenance:

An EVSE manufacturer or reseller may provide EV chargers. CPOs are often in charge of choosing and installing the necessary charger layout for semi-public or public charging. Software charging solutions: CPOs manage their network of charging points using system management software, which is also used for other back-end services including client subscription administration, pricing structures management, and charging session tracking and control. Customer's services at public and semi-public charging facilities are the responsibility of CPOs and e-MSPs in addition to implementing stakeholders. Charging solutions may be provided as white-label solutions from third-party vendors or may be created internally by Cosign. For further information on their duties, go to Chapter 2. The stakeholder group in charge of charging infrastructure procurement has identified three general implementation options for charging infrastructure: the government-driven model, the consumer-driven model, and the service provider-driven model.

Governmental organisations are in charge of providing the infrastructure for public charging in several places. Local government entities like municipal corporations and urban development authorities are among them, as are state nodal agencies (SNAs) in charge of the infrastructure for public charges. The construction of charging stations is permitted on public property that has been pooled together from various governmental and public sector organisations. The government or a Business with a contract to manage and run the charging services may own the charging equipment[4].

Public sector organisations purchase the EVSE equipment via an EPC contract with a partner for self-owned EV charging infrastructure. You may handle charging services yourself or hire a CPO to do it for you. As an alternative, government agencies may sign a PPP agreement with a partner. Here, the appropriate government agency solicits CPOs to set up and run EV charging stations for the general public. Under this concept, governments provide financial incentives, favourable land distribution, and/or energy supply to encourage CPOs to lower implementation capital costs.

Public charging is adequately accessible thanks to the government-driven paradigm, an example of which is shown in Box J. In order to establish a foundational network of public charging stations, this strategy is anticipated to be more prevalent in the early stages of the development of the EV ecosystem. As the State Nodal Agency (SNA) for charging infrastructure, Delhi Transco Ltd (DTL) has issued a request for proposals to commercial organisations for the construction and management of public charging stations (PCS) around the city. The businesses with the lowest service rates will get the tender. Throughout the duration of the specified lease term, the concessionaire is in charge of providing, erecting, testing, commissioning, maintaining, and operating the PCS at its own expense. By service charges, the concessionaire/CPO will recoup the expense.

Government-provided land parcels assembled from different public entities are used to build charging stations. Throughout the length of the contract term, the concessionaires will pay a set rate of INR 0.70/kWh of electricity supplied to the site-owning agency for the land that is granted on a revenue-sharing basis (60 months). Electricity connections up to 100kW of sanctioned load must be made available by the DISCOMs for the public charging facilities. Concessionaires are in charge of getting EV metered connections and paying energy costs for used power[5].

The SNA or any other authority required by the contract provides regulatory assistance for applications, permits, quality inspections, site feasibility, approvals, etc. to the concessionaire. Also, the concessionaire will get assistance from the SNA in requesting an early release of the power connection from the appropriate DISCOM. After receiving approval from the land-owning agency and DISCOMs, the concessionaire may decide to assume ownership of the charging infrastructure assets at the conclusion of the lease term. This is a typical instance of a public-private partnership (PPP) for the installation of EV charging. Similar concepts are being considered by SNAs in other states. For private and partially public charging stations, the consumer-driven paradigm is used. Private businesses who have parking accessible on their property and want to host EV charging stations include malls, commercial or institutional buildings, retail stores, restaurants, etc. as primary procurement players. To handle EVSE supply, installation, and maintenance as well as the administration of service activities, they will often collaborate with a CPO. Although private entities normally acquire EVSE via direct purchases, new business models that include leasing EVSE equipment from suppliers or CPOs are also developing.

Moreover, fleet managers and individual EV owners are customers who use this approach. Owners of EVs may purchase the EV charger from their car Manufacturer, an EVSE merchant, a CPO, or their DISCOM, making the implementation model simple. EV owners may have access to software services via a mobile application to manage charging sessions, take advantage of ToD prices, etc. depending on the charger type and power connection. For their EV fleets, fleet operators demand charging stations. In this situation, the fleet operator, who may own or rent the land, provides it. Charger management services may be managed internally or outsourced to a CPO. EVSE equipment supply, installation, and maintenance are done via direct contracts with suppliers or CPOs. The consumer-driven paradigm for new real estate projects is shown in Box K. To enable increased rates of EV adoption, access to charging infrastructure in residential townships and office campuses is crucial. Numerous host businesses have begun putting in EV charging stations in their buildings, either to meet regulations or as a perk for locals and guests. Private CPOs are offering plug-and-play solutions for semi-public charging facilities for both existing and new properties in order to meet this expanding demand. Two wall-mounted charger types, 3.3kW AC and 7.5kW AC, have been created by One CPO for usage in residential areas[6], [7].

The CPO offers comprehensive hardware, software, installation, operations, and maintenance support as a part of its service portfolio. The charger has wireless data recording and monitoring capabilities that are enabled through the CPO's internet and mobile platforms. Residential societies' current facilities management software is integrated with the user software, easing resident billing and authentication procedures. Operations and fee collection are handled through a mobile application, therefore dedicated staff is not needed. In addition to installing the EV billing metre and conducting a safety check of the charging station, the CPO collaborates with the DISCOM. This concept is anticipated to grow up dramatically when building bye rules take effect and EV charging stations become necessary utilities.

DISCUSSION

Private CPOs want to create a network of charging stations in key areas where there is a lot of potential for charging demand. They obtain land parcels from public or private organisations in certain areas, install EVSE equipment made by manufacturing partners, and provide for-profit EV charging services for the general public or a portion of the general public. With regard to the usage of land, CPOs may come to revenue-sharing agreements with host businesses or other landowners. As may be seen in Box L, DISCOMS (public and private) are also making Serious entries into the market for charging infrastructure. These organisations often build public EV charging stations on their own property and run them as for-profit businesses. Private EV owners may also get bundled charging services from DISCOMs, with the capital and operational expenses covered by power prices. EV manufacturers that are establishing charging infrastructure networks as ancillary services and industrial businesses that are investing in charging infrastructure are two more parties pushing the service provider model of EV charging deployment.

The infrastructure for public charging is now being developed by a combination of public and private CPOs. By January 2020, the public-sector company EESL (Energy Efficiency Services Limited) had more than 200 charging stations up and running. BSES Rajdhani and Tata Power are two examples of private-sector DISCOMs that have been involved in the development of public charging infrastructure. The EV charging network of Tata Power has more than 500 stations spread over 100 cities. A tender to choose charging infrastructure providers to set up standard-power AC and DC chargers for semi-public and private usage in Delhi was issued by BSES Rajdhani in July 2020. This is a groundbreaking tender that will certify CPOs and provide a single-window facility for efficient EV charging installation.

Among the major private CPOs with networks of public chargers are Fortum, Magenta, Charge+Zone, Volttic, Statiq, and Charzer. Certain CPOs specialise in various public charging use cases, from small 3.3kW AC charge points to 50-60kW DC fast charging stations and streetlight charging systems. Sun Mobility and Lithion Power are two battery charge and replacement service providers. A maker of EVs called Ather Energy offers a network of DC chargers specifically for electric two-wheelers. To build and expand public EV charging infrastructure, public and private CPOs are collaborating with a number of partners, such as oil and gas firms and EV manufacturers [8].

1. Published revised versions of the "Guidelines and Specifications for Charging Infrastructure for Electric Vehicles" in 2018. 1 The guidelines' key points are:
2. State governments must designate state nodal agencies (SNA) for the installation of public charging infrastructure; the Bureau of Energy Efficiency serves as the central nodal agency (CNA) for all public EV charging infrastructure.

3. The provision of standards and specifications for infrastructure for public charging, such as charger types, specifications for electrical systems, criteria for testing and certification, and phased implementation.
4. Any lab or facility that has been granted accreditation by the National Accreditation Board for Testing and Calibration Laboratories shall test electric car charging equipment (NABL).
5. The use of EV charging stations should be seen as a service rather than the purchase of power.
6. There is no licencing needed to operate EV charging stations.
7. Notice on the maximum rate for private billing at homes and businesses, which cannot exceed the average cost of supply + 15%.
8. Added the following to the "Technical Specifications for Connectivity of the Distributed Generation Resources 2019":
9. Distinguishes between "charging station" and "charging point."
10. Recognizes EV as a source of energy production.
11. Establishes criteria for charging stations looking to connect to the power grid.
12. Including EV charging stations to the list of "Measures pertaining to Safety and Electric Supply."
13. General safety, preventing fires, and routine maintenance and evaluation.
14. Upkeep of technical, safety, and performance requirements, standards, and guidelines for installation and operators of public charging stations.
15. In charge of implementing public EV charging infrastructure throughout the nation.
16. Provide technical assistance to the Go Electric initiative at the federal and state levels (to the SNAs).

DEPARTMENT OF HEAVY INDUSTRY

Is charge of managing FAME-II funding for EV charging infrastructure. The Bharat Public EV Charger Specifications were made public in order to support FAME-II public charging stations. Accountable for allocating subsidies for the nation's EV charging infrastructure along national routes. Added requirements for parking spots in residential and commercial buildings to include charging infrastructure in the "Model Building Bye Laws 2016".

1. General EV charging norms announced by
2. Bureau of Indian Standards.
3. Assistance with the creation of Indian Standards for the infrastructure of EV charging.
4. Standard notification for ""Electric Vehicle Conductive Charging System," which details product specifications, station dimensions, testing procedures, and safety requirements.
5. Standard notification for "Road Vehicles - Vehicle to Grid Communication Interface" that outline the physical, data connection, network, and application protocol requirements.

Reduced GST on chargers from 18% to 5%.

- **Alternating current (AC) power:** electricity that is often accessible through power outlets and provided by the power grid. The term is derived from the current's waveform. CMS: Central Management System Real-time data exchange between the electric car, its charger, and the charge-point operator is made possible by an intelligent back-end system.

- **Charge point operator (CPO):** A company responsible for setting up and overseeing the charging infrastructure. A CPO may be the owner of the infrastructure for charging or it may provide services on the charge point owner's behalf. Charger types: a categorization system used in Europe that takes into account power output, charging rates, and communication between electric vehicles and their supply equipment Four modes are available.
- **C- Rate:** A measurement of the rate of charging or discharging a battery. According to 1 C-rate, the battery will be completely discharged in an hour by the discharge current. charging via conductance: between the electric car and the electric vehicle supply equipment, charging through a connected link A kind of energy that is often produced by batteries, solar cells, fuel cells, etc. is known as direct current (DC) power. It is distinguished by a one-directional flow of electric charge, in contrast to AC power. Distributed energy resources (DER) are electricity-generating assets or controlled electrical loads that are linked to a host facility or a local distribution system. Solar power, combined heat and power plants, energy storage, electric cars, and electrical appliances like air conditioners and water heaters are some examples of DERs.
- **Distributed energy resources management system (DERMS):** A tool that aids in managing a power distribution utility's distributed energy resource asset, such as electric cars.
- **Distribution transformer (DT):**By stepping down the voltage utilised in the distribution lines of the electric power distribution system to the level used by the customer, it offers the system's final voltage transformation. Provider of e-Mobility services (e-MSP): An organisation that provides EV drivers with access to charge sites on its network and on other networks through e-roaming.
- **Electric Vehicle Supply Equipment (EVSE):**An EVSE provides electricity for recharging EVs. The EVSE system's electrical conductors, associated hardware, software, and communication protocols efficiently and securely provide energy to the vehicle. E-roaming, or EV-roaming No matter whether charging network a station or charge point is a part of, it enables EV users to charge their cars there. Either open communication protocols or proprietary roaming networks, which connect several CPOs and e-MSPs to a single platform, allow e-roaming [9].

1. **High tension (HT) connection:** The electrical connection that is served by a supply line operating at a voltage between 11 kV and 33 kV.
2. **Kilovolt (kV):** A unit equal to 1,000 volts, used to express voltage of electricity transmission and distribution lines.
3. **Kilowatt (kW):** A unit equal to 1,000 watts, used to express the power of an electrical appliance or generator.
4. **Kilowatt-hour (kWh):** A unit equal to one kilowatt (kW) of power sustained for one hour, used to express the amount of electrical energy consumed by an electrical appliance or produced by an electrical generator.
5. **Open Charge Point Interface (OCPI):** An open application protocol that supports connections between e-mobility service providers (eMSPs) and charge point operators (CPOs).
6. **Open Charge Point Protocol (OCPP):** An open-source, freely available standard that enables communication between an EVSE and a CMS, also known as a charging station network.
7. **Open Automated Demand Response (OpenADR):** A protocol designed to facilitate demand response signals between power distribution utilities and EV users.

8. **Public charging station (PCS):** It is an EV charging facility that is typically accessed by all EV users for charging.
9. **Power Purchase Agreement (PPA):** It is a contract between two parties, one which generates electricity (the seller) and one which is looking to purchase electricity (the buyer).
10. **Smart Charging:** Unidirectional active management of electric vehicle charging, including ramping charging levels up or down.
11. **Time of Day (ToD) tariffs:** Different electricity rates at different times of the day, with higher prices in peak periods of high electricity consumption and lower prices in off-peak periods.

The design of the handbook's pictures draws inspiration from the Madhubani and Gond Arts, two art forms that have their roots in the rich and diverse cultural traditions of many parts of our nation. The ladies of communities from an area in Bihar historically produced the Indian painting style known as Madhubani Art. One of the biggest tribes in India, the Gonds, who are mostly from Madhya Pradesh but also live in certain areas of neighbouring states, perform a folk art known as "Gond Art."[10]

CONCLUSION

The manual seeks to demystify electric car charging, an essential element of electric mobility and a highly complex subject. By using graphics that resemble primitive art to enhance the text and deepen the reader's grasp of the topic, the design approach was chosen with the intention of adding a story-telling element to the material. It was discovered that the ideal style for portraying the images was a combination of Madhubani and Gond art, with the proper degree of details and form simplification. The intricacy of the masses in vehicles reflects Gond Art, while the representation of the eyes and the anatomy of human shapes reflects Madhubani Art. Due to the fusion of the two creative forms, a modern but traditional illustration style has emerged, symbolising India. The vibrant colours of the colour scheme are symbolic of India's cultural liveliness, and they are balanced with modern typography.

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CHAPTER 11

WIRELESS POWER CONSORTIUM (WPC)

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ABSTRACT:

BIS Research is a leading market intelligence and technology research company. BIS Research publishes in-depth market intelligence reports focusing on the market estimations, technology analysis, emerging high-growth applications, deeply segmented granular country-level market data and other important market parameters useful in the strategic decision making for senior management. BIS Research provides multi-client reports, company profiles, databases, and custom research services. This document contains highly confidential information and is the sole property of BIS Research. Disclosing, copying, circulating, quoting, or otherwise reproducing any or all contents of this document is strictly prohibited. Access to this information is provided exclusively for the benefit of the people or the organization concerned. It may not be accessed by or offered to, whether for sale or otherwise, any third party.

KEYWORDS:

Charging, Electricity, Mobile, Networks Wireless Charging, Wireless Power Consortium (WPC)

INTRODUCTION

Semiconductors are a fundamental building block for many consumer electronics applications that serve as a data-processing component for any device, from a smartphone to a spaceship, in the present era of technological profusion. Due to several developments in integrated circuits, including improvements in reliability, power consumption, cost, and system size for devices, the semiconductor industry is now expanding quickly. Because of the fast advancements in the microelectronics sector over the last ten years, we now utilise more battery-powered electronic gadgets in our daily lives. One of the key drivers of the wireless charging industry's expansion in recent years has been the rising need for a practical charging solution. There are now many possibilities for wireless power transmission, and current market trends point to a promising environment for rapid expansion[1].

Throughout the projected period of 2019–2020, the BIS Research report provides a broad view on the worldwide wireless charging market. The market penetration of wireless technologies, components, and applications, as well as their expansion prospects, are also examined in the study. The report focuses on how the wireless charging industry is evolving as a result of the capacity expansions of major competitors. The study is based on in-depth primary interviews with market participants, business executives, and industry experts, secondary research from a variety of commercial and free sources, and analytical tools that were used to create forecast and prediction models. The research includes a collection of many market segmentations, such as a breakdown of the market by implementation type, such as integrated or aftermarket. The research includes a thorough analysis of the various transmitter and receiver applications in addition to outlining the major driving and restraint factors for the global wireless charging market. The research is based on conversations and interviews with senior executives from a number of key original equipment manufacturers (OEMs), tier 1 suppliers, and solution providers for wireless charging.

Accordingly, this report divides the industry into the following geographical segments: North America (the U.S., Canada, and Mexico), Europe (Germany, the U.K., France, and Rest of Europe), Asia-Pacific (China, India, Japan, South Korea, and Rest of APAC), and Rest of the World. The wireless charging market is not anticipated to develop in the same way for every region or application (Latin America, and Middle East & Africa).

Many industrial verticals are being redefined as a result of the rapid worldwide progress and integration of digital technology to improve their core operations. Internet of things (IoT) has fundamentally changed how many sectors operate as a result of recent technical breakthroughs in the area of digitalization. The growth of automation in routine processes has enhanced customer experience while also reducing burden in the sector. IoT is a vast internet-based network of interconnected gadgets. IoT use is rapidly rising around the globe, and the technology is expected to profoundly impact many different industrial sectors, including healthcare, retail, consumer electronics, manufacturing, and automotive, among others. The fast growth in data transmission rate, which is attributed to the rise in connected consumer devices like smartphones, tablets, and laptops, is one of the important reasons driving the adoption rate of IoT technology.

The networking, AR/VR gaming, touch-sensitive controls, and other aspects of mobile technologies are constantly improving, which raises the battery power requirements of smart devices. These devices are utilised for extended periods of time, and their real-time connectivity function regularly drains the battery of any connected device. While this aspect of the linked ecosystem makes it possible for each user to always have access to real-time information, it also necessitates that the device be kept sufficiently charged. This may be accomplished via either wired or wireless charging, with users favouring wireless charging for its comfort and convenience.

Simply said, wireless charging means not using cables to charge electronics. A battery-powered item may be automatically charged thanks to wireless charging technology when it is positioned close to a transmitter. In the last three years, wireless charging has undergone substantial progress, and the dependability and benefits it provides open doors to a vast potential for the wireless charging business. The majority of firms' adoption of the Qi standard, which is pronounced "chee," has significantly boosted the wireless charging market since it allows for device compatibility. Moreover, due to the development of particular standards and the widespread use of wireless technology in the smartphone and wearable device markets, wireless charging is expected to become more prevalent in other industries, including healthcare, aerospace, and military, in the years to come. The inconveniences of utilising cables and carrying a charging cord around have substantially decreased with the development of wireless power transmission. This has made it more comfortable for the end user to wirelessly charge their gadgets using electromagnetic radiation or inductive charging.

Increased shipments of smart handheld devices, technical advancements, dynamic design improvements, standardisation of wireless laws promoting consumer propensity, and rising battery concern among consumers are some of the reasons driving the worldwide wireless charging market. The market for wireless charging has been expanding because to innovations and continuous research in consumer electronics like smartphones and wearables. In the smartphone market, wireless charging is seen as the next big thing, and several manufacturers have already begun producing smartphones with this feature. The bulk of wirelessly equipped phones, however, now fall into the luxury smartphone category. The technology is anticipated to be integrated into a wider variety of devices, including drones, laptops, portable devices, and mid- and low-range devices as the industry expands and the need for wireless power transmission rises.

Wireless charging has previously been included into cellphones by businesses including Samsung Electronics Co. Ltd., Google LLC, LG Electronics Inc., Microsoft Corporation, Apple Inc., and Motorola Inc. A significant advance in the wireless charging business was the founding of the New Jersey-Based Wireless Power Consortium (WPC, an international technological consortium, estb. 2008), which cleared the way for manufacturers to certify their devices and have them approved on a global scale[2].

The market for wireless charging was valued at $XX billion globally in 2018 and is anticipated to increase at a compound annual growth rate (CAGR) of XX% from 2019 to 2020, reaching $XX billion. When energy is sent as electromagnetic waves from a transmitter to a receiver, wireless charging occurs. Nowadays, inductive wireless charging is the most popular method of wireless charging, making up around XX% of the market globally in 2018. This is partly due to consumers' increased preference for inductive charging's faster, more efficient charging capabilities.

Inductive technology has a market value of $XX billion in 2018 and is anticipated to grow at a CAGR of XX% from 2019 to 2020 to reach $XX billion. The broad adoption of the Qi standard for inductive wireless charging technology for smartphones is largely responsible for the strong growth. In order to incorporate the Qi standard into their products and promote them, the majority of device makers have teamed with technology suppliers. Yet recent advancements in resonant technology by the AirFuel Alliance have shown an improvement in the effectiveness of wireless chargers and have furthered the market expansion for resonant technology products.

When it comes to implementation, the global wireless charging market has generally been divided into integrated and aftermarket sectors. For transmitters and receivers separately, further study has been done. Integrated wireless charging technology has a market value of $XX billion in 2018 and is anticipated to grow at a CAGR of XX% from 2019 to 2020 to reach $XX billion. The consumer market's rising demand for smartphones and smart wearables is a major driver of the market for integrated wireless chargers. This is due to the less efficient aftermarket methods, which need the user to utilise an aftermarket phone cover or a comparable device in order to enable wireless charging.

The wireless charging receiver industry is now dominated by consumer electronics both in terms of volume and value. Consumer electronics produced $XX billion in revenue in 2018 and are projected to earn $XX billion by 2020 at a CAGR of XX% during the forecast period of 2019-2020. The rising shipping of wireless charging-capable smartphones is largely responsible for consumer electronics' supremacy[3], [4].

Both in terms of volume and value, the consumer electronics sector leads the world market for wireless charging transmitters. Consumer electronics as a category produced $XX billion in sales in 2018, and it is anticipated that this revenue would increase by $XX billion by 2020 at a CAGR of XX% during the projection period of 2019–2020. The rising shipping of wireless charging-capable smartphones is largely responsible for consumer electronics' supremacy. In the next years, the market for wireless charging will grow most quickly in APAC.

DISCUSSION

This study also examines the regional aspects of the worldwide wireless charging market and offers revenue for the major markets in North America, Europe, Asia-Pacific (APAC), and the rest of the world (Middle East, Africa, and Latin America). In 2018, North America had a XX% share of the worldwide market for wireless charging, and it is predicted that it will continue to hold this position during the projected period. The North American wireless charging market had revenues of $XX billion in 2018 and is projected to increase at a CAGR of XX% from 2019 to 2020 to reach $XX billion.

The U.S., Germany, and France are among the developed nations with the largest markets for wireless charging. Electric vehicle (EV) demand is increasing exponentially, hence many EV manufacturers are already using wireless charging technologies. For instance, BMW 530e is one of the versions sold in the United States that comes with wireless charging capabilities. Moreover, one of the main application fields for wireless charging in the nation is consumer electronics. The Apple Watch, other wearable technologies, and Samsung's Galaxy smartphones' continuous adoption of wireless technology are also anticipated to increase demand for wireless charging for consumer gadgets in the nation.

The competitive environment of the wireless charging industry shows a propensity for businesses to pursue tactics including joint ventures, company expansions, product launches, and acquisitions of up-and-coming enterprises. Also, since the business is developing, manufacturers are using the aforementioned techniques to expand their market presence in addition to planning and participating in multiple events. The majority of producers of wireless charging have comparable financial standing, and since there are so many competitors in the market, the industrial environment is extremely competitive.

While still in its infancy, the worldwide wireless charging industry is one of the most competitive in its sector, with top competitors vying with one another for a firm grip on the client base. Energous Corporation, Integrated Devices Technology Inc., Infineon Technologies, NXP Semiconductors, Qualcomm Inc., Aircharge, Belkin International, Witricity Corporation, Samsung Electronics Ltd., and Texas Instruments are a few of the market's top competitors. To further improve the functionality and standard of the wireless charging infrastructure, these businesses are pushing for a larger variety of product offerings and partnerships.

Wireless charging is the technique of electrically or wirelessly transferring electricity between devices or equipment that runs on batteries without the need for a connected electrical connection. Power is delivered wirelessly using electromagnetic induction, and the process is sometimes referred to as inductive charging. Electromagnetic waves are employed to transmit energy in the case of inductive charging instead of the more traditional wired cords. Wireless chargers are now readily compatible with a wide range of consumer electronics, including smartphones. The apparent design and technological comparability of communication model is the sole requirement that must be met. The transmitter and receiver must both meet QI requirements. It works on the very simple premise that the Qi transmitter is responsible for sending the necessary energy to the Qi receiver. Mobile phones and other tiny portable gadgets are often charged with it[5].

Throughout the forecast period of 2019–2020, a solid growth rate is anticipated for the worldwide wireless charging market. The industry is growing quickly as a result of ongoing innovation and breakthroughs in wireless charging technologies. One of the main reasons why wireless charging technology has been adopted is the requirement for easy and simple charging. The rise in shipments of smartphones and wearables with wireless charging capabilities has been the main factor driving the industry. Some of the main factors driving this business are Wireless Planning and Coordination's (WPC) standardisation of laws for wireless charging and a growth in integrated wireless charging systems. Yet, ineffective fast charging and the expensive cost of wireless charging have posed some of the biggest problems for the industry. The main market drivers for wireless charging are covered in this section, and it is predicted that they will continue to fuel market expansion during the projected period. One of the key drivers of this market's expansion has been the widespread use of smartphones and wearable technology.

With the introduction of next-generation smartphones, there has been a rise in the requirement for an effective charging infrastructure due to the continued research and development in the area of consumer electronics products. There is now a high need for charging infrastructure that is simpler to use, securely transmits electricity to the device, and puts less load on the charging port. Several manufacturers, including Samsung Electronics Co. Ltd., Google LLC, LG Electronics Inc., Microsoft Corporation, Apple Inc., and Motorola Inc. have begun integrating wireless charging in their luxury segment smartphones as it emerges as one of the key technologies in the smartphone business. Manufacturers in a variety of sectors, including aerospace and consumer goods, are attempting to integrate wireless charging into a number of their products, including laptops and drones, while the technology is still in the research stage. In order to guarantee that customers obtain genuine, high-quality wireless chargers, certification and standards are required due to the abundance of wireless chargers on the market.

Similar trends in standards and organisations have been promoting the development of wireless charging in the industry. One of the key groups driving the development of wireless charging is the Wireless Power Consortium (WPC). The New Jersey-based consortium was founded in 2008 and now has XX members, including businesses from the semiconductor, consumer electronics, and wireless operators sectors. With an emphasis on inductive charging, WPC runs a network of laboratories in several nations where wireless charging devices may be tested for compliance with the Qi ("chee") standard. With a number of collaborations between businesses and end users, the group has also made it easier for people to utilise Qi-standard wireless charging apps in cafes, hotels, airports, and public charging stations. The PowerbyProxi standard for resonant charging for one-to-one or one-to-many solutions is another area of emphasis for WPC.

The U.S.-based AirFuel Alliance, which was created in 2015 as a result of the union of the Alliance for Wireless Power (A4WP) and Power Matters Alliance (PMA), is another well-known company in the wireless charging sector. The company is in charge of resonant, inductive, and other wireless power transmission techniques. For the wireless charging sector, the AirFuel Alliance has been creating standards, infrastructure, and network protocols[6].

The wireless charging market saw standardisation implemented as the industry matured, giving a global interoperable standard that manufacturers may adhere to to provide a better user experience. With the least amount of interference from other RF frequencies, the devices that adhere to these specifications may concurrently power several devices with various power needs. So, given the present situation and going forward, standards and associations will play a crucial role in the development of the wireless charging sector.

In the recent years, the global wireless charging market has seen a number of technical and strategic advancements made by the various market players to secure their respective market shares in this developing industry. Product launches, joint ventures, and mergers and acquisitions are a few of the methods discussed in this section. Product introductions have been the firms' go-to tactic for bolstering their position in the worldwide wireless charging market[7], [8].

The major companies in the worldwide wireless charging market are introducing a variety of products to match those of their rivals. One of the most important tactics for acquiring a competitive edge in the expanding wireless charging market is product introduction. The following graph shows the various firms' product launches: The wireless charging supply chain is shown in the following diagram, which also covers research and development (R&D), technology providers, suppliers of raw materials and equipment, as well as manufacturers, integrators, and end users of devices [9], [10].

CONCLUSION

The wireless charging market's supply chain analysis is shown in the previous figure. The world-famous companies ITRI International Inc., Fraunhofer, Woodside Capital Partners, and Tarrant Capital IP, LLC are among those actively working on wireless charging research and development. Among the many raw materials utilised in the production of wireless charging are switches, plastic/fiber bodies, and copper wire/coils. In order to promote interoperability amongst Qi enabled products, suitable standards, such as the Qi standard, are used to create the transmitters and receivers. The device maker also completes the component integration. The businesses that compete in the wireless charging industry distribute their goods through owned locations or online retail stores. In this supply chain, forward integration (the strategy to grow a company's business to directly manage distribution and supply of the company's product) is conceivable since the firms seek to enhance their distribution channels and services.

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CHAPTER 12

A BRIEF STUDY ON WIRELESS CHARGING RECEIVERS

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ABSTRACT:

The scope of this report is focused on wireless power transfer the market has been mapped on the lines of the type of components in wireless charging, namely transmitters and receivers. Based on the classification, the average selling price (ASP) was calculated by the weighted average method. ASP calculations are completely based on the number of data points taken into account while conducting the research. The base currency considered for the market analysis is US$. Currencies other than the US$ are converted to the US$ for all statistical calculations, considering the average conversion rate for that particular year. The currency conversion rate is taken from the historical exchange rate of Oanda website. Nearly all recent developments, from January 2016 to November 2018, are taken into account in this research study.

KEYWORDS:

Charging, Electricity, Mobile,Networks Wireless Charging.

INTRODUCTION

In the wireless charging industry, the market size for the various component types is taken into account in terms of volume and value. Also, the volume and value of the wireless charging market are examined by application, component, implementation, and region. From 2018 through 2020, the compound annual growth rate (CAGR) is computed. In the wireless charging industry, the market has been divided by component type, application, kind of implementation, and region. North America, Europe, Asia-Pacific, and the rest of the world make up the geographical regions (RoW). For a structured analysis, North America is broken down into the United States, Canada, and other countries; Europe is broken down into Germany, the United Kingdom, France, and other countries; Asia-Pacific is divided into India, China, Japan, India, South Korea, and other countries; and RoW includes Latin America, the Middle East, and Africa.

The report's data is a compilation of in-depth expert interviews, surveys, and secondary research. Where relevant data was unavailable, extrapolation and proxy indications were used. The market assessment and prediction did not account for the impending economic slump. Current technologies are anticipated to endure throughout the predicted period without any material advancements. An overview of the market for wireless charging technology is provided in this section. In the last ten years, there has been a significant technical advancement in the wireless charging industry, leading to the creation of both near-field and far-field wireless charging. Three major categories may be used to categorise the technology utilised for wireless charging: inductive, resonant, and radio frequency (RF) technology. Yet, there are a number of different technologies available that have not been widely adopted in this sector[1].

When energy is exchanged through electromagnetic waves, wireless charging or power transfer takes place. Inductive wireless charging, which accounted for around XX% of the market for wireless charging worldwide in 2018, is now the most extensively used method. The market prognosis for wireless charging in terms of technology is shown in the following table: In 2018 the worldwide wireless charging market was led by inductive technology, both in terms of sales volume and sales revenue. With a CAGR of XX% during the forecast period, the inductive wireless charging technology is expected to produce sales of XX million units by 2020, up from XX million units in 2018. Revenue from inductive technology was $XX billion in 2018, and it is anticipated that it will grow at a CAGR of XX% from 2018 to 2020 to reach $XX billion. The greater use of inductive technology because to its higher efficiency compared to resonant and RF technology is what has led to its supremacy. Inductive charging has become quite popular due to the recent development of resonant wireless charging technology.

The inductive coupling creates an electromagnetic field that is used by inductive wireless charging technology to transmit electricity. An electromagnetic field is produced when electricity is transmitted from a transmitter to a receiver coil using an induction coil to generate alternating electromagnetic current. The electrical current created from this electromagnetic field is then utilised to charge a gadget. The development of this wireless charging technology has largely been supported by the "Qi" (pronounce it "chee") standard. The majority of smartphone manufacturers, who make up the bulk of the wireless charging industry, have embraced the Qi standard. Its broad use has helped inductive charging's market expansion.

The Wireless Power Consortium (WPC), which created the Qi standard, has more than XX members as of the present including Samsung, Nokia, Apple, and HTC, among others. The interoperability of diverse wireless transmitters and receivers has been made possible by the Qi standard. With Qi-enabled transmitters, any Qi-enabled receiver may function flawlessly. Adoption of the Qi standard by a large number of smartphone inductive wireless chargers. Worldwide Market for Wireless Charging, by Implementation Together, transmitters and receivers comprise the fundamental building block of wireless charging and serve the most important function. Both the transmitter and the receiver are required to adhere to Qi standards in order for electricity to be transferred wirelessly in any electronic device. Due to the broad use of the Qi standard for receivers, demand for both has increased significantly in recent years. Demand for transmitters has recently been fuelled by shipments of receivers. Businesses are increasingly concentrating on building a consumer-friendly wireless charging environment for gadgets[2].

These transmitters and receivers are sold on a global scale via two channels: integrated and aftermarket. The market prospect for implementing these components is presented in this chapter. The market for wireless charging is shown in the following image by the use of these elements. At a CAGR of X%, the integrated wireless charging technology market is projected to grow from XX million units in 2018 to XX billion units in 2020. Integrated wireless charging technology has a market value of $XX billion in 2018 and is anticipated to grow at a CAGR of XX% from 2019 to 2020 to reach $XX billion. In terms of value, the aftermarket for wireless charging technologies made up just a small portion of the industry in 2018. Due to the technical challenges of installing wireless chargers with aftermarket and worries about their effectiveness, it is anticipated that the share for aftermarket will continue to hold just a modest part in the next years.

The receivers that are built into the device during production are called integrated receivers. Receivers are maintained in close proximity to magnetic plates that are used to transform magnetic signals into electric current, or within a certain distance of them. The integrated kind of solution dominates the wireless charging receiver market. The majority of smartphone, smart wearable, and other consumer electronics manufacturers, including kitchen appliance and electric toothbrush manufacturers, have integrated wireless charging receivers in their products in response to the rising demand for wireless charging-capable devices governed by the development of the Qi standard. A device with an integrated receiver for wireless charging cost $XX billion in 2018 and is anticipated to reach $XX billion by 2020 at a CAGR of XX% during the forecast period of 2019–2020 from companies like Samsung Electronics, Apple, and Panasonic.

In this part, the implanted receivers for electronic devices are taken into account. Market participants are making sure that these wireless chargers are compatible with traditional electrical gadgets as well in order to assure a large level of acceptance of the wireless technology. For instance, users are choosing phone covers that enable wireless charging rather than buying a brand-new smartphone that supports the technology. Products like mats and accessories that allow wireless charging for any device are available in the aftermarket or accessory market for wireless charging receivers. Due to the poor consumer adoption of wireless charging accessories like phone cases, the aftermarket for wireless charging is presently not a very appealing industry. Yet, there are products on the market that include phone covers that can allow wireless charging in a device that does not already have one. The poor pace of uptake of these goods is due to the low efficiency of these solutions and the length of time required for charging compared to turbo or fast-wired charging.

Companies like Antye, Nillkin, and Tech Corp already provide products that can turn any phone into a wireless charging-capable phone. These items, which are essentially cushions or mats that may adhere to a smartphone's back, have been taken into consideration for the aftermarket of wireless charging receivers. The examination of the aftermarket wireless charging. With a CAGR of XX%, the aftermarket for receiver wireless charging technology is predicted to grow from XX million units in 2018 to XX million units in 2020. The aftermarket for a receiver for wireless charging had a market value of $XX million in 2018 and is anticipated to grow at a CAGR of XX% from 2019 to 2020 to reach $XX million. Throughout the projection period, a respectable rise is anticipated in the receiver aftermarket. Yet, compared to integrated solutions, the adoption rate for aftermarket receivers is lower. In addition, these solutions' poor efficiency and previous goods' expensive price are proving to be a barrier.

In recent years, wireless charging has gained a lot of traction in a variety of consumer electronics, automotive, and healthcare applications. The many application sectors where wireless charging is being employed are thoroughly examined in this section. In the next years, wireless charging is sure to spread into a lot more application areas thanks to the constantly developing technology for wireless charging transmitters and receivers. Apps for mobile devices and tablets

Nowadays, wireless charging is utilised in a wide range of applications, including charging for smartphones, wearable technology, laptops, tablets, power tools, service robots, electric toys, medical equipment, smart home IoT devices, and automobiles, among others. The many application verticals in which wireless charging receivers are employed as integrated goods or aftermarkets are covered in this section. Wireless charging has grown rapidly in recent years thanks to applications in consumer electronics, healthcare, and the automotive industry, among others. This trend is anticipated to continue from 2019 through 2020.

Many still use wired chargers to power their phones despite the contemporary world's increasing mobility. The time it takes to charge smartphones has been greatly decreased thanks to solutions offered by wired charging. Yet there are still challenges to be faced in the charging arena, like the inconvenience of dealing with cables and the lengthy charging times. As a result, wireless charging systems were created that use a receiver and transmitter to send electricity via electromagnetic waves.

The wireless charging receiver industry is now dominated by consumer electronics both in terms of volume and value. Consumer electronics receiver sales volume was XX million units in 2018 and is anticipated to increase by XX million units by 2020, at a CAGR of XX%. The consumer electronics application produced $XX billion in revenue in 2018, and it is anticipated that this revenue would increase by $XX billion by 2020 at a CAGR of XX% during the forecast period of 2019–2020. The rise in smartphone shipments that support wireless charging is largely responsible for consumer electronics' domination.

Around XX% of the world's wireless charging receiver market is made up of consumer gadgets. One of the main reasons propelling the expansion of this market over the last two years has been the multiple advantages of wireless charging. Customers have focused more on practical wireless charging options, which may provide advantages like more placement flexibility and quicker charging periods. The bulk of the market demand is seen in apps for smartphones and tablets among other consumer electronics devices. Owners of traditional phones that lack wireless charging are choosing separate phone cases that include a full setup for wireless charging[3], [4].

Although though wireless charging has been available for three years, it has not gained as much traction as other smartphone technologies like Bluetooth and infrared. Yet, one of the key elements that is anticipated to considerably influence development in the next years is the adoption of the Qi standard. The rise towards wireless charging-capable tablets has also been noticeable. Due to the comparatively limited market potential and yearly sales, these devices' growth has lagged behind that of smartphones.

As customer knowledge and trust are crucial for the broad adoption of wireless charging in the next years, the industry at this point is primarily focused on growing its user base. The wireless charging sector must, however, overcome a number of obstacles including quick charging, product efficiency, and price. The market situation for a wireless charging receiver for tablets and smartphones is shown in the following figure: The number of units sold by receiver for smartphones and tablets was XX million in 2018, and it is anticipated that number would increase by XX million by 2020 at a CAGR of XX%. The receiver for smartphones and tablets earned $XX billion in sales in 2018, and it is anticipated that this revenue would increase by $XX billion by 2020, at a CAGR of XX% during the projection period of 2019–2020. An important factor in this segment's significant growth is the rise in the shipping of smartphones with wireless charging capabilities.

DISCUSSION

The chapter analyses the wireless charging market geographically in relation to North America, Europe, Asia-Pacific (APAC), and the rest of the world (RoW). Based on a thorough push-and-pull force analysis, the chapter identifies significant growth facilitators. By delving into past and present governmental laws, macro and microeconomic variables, and notable finished, continuing, and prospective projects, the section further evaluates the current developments in the sector in key locations. The market growth by region is shown in detail in the following graph[5].

The market for wireless charging was valued at $XX million in 2018 and is anticipated to grow at a CAGR of XX% from 2019 to 2020 to reach $XX million. With a market size of $XX billion in 2018, North America led the world in wireless charging. This market is expected to grow to $XX million by 2020, at a CAGR of XX%. This is because end-user industries including automotive, consumer electronics, healthcare, and others have more demand than before. Asia-Pacific is anticipated to see the largest volume growth throughout the projected period. This is due to wireless charging's growing dominance in the consumer electronics sector. A few additional reasons driving the need for wireless charging in the Asia-Pacific area include the recent increase in demand for electric cars and government measures to reduce the usage of fossil fuels.

With a sizeable market share of around XX% of the worldwide market in terms of volume, North America has been at the forefront of wireless charging in the global context. North American nations have been adopting wireless charging for a time now since they are among the nations that accept new technology the quickest. The U.S. and Canada are noted as the two biggest markets for wireless chargers in North America. Large semiconductor firms including Infineon Technologies, Intel Corporation, Xilinx, National Semiconductor Corporation, Fujitsu Microelectronics, and ON Semiconductor are present in the area, which aids in the early adoption of cutting-edge technical developments.

The prevalence of major players in this area, including Belkin International, Integrated Device Technology, Inc., and Apple Inc., among others, has greatly accelerated the adoption of wireless charging throughout the world in a variety of applications, including consumer electronics, transportation, and business, among others. Another important aspect influencing the market situation in North America at the moment is the shipping of wirelessly charging smartphones with Qi compatibility. A huge number of significant electric car companies now operate in the North American area, which also has the most developed electric vehicle market at this time. The region's automotive sector has evolved as a result of the development of electric car and electric vehicle battery technologies by businesses like Tesla and General Motors[6].

In terms of volume, North America now controls the wireless charging industry. The market size was estimated to be worth XX units million in 2018 and is anticipated to expand at a CAGR of XX% from 2019 to 2020 to reach XX units million. The growth in this area is mostly related to the rising demand for gadgets with fast and effective CPUs, such the newest smartphones and tablets. Also, the area is renowned for its technological achievements and for having a sizable semiconductor sector that serves as a basis for many important firms. As a result, big discoveries often occur in the North American market first. The wireless charging industry is now dominated by the United States in terms of revenue. The market was worth $XX million in 2018 and is projected to increase at a CAGR of XX% from 2019 to 2020 to reach $XX billion. The fast growth and sizable share are related to the adoption of cutting-edge technology and the competition to keep ahead of other areas in terms of technological advancement. Also, customers are supporting the rapidly developing microelectronics sector, which is shrinking the size of devices while simultaneously enhancing their processing capacity by raising the microprocessor clock frequency.

The usage of wireless charging has deepened its roots in the American market, much like earlier disruptive technologies. The Semiconductor Industries Association (SIA) in the United States created the International Technological Roadmap for Semiconductors (ITRS), which has continuously worked to improve semiconductor device scaling. As a result, consumer electronics have seen greater technical improvements in terms of compactness and effective power use.

A few of the major reasons influencing the rapid acceptance of wireless charging in the nation include the use of wireless charging for industrial applications and rising consumer knowledge of wireless power technology. Several EV manufacturers are now switching to wireless charging systems as the demand for EVs grows at an exponential pace. For instance, customers of the BMW 530e, a BMW product available in the United States, may utilise wireless charging devices. One of the main application fields for wireless charging in the nation is also the consumer electronics industry. The Apple Watch, other wearable technologies, and Samsung's Galaxy smartphones' continuous adoption of wireless technology are also anticipated to increase demand for wireless charging for consumer gadgets in the nation.

Nine public and six private firms are included in the total number of company profiles. Each company's profile includes an overview table, a list of all of its products, financial information, a financial summary, and a SWOT analysis. All of the firms mentioned have been selected based on their product offers, worldwide reach, and revenue production. Energous Corporation, Integrated Devices Technology Inc., Infineon Technologies, NXP Semiconductors, Qualcomm Inc., Samsung Electronics Ltd., Semtech Corporation, TDK Corporation, and Texas Instruments are a few of the public firms covered.

Aircharge, Belkin International, Convenient Power Ltd., Powermat, Witricity Corporation, and NuCurrent Inc. are among the private enterprises covered. Additional Goods and Services Airbridge, Point of Display Block, Double ORB Point of Display Block, Executive Point of Display Block, Wireless Charging Desk Mat, Wireless Charging Valet Tray, Wireless Charging ORB Receiver, Wireless Chargers, Wireless Charging Receivers, and Battery Pack

The firm, with its headquarters in Wantage, OXON, develops and produces wireless charging systems for households and businesses. The firm was established in 2014, and its product line now comprises surface chargers, wireless chargers, and wireless charging receivers. The company's goods are used, among other places, in hotels, restaurants, and airports. Leading companies including Mercedes Benz, BMW, and Vodafone use these goods. The business is a member of the Wireless Power Consortium and works with current and upcoming Qi capable gadgets (wireless charging). There are more than XX nations and XX places where the firm has a presence. In November 2018, the business placed wireless charging stations for tablets and smartphones in London's Waterloo trains, giving customers the convenience of quick charging.

1. **Wireless Chargers:**The company provides a variety of wireless chargers in the form of travel charger, simline charger, executive charger, Apple watch executive charger, and black edition executive charger.
2. **Wireless Charging Receivers:**The receiver’s portfolio includes micro-USB wireless charging receiver, MFi Apple lightning wireless charging receiver, keyring receiver.

The following figure depicts the SWOT analysis of Aircharge:

1. The company has partnership with Apple Inc. and holds Made for iPhone (MFi) certification.
2. The company has a strong geographical outreach, with its offices being located in more thanX countries, worldwide.
3. The products offered by the organization are compatible with smart phones, which have in-built wireless technology and are built by key players, such as Nokia and

Samsung. The company has not laid focus on developing products for electric vehicle wireless charging which have a great potential in the coming years.

4. The company through collaborations and acquisitions can look to further expand its businesses.
5. The company can focus on developing strategic alliances with smartphone and automotive manufacturers to further strengthen its brand image.

The research is an in-depth analysis of the worldwide market for wireless charging. It contains in-depth analyses of the various component kinds, including transmitter and receiver. To better understand how the technology in wireless chargers performs, the global wireless charging market has also been divided into several application categories. It goes on to describe the market's driving factors, difficulties, and growth prospects. Based on revenue generation, regional presence, and market advancements, the key players in the wireless charging market have been identified. To comprehend the strategic behaviour of the participants, a thorough business profile was conducted. On the basis of geography, the wireless charging market has also been further described and examined. Four areas have been identified for the geographical analysis: North America, Europe, Asia-Pacific, and the rest of the world (Middle East & Africa and Latin America). To get a thorough view of the worldwide wireless charging industry, a country analysis has also been conducted. The frequency of wireless charging product adoption and continuous private sector development in the areas are some of the elements used to determine the growth rates of various nations. The following figure summarises the size of the wireless charging market:

1. Competitive Insights
2. Market Size
3. Key Strategies and Developments
4. Market Restraints
5. Market Size Analysis
6. Industry Trends
7. Leading Player Analysis
8. Market Drivers
9. Market Opportunities
10. High Growth Segments
11. Key Associations and Consortiums
12. Compound Annual Growth Rate (CAGR)
13. Industry Analysis
14. Macro-Economic Factors
15. Competitive Benchmarking

The data were gathered from a combination of primary and secondary sources according to the research approach used for this particular study. The forecast and prediction models have been developed using a combination of primary sources internal experts, business leaders, and market participants and secondary sources a wide range of commercial and free databases in addition to analytical tools[7], [8]. The key sources are from industry specialists in the field of wireless charging, including distributors, manufacturers, and suppliers of devices. CEOs, vice presidents, marketing directors, and directors of technology and innovation were among the resources consulted to gather and confirm information for this research study's qualitative and quantitative components.

1. The key data points taken from the primary sources include:
2. Validation and triangulation of all the numbers and graphs
3. Validation of report’s segmentation and key qualitative findings

4. Understanding the competitive landscape
5. current and proposed production values of a particular product by the market players
6. validation of the numbers of various markets for market type
7. percentage split of individual markets for geographical analysis

Secondary Data Sources

A. The research study involves the usage of extensive secondary sources such as databases, company website, and annual reports:
B. The following figure exhibits the key secondary data sources:
C. The key data points from the secondary sources include:
D. Segmentation breakups, split-ups, and percentage shares
E. Data for market value
F. Key industry trends of the top players of the market

Qualitative perceptions of the market's numerous facets, major trends, and innovative frontiers. Finding the collection of underlying elements was the major objective for a detailed investigation of the global wireless charging industry. The basic parameters taken into account for the market assessment in this instance were the units sold of various kinds of devices in various applications, coupled with their average selling prices (ASPs). The precise technique used for calculating and projecting the worldwide wireless charging market is shown in the following figure: The aforementioned method has been used to estimate the market for all products linked to the worldwide wireless charging industry, broken down by technology and application. The projection uses a number of macro parameters, including population, disposable income, and gross domestic product, after estimating the size of the worldwide market (GDP). In addition, the quantification of the following criteria forms the basis for the prediction of the worldwide wireless charging market:[9]

Currency Conversion

1. The base currency considered for this study is the US$.
2. In the Company Profiles section, the revenue for companies mentioned in any other currency is converted into US$.
3. The currencies other than the US$ have been converted to the US$ for all statistical calculations considered average conversion rate for the particular year.
4. The currency conversion rate has been taken from the historical exchange rate as provided in the Loanda website.

Limitations

Current technologies are anticipated to continue to be employed throughout the projected period without any significant advancements. The market assessment for the foreseeable period has not taken any potential economic downturns into account.

A. Average Selling Price (ASP)
B. The ASP has been calculated for 2019 and the currency that has been considered is the US$.
C. For calculating the ASP of the marketed products, the weighted average of the list price of products has been considered.
D. Assumptions for Market
E. Estimation
F. The base year considered for the calculation of market size is 2018.

G. Instances where the market size for FY2018 was not available from primary or secondary sources, the values have been estimated based on the Delphi method.

The historical year research included the fiscal years FY2017 through FY2019, and the market size was predicted for the years FY2019 through FY24. We are on a mission to use disruptive technologies to their full potential in order to help companies prosper in the current digital era. In order to provide corporations and other organisations throughout the globe with market information about cutting-edge technologies, recommendations, and other creative solutions, we have a mission to become a top knowledge partner[10].

CONCLUSION

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CHAPTER 13

ENERGY CONSUMPTION AND PEAK DEMAND

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ABSTRACT:

Just as future transport must be increasingly electrified, future power systems must make maximum use of variable renewable energy sources. Smart charging minimizes the load impact from electric vehicles and unlocks the flexibility to use more solar and wind power. Smart charging for electric vehicles holds the key to unleash synergies between clean transport and low-carbon electricity. Batteries in cars, in fact, could be instrumental to integrate high shares of renewables into the power system. The advent of electric vehicles (EVs) promises to be a game-changer for the world's shift to sustainable energy and particularly to renewable power generation. This is true for several reasons. Most notably, along with transforming the transport sector, EVs present a viable opportunity to introduce much higher shares of renewables into the overall power generation mix.

KEYWORDS:

Consumption, Charging, Electricity, Mobile,Networks Wireless Charging.

INTRODUCTION

Electricity usage may increase significantly as a result of EV charging. With the help of renewable energy sources like grid-connected solar and wind power, this may be done feasibly and affordably. Such advancements provide a tempting opportunity, especially for cities, to decarbonize transportation while simultaneously decreasing air and noise pollution, reducing reliance on fuel imports, and implementing novel urban mobility strategies.

Electricity is a desirable low-cost energy source to power the transportation industry due to ongoing cost decreases for the production of renewable energy. Scaling up EV adoption is also an opportunity for power system development, with the ability to increase electrical networks' much-needed flexibility and facilitate the integration of significant amounts of renewable energy. From the standpoint of the electrical system, EVs are a novel invention since they were not created for the power industry and are not mainly a grid flexibility solution. Instead, serving mobility demands is their main goal. It is necessary to carefully consider which use cases would best align for both sectors in order to make the most of EVs. The grid may ideally reap significant advantages from EVs fueled by renewable energy sources without suffering any detrimental effects on transportation efficiency[1].

Typically, cars including EVs park themselves for around 95% of their lives. Due to their extended periods of inactivity and extensive battery storage, EVs may provide an alluring power system flexibility option. Each EV may essentially transform into a mini grid-connected storage unit with the ability to provide the system a variety of services. Uncontrolled charging, however, may cause the grid to experience more peak strain, demanding distribution-level modifications[2].

Upcoming advancements in EV smart charging include commercial strategies, technology, and regulatory frameworks (IRENA, 2019a). To include renewable energy sources and prevent network congestion, they will be essential. This innovation perspective also covers the potential effects of the anticipated disruptions in mobility, such as mobility-as-a-service and the widespread use of fully autonomous cars during the next two to three decades.

The Center for Solar Energy and Hydrogen Research (ZSW) in Germany estimates that 5.6 million electric vehicles (EVs) were on the road worldwide at the start of 2019. The two biggest markets, with 2.6 million and 1.1 million EVs, respectively, were China and the United States. More than 1 billion EVs might be on the road by 2050 if electric cars made up the majority of passenger vehicle sales starting in 2040. Future EV battery capacity may much exceed stationary battery capacity, according to IRENA study. Compared to 9 TWh of stationary batteries, about 14 TWh of EV batteries would be available to supply grid services in 2050. (IRENA, 2019b)[3].

Large amounts of power may be stored by EV fleets. But, the particular energy blend will determine the best charging patterns. As opposed to systems where wind power predominates, EV integration is different in systems with substantial proportions of solar-based production. Smart charging techniques for EVs would eliminate the need to invest in flexible, but carbon-intensive, fossil-fuel power plants to balance renewable energy sources if they were made available immediately.

A considerable amount of control over the charging process is possible with smart charging. It offers several alternatives for technical and price charges. Consumers are encouraged to shift their charges from peak to off-peak hours via the most basic incentive time-of-use pricing model. In order to supply near-real-time balancing and auxiliary services at larger penetration levels, more sophisticated smart charging strategies, such direct control mechanisms, will be required. The major types of charging for such devices are V1G, V2G, V2H, and V2B.

Each sort of strategy opens up a variety of opportunities to improve power systems' adaptability and assist the integration of VRE, namely wind and solar PV. The relationship between modern smart charging techniques and the availability of flexibility in power networks is summarised in Figure S3. It demonstrates how more sophisticated smart charging techniques might enable the system to be more flexible.

Flexibility might be offered by smart charging both at the systemic and local levels. Smart charging could make it easier to balance the wholesale market at the system level. By altering their charging levels, V1G enables the regulation of EV charging patterns to flatten peak demand, fill load troughs, and provide real-time grid balancing. Using V2G, EVs might potentially provide supplementary services to transmission system operators by feeding power back into the grid. Customers may monitor their energy use and raise their rates of self-consumption of renewable energy with the aid of smart charging, which might also assist distribution system operators in controlling congestion.

The Danish project Parker is an example of a V2G project that makes use of intelligent charging technology and depends on collaboration between the power and automotive sectors to show how electric cars may assist and balance power grids based on renewable energy. Experts in grid integration like Enel, Nuvve, and Insero, as well as automakers Nissan, Mitsubishi, and PSA Groupe, have shown that cutting-edge cars from different auto brands can help the energy grid by offering services like frequency and voltage management using V2G technology. Effect of EV charging on urban electrical grids. EV charging affects the best options for urban grid construction and the patterns of total energy consumption [4].

Energy consumption and peak demand

Many studies have shown that unrestrained EV charging very slightly boosts both power generation and consumption. The effect on peak demand, however, may be substantially bigger. Evening peak demand would grow by 3 GW with uncontrolled charging in a United Kingdom (UK) scenario with 10 million EVs by 2035, whereas it would increase by just 1% without it.

Electricity infrastructure

The local grid might experience congestion if, as predicted by IRENA in 2018, there are more than 160 million EVs in the power system by 2030 and large concentrations of them are charging uncontrollably in certain geographic locations. Reinforcement of the local grid would be necessary to prevent this scenario. Such expenditures may mainly be avoided with smart charging. Slow charging is often paired with smart charging [5].

DISCUSSION

A 9% EV share, for instance, would result in blockages in 15% of the feeders in the city's distribution network, according to research conducted by the local distribution system operator in Hamburg, Germany. A smart charging method was chosen to prevent this, and the distribution system operator is now installing control devices to monitor charging station loads.

- **Slow chargers**: The most common power output for home and business charging is up to 22 kW. Slow charging increases the potential of offering flexibility services to the power system by keeping the EV battery connected to the grid for extended periods of time.
- **Fast chargers**: Often 50 kW and higher - are mostly utilised in direct current (DC) networks, frequently along highways, while some cities are also installing them for street charging (for example, Paris' Belib).
- **Ultra-fast chargers**: soon be accessible, helping to allay consumer concerns about electric mobility and serving as a vital supplement to home- and office-based slow charging over 150 kW.

Batteries are not linked to the system for long enough to enable flexibility with rapid and ultra-quick charging. By placing charging stations where local peak demand and congestion are minimal, the effect of rapid charging on the grid may be reduced. Moreover, through buffering, integrating fast-charging infrastructure with locally installed VRE and stationary energy storage may improve the station's flexibility with respect to the grid. Battery replacement may become more significant, at least in certain applications (like buses) or regions of the globe (e.g., China). More potential for the grid may arise from effectively "decoupling the batteries from the wheels." Innovations in transportation and renewable energy also promise to lower customer energy expenses [6].

Impact of EV smart charging on VRE integration

In this research, modelling was done to investigate the advantages of smart charging at the system level, both for short-term system functioning and long-term system growth. The precise statistics should not be regarded as generally valid since the findings of this experiment seek to show exactly how much smart charging benefits the power grid. The effects of smart charging depend on the peculiarities of each power supply and how it is used.

The advantages of smart charging over uncontrolled charging were well shown by the short-term operation study, which evaluated the effect of various vehicle-grid integration schemes in remote systems with strong solar irradiation. The use of unidirectional smart charging (V1G) and bidirectional smart charging (V2G) steadily lowers curtailment to zero levels, as shown in Figure S5. Since solar power now accounts for a larger portion of the system's load-side coverage, carbon dioxide (CO2) emissions are subsequently considerably decreased. Peak load is decreased in both V1G and V2G as a result of charging being distributed throughout the day. The average price of producing power might decrease.

Long-term impact

In order to fulfil demand in 2030, the long-term study took into account system expansion with the best capacity mix based on wholesale energy pricing. Isolated systems powered by the sun and the wind were also investigated. The investigation showed higher renewable energy generation, particularly for solar with V2G, and subsequently increased renewable energy investment.

With the exception of workplace charging and, to a lesser extent, public charging throughout the day, solar PV power patterns do not often correspond with uncontrolled EV charging. With solar, the additional advantages of smart charging might have a significant influence on renewable capacity, especially if they employ reasonably priced batteries that can store extra renewable energy that is not used during the day and then release it later. Even with uncontrolled EV charging, there may already be a high match between wind power generation and EV charging profiles since wind generating may take place at night, when EV charging is most popular. As a result, annual peak load declines in a manner consistent with the short-term study. CO2 emissions are significantly reduced when either solar or wind power is increased in the system.

Growing amounts of renewable energy in the system, in both the solar and wind smart charging situations, are what's causing the reduction in CO2 emissions. The decline in short-term marginal cost is mostly a result of the increasing percentage of renewable energy sources. When V1G or V2G are simulated, large curtailment differences are seen. The findings of comparable research examining the influence of smart charging on VRE integration are consistent with IRENA's stance on innovation. Additional studies have shown that smart charging has a positive effect on reducing peak demand in the system, along with associated CO2 emissions and renewable curtailment mitigation.

Mobility-as-a-service less compatible with EV-based flexibility

Consumer behaviours are already shifting as a result of carpooling and vehicle sharing. With the onset of digitalization, it is anticipated that the trend towards shared mobility and mobility-as-a-service (MaaS) would accelerate. This tendency will continue to grow as a result of fully driverless cars, which are anticipated to begin operating on a wider scale in metropolitan areas around 2040. These cars will mostly be electric.

Most of the world's population is expected to live in cities by 2030, and between 70 and 80 percent by 2050, so these changes should be most noticeable there. The rate of economic growth and population density will determine how much of an influence this has. In the long run, the rise of MaaS and autonomous driving might reduce demand for EV light-density cars in highly populated cities sales of two-wheelers may be less affected. The EV driving range will expand at the same time as off-peak transportation will continue to take place at night[7].

As a result, the system's overall flexibility for balancing solar power may be reduced, particularly during the day. Less parking time, or less battery capacity for grid services, will result from the higher daily mileage per vehicle. In comparison to a transportation system based on private EV ownership, the availability of EV flexibility may diminish in the future under a system based on shared autonomous cars. Yet until then, EV-based smart charging may be a key component in expanding variable renewable energy.

The development of the flexibility that an EV may provide to the grid via smart charging. If the market penetration is aided by ambitious governmental objectives and the availability of smart charging capabilities by 2030, flexibility from EVs may rise significantly. By 2030 and 2050, 200 kilowatt-hour (kWh) batteries and vehicles with a 1,000-kilometer range are possible. But, since there won't be much demand for such ranges, how widely they are used will depend on how expensive and heavy these batteries are.

600 kW of ultra-fast charging power may become accessible someday, but it would still only be utilised sparingly. Mobility-as-a-service and autonomous cars will revolutionise transportation by 2050, and they'll probably even out the growth in system flexibility. The flexibility available for balancing solar power may be diminished when shared cars park for shorter periods of time and concentrate largely at hubs in city suburbs.

Policy priorities

Countries must set challenging transportation goals in addition to expanding the use of renewable energy. CO2 reduction objectives for transportation might be taken into consideration in addition to the mobility goals and CO2 standards that are currently in place in certain nations. Temporary incentives for EVs should be introduced in areas where they are not currently in place in order to jumpstart the industry. Non-monetary incentives should gradually predominate when direct monetary incentives are phased out in response to regional conditions and demands.

Incentives for intelligent charging infrastructure should be created by governments and municipal authorities in developing EV markets. For instance, only "smart" home chargepoints in the United Kingdom will be qualified for government financing under the Electric Vehicle Homecharge Programme beginning in July 2019. The complicated market categories, such ultra-fast charging and multi-unit housing, should be addressed by all governments.

Regulatory priorities

The most important legislative elements required are the implementation of time-of-use tariffs for EV charging at first, followed by dynamic rates, allowing EVs to engage in ancillary service markets, enabling value stacking, and preventing duplicate charges. Initially, implementing smart charging requires the use of suitable pricing signals. It would be feasible to move the demand for EV charging to off-peak times and match it with the availability of renewable energy sources by sending price signals to EV customers. If customers do not get relevant pricing signals, they will not be able to link their EV charging with VRE generation. As automation rises, this system will be easier to administer for both service providers and drivers. Several shops, mostly in the US, have implemented EV home charging tariffs that give charging rates that are up to 95% less expensive at night than they are during the day[8].

In order for EVs to charge as much as possible at those times when plentiful VRE is available at almost zero marginal cost, retail energy pricing for EV consumers must reflect the real power mix. It will be important to use dynamic pricing and updated distribution grid tariffs to inform cars when to charge and discharge (in case of V2G). Working wholesale and retail markets must be established globally for that to happen, which is not the situation right now, not even in the top 10 e-mobility economies. Retail pricing control is often a very touchy political subject.

Second, a business case for V2G in particular will probably not be strong enough with only one income source. To put it another way, the batteries will need to "stack" the income by supporting a number of applications and offering local as well as system-level services, as depicted in Figure S4. In addition to dynamic pricing, there are other conditions that must be met for this to happen. Competitive balancing/ancillary services are available everywhere.

Total cost of ownership parity with gasoline and diesel

1. Small batteries (30-60 kWh)
2. Low driving range (150-300 km)
3. Large batteries (90-200 kWh) High driving range (600-1000 km)

Smart charging immature Increasing impact on peak demand and distribution grid overloads as EVs spread

1. Smart charging (V1G and V2G) available as default functionality
2. Individually owned cars parked 90% of time at home or workplace
3. Flexibility potential from EVs
4. Large-scale uptake of autonomous vehicles before 2040
5. Large-scale uptake of autonomous vehicles after 2040

Local grid operators are not permitted to handle grid congestion in any other manner than by strengthening the system, and there is no example of the potential flexibility from a single electric light-duty car in an urban context market. These marketplaces, as well as a number of other areas, will need to be accessible to combined EVs. High charges for EV smart charging may deter usage that have positive systemic effects. When energy is consumed from and provided to the grid using V2G technology, this may happen due to double taxation, such as the collection of taxes both for charging a vehicle and for injecting power into the grid, as well as network costs.

Business models

The demands of the power system (remuneration from supplying services to power systems) and the vehicle owner must be taken into consideration in business models (mobility and preserving the condition of the vehicle and the battery). Thus, it is necessary to keep an eye on variables like charging speed, EV battery health, possible shortening of battery lifespan, and others. While choosing the smart charging business model, these should be considered. As an example, offering operation services would need the battery acting "on call" while earning steady income only for being accessible. Contrarily, power price arbitrage necessitates frequent charges and discharges, which significantly shortens battery life.

The power capacity of EV batteries is limited, therefore a single EV cannot offer these services for the length of time required by the power system. But, EV batteries can provide the quick reaction needed for certain auxiliary services. Yet when EVs are combined, they can support one another, creating a virtual power plant with a quick reaction and the capacity to provide services for whatever long is required[9].

As the operator of a virtual power plant, Next Kraftwerke, and Jedlix, an EV aggregator and smart charging platform provider, have started a global test project, TenneT, the Netherlands' transmission system operator, will get secondary control reserve from EV batteries via this initiative. For a continual projection of the capacity, Jedlix will be able to integrate customer preferences, vehicle data, and charging station information. Next Kraftwerke then utilises this in TenneT's bidding procedure to purchase grid services.

Technology priorities

It is important to design smart charging while taking into account the unique characteristics of every power system. Depending on the dominant VRE source in the power system and its generation profile, the smart charging approach may change. With solar-powered systems, the incremental advantages of smart charging will be especially important. Increased shares of solar might be integrated at the system and local grid levels by changing charging to better coincide with solar PV power and by deploying V2G, which would reduce the requirement for distribution infrastructure investments. In order for EV charging to operate in conjunction with solar, charging must move to the middle of the day, which also necessitates the installation of charging stations at offices and other commercial locations where EV owners park their cars throughout the day. Workers could be allowed to charge devices at work using free renewable energy and then later use renewable power at home for V2H. Pre-cabling and smart chargers should be pushed in business buildings in order to achieve this.

Profiles of wind generation are more region-specific. Since wind could blow more in the evening and at night, when EVs often charge, in certain places these patterns may correspond well with EV charging profiles, even if EVs are charged in an unregulated manner. In these systems, the emphasis should mostly be on nighttime home charging and dynamic wind production adjustment. With the rise of mobility-as-a-service and the ultimate transition to completely autonomous cars, particularly in metropolitan areas, these tactics will need to be further altered. EVs will continue to be used largely for transportation and just incidentally as "batteries for the system." This would encourage the development of new technologies like wireless charging and shift charging away from homes and offices and towards hubs. It is important to carefully consider the consequences for the availability of EV flexibility, which may be lessened in a future transportation system based on shared autonomous cars than in a system based on private EV ownership.

However, only a small percentage of public and residential charging stations are smart grid capable, and only a small percentage of vehicles support V2G. The need for standardised charging infrastructure and interoperable solutions between charging stations, distribution networks, and the EVs themselves will grow as the prevalence of EVs rises. In addition to protecting against vendor lock-in for charging infrastructure, interoperability is essential to enabling cost-effective connection of EVs with a variety of charging infrastructure and metering.

Variable renewable energy sources will be used more and more in future power systems. Electrification of transportation networks will increase in the future. One possibility for the future is an integrated, emissions-free electrical and transportation system that uses renewable energy to power both grids and electric automobiles (EVs). When coupled with other technologies, EVs have the potential to help both the electricity and transportation sectors move towards a low-carbon future. Particularly in an urban setting, cities may gain from decarbonizing transportation, drastically decreasing air and noise pollution, as well as fuel imports, and offering new technological possibilities to reimagine urban mobility.

Electricity is a desirable low-cost fuel for the transportation industry because to consistent cost decreases in renewable energy sources. The electrical system has the chance to benefit from a large scaling up of EV deployment by potentially providing much-needed flexibility in a system with a high percentage of renewables. Unlike other flexibility alternatives, EVs were not created to support the power system; rather, they originate from a different sector, making them a special invention. Nonetheless, they provide the power system many wonderful possibilities. In order to take advantage of the potential synergies between the two sectors, innovations in technology, business structures, and legislation are required. This innovation overview looks at the potential for complementarity between VRE and EVs and how smart charging might help to realise that promise between 2030 and 2050.

The following sections make up the report:

The section outlines the situation and gives a rundown of recent EV industry advancements as well as how they interact with renewable energy sources. The section discusses the future of smart charging, including the many charging methods that are now available as well as current research initiatives. It examines potential medium- and long-term (2030 and 2050) developments for EV flexibility. The appropriateness of various charging infrastructure types for smart charging is also evaluated, as is the application of digitalization as a smart charging enabler. This section evaluates the value chain and business concepts for the EV market. It also evaluates obstacles and ideal methods for integrating vehicles with grids (VGI).

The prospects for e-mobility are presented this section. It evaluates how competitive electric vehicles (EVs) are with regard to cars with internal combustion engines (ICEs) and how this is anticipated to change. The development of battery technology, the shift to mobility as a service, and the potential adoption of autonomous cars are all discussed. The section addresses how smart charging affects the world energy grid. It summarises the findings of modelling that was done to determine how the main anticipated advancements in electromobility will affect the EV-grid nexus. A final policy check list provided by Section summarises the most important findings of the quantitative modelling and the innovation forecast. It generates a list of the crucial actions that regulators and other interested parties must do in order to implement the most promising developments in order to maximise the synergies between EVs and renewable energy sources. A summary of recent market developments for electric vehicles is provided in this part, along with information on the legislative incentives in place for light-duty vehicles including buses, lorries, and light commercial vehicles up to 35 tonnes. It also lists the important factors that determine how flexible an EV [10].

CONCLUSION

The Center for Solar Energy and Hydrogen Research Baden-Württemberg (ZSW) estimates that 5.6 million electric vehicles (EVs) were on the road in the globe at the beginning of 2019. The main markets for EVs are China and the US, with 2.6 million and 1.1 million units, respectively2. At a compound annual growth rate (CAGR) of 57% from 2012 to 2017, EV sales generally increased quickly. As the industry is still in its infancy, just 1.3% of all light-duty cars purchased in 2017 were electric vehicles. The primary forces behind the market's adoption of EVs are policy support programmes and pledges made on an international, national, and private level.

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CHAPTER 14

CHARGING INFRASTRUCTURE INCENTIVES

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ABSTRACT:

The Chinese EV market has experienced the largest increase in sales, with a CAGR of 114% between 2012 and 2017. In 2015 China surpassed the US in total EV sales, and in 2017 it was responsible for 48% of worldwide electric light-duty vehicle sales. The Chinese government has offered direct monetary incentives to support the purchase of EVs, including one-time subsidies and purchase tax exemptions, as well as non-monetary incentives, such as restrictions on registrations for ICE vehicles. After China and the US, the next largest markets are in Europe, with considerable growth in EV sales from 2012 to 2017 in Germany (CAGR of 75%), Norway (70%) and the UK (68%).

KEYWORDS:

Charging, Electricity, Infrastructure, Mobile,Networks Wireless Charging.

INTRODUCTION

EV sales are mostly concentrated in China and the US, while other nations have had more success incorporating EVs into their entire fleets of vehicles. The development of EVs' market share in light-duty car sales. Since 2012, Norway has made incredible strides, rising to the top in the world with a nearly 40% proportion of electric vehicles in 2017. This was the outcome of a supportive legislative climate in recent years that included several different incentives, including as tax reductions and exemptions as well as waivers on ferry and road tolls.

After Norway, Sweden, the US, and the Netherlands had the fastest growth in EV integration between 2012 and 2017, with EV shares totaling 5.1%, 3.3%, and 2.7% of the market for light-duty vehicles, respectively. The percentages of EV penetration in the other six top markets did not reach 2.5% and they placed close to the worldwide average. Please take note that the 2017 statistics only apply to EV adoption in the passenger vehicle category.

Key factors that will accelerate EV adoption include the advent of total cost of ownership parity with internal combustion engines (ICE), significant governmental backing, and the determination to decarbonize the transportation industry. Together with the slow transition of ordinary customers to EVs, businesses are increasingly turning their fleets "green" as part of ambitious objectives to reduce emissions or to qualify for generous subsidies. These kinds of efforts will serve as a demand signal for the EV market and inspire other business-to-business (B2B) clients to engage in like actions.

The Climate Group's EV100 programme, which was introduced in 2017, urges businesses to make a commitment to transitioning to 100% electric corporate fleets and to develop charging infrastructure. The programme signed on 10 international companies in its first few months, including the Swedish power business Vattenfall, the IKEA Group, and the Chinese internet behemoth Baidu (The Climate Group, 2017). As part of its objective to be carbon neutral by 2050, Vattenfall has set goals to convert its fleets of 3 500 light-duty vehicles to 100% electric by 2020, which is the initiative's most time-ambitious goal to yet. Fleets from Sweden, Germany, and the Netherlands will all be replaced during a five-year period[1].

A leader in the industry is the French postal service La Poste, which has 35 000 EVs in its fleet of 75,000 cars. Deutsche Post DHL Group, a German company, likewise declared a goal to achieve zero-emission logistics by 2050, partially via the usage of EVs. There is a sizable market for various kinds of EVs, such buses and trucks, in addition to electric versions of traditional light-duty vehicles. Plug-in hybrid EVs (PHEVs) and battery-only EVs are options for electric drive buses and trucks, much like in the market for light-duty vehicles (BEVs). The Asia Pacific region accounts for the majority of the global market for e-buses, with a market penetration rate of 27.6% in 2016. Since 2014, China has seen a significant increase in the usage of e-buses and currently accounts for 99% of global sales and fleet. Market penetration in Western Europe and North America is around 0.6%. The UK has the biggest fleet of e-buses in Europe, with just 344 units, whereas China reached 340 000 in 2017. (BNEF, 2018a). Yet, certain markets, like school buses in the US, offer electrification potential that is drawing more and more investors' interest.

As a result of the severe air pollution issues in major cities and industrial areas, China is in the forefront of the electrification of public transportation vehicles. The goal of municipal governments that seek to cut air pollution is the technique of electrifying public transportation. For instance, Shenzen's strong and quick adoption of e-buses has significantly decreased the city's greenhouse gas emissions. The national government, which has lofty aspirations for public transportation, also supports the switch to e-buses. China has made investments in a national high-speed rail network, subways, and bus rapid transit in addition to electrification.

In the next years, it's anticipated that the number of e-buses in Europe will increase significantly. At least 25 municipalities and public transportation providers in 25 European cities have developed e-bus policies for 2020. (UITP, 2016). The e-bus market, while being a small-production vehicle category and still in its early stages of development, has a lot of room to expand in the next years owing to rising demand and the need for governments to decarbonize the transportation industry.

Asia Pacific is the biggest market for electric drive trucks, accounting for around half of global sales in 2016. Yet, Western Europe had the greatest market penetration for electric vehicles. With fewer than 10,000 units delivered in 2016, this industry is currently modest, but the usage of electric vehicles is anticipated to increase quickly in several industries, such as smaller service and delivery trucks (IRENA, 2017a). The present market penetration of EVs has been primarily fueled by public and governmental support for electric vehicles as well as by the expansion of the infrastructure for charging them. The increase in EV sales seen over the last five years was a result of both financial and non-financial incentives. At the local, state, and federal levels, these incentives have been put into place.

Financial incentives include tax hikes on ICE car usage adopted in the Netherlands, Norway, and Germany as well as tax rebates or exemptions for EVs. For the purchase of EVs, France, Germany, and the UK have implemented one-time incentives (EC JRC, 2017). Non-monetary rewards may function as effective substitutes for pricey subsidies. For the benefit of customers, nations like the US and Norway permit EVs to utilise bus lanes or carpool lanes. As in certain German and British cities, the establishment of low-emission zones to provide preferential access to low-emitting cars is also a widely used and effective measure for cities to encourage e-mobility. Yet, the market for e-mobility is only temporarily being boosted by such regulations. Permanently keeping them in place might have negative repercussions like clogging up bus and carpool lanes. A change in toll road pricing may also be necessary[2].

Some countries have established e-mobility-related goals. A summary of the most important EV markets' significant government e-mobility goals. The objectives differ each nation in terms of how ambitious they are such as target year or absolute numbers as well as how they are constructed. The Paris Agreement on climate change also plays a critical role in motivating nations' promises to emissions reduction in the transport sector, thus lowering local air pollution is not the sole reason for these efforts. The governments of France, the Netherlands, Norway, Spain, and the United Kingdom have all set deadlines for outlawing the sale of automobiles powered by fossil fuels.

These governmental objectives go beyond carbon dioxide (CO2) regulations, such those in place for new vans and vehicles in the European Union (EU). The EU seeks to encourage innovation and the market entry of zero- and low-emission vehicles by imposing restrictions on the average CO2 emissions of new passenger cars and vans. In addition to fleets of vehicles, several governments have established goals for the deployment of charging infrastructure since a lack of adequate charging infrastructure is a significant obstacle to EV sales. The construction of charging stations at the domestic level, in semi-public settings like workplaces, and in public venues is encouraged by governments and public utilities all over the globe.

Ambitious installations of charging stations, also known as EVSE or electric vehicle supply equipment, as well as goals and dedicated financing for implementation projects all support the growth of the charging infrastructure. China, a number of European nations, and Japan have also offered significant help. Introducing fast-charging networks is one example. A group of four automakers and the utility TEPCO (Nippon Charge Service) is receiving funds from the Japan Development Bank, while 88 pilot towns in China that have been working with State Grid Company of China are receiving assistance from Chinese city governments. In the US, the government has partially funded charging infrastructure, and investor-owned utilities in California and a number of other states may apply for permission to deploy EVSE that are ratepayer funded (i.e., regulated). This requires review from utility regulators to ensure that such investments benefit all ratepayers and are not anti-competitive, and it also requires that the EVSE be deployed. An essential part in accelerating the transition from dirty transportation to clean energy is played by international conferences of the world's major economies. The Clean Energy Ministerial's EV effort is described in Box 3 (CEM). Below is a summary of the many EV policy supports that are now in place, including both monetary and non-monetary incentives, as well as a number of case studies. In Europe, unbundled distribution system operators' regulated asset bases cannot include the cost of EV charging infrastructure. Thus, only commercial ventures are viable.

COUNTRY TARGETS

Austria

- 1.3% to 3.4% share of EVs on the road by 2020
- Between 3 500 and 4 700 publicly accessible charging points by 2020

Belgium

- 1.3% share of EVs on the road by 2020
- 8 300 publicly accessible charging points by 2020
- Ban on circulation of diesel cars in Brussels from 2030 (Manthey, 2018)

China

- 4% penetration of EV (PHEV and BEV) sales in the passenger car market by 2020
- In 2017 the country discussed a possible ban on the production and sale of diesel and petrol cars, to be implemented “in the near future”.

France

- Ban on sales of fossil-fuel cars as of 2040

Germany

- 1 million EVs on the road by 2020
- 1 000 new EV charging stations on highways between 2017 and 2020

India

- Ban on sales of fossil-fuel cars as of 2030

Japan

- Increase the share of EV sales to between 20% and 30% by 2030

Netherlands

- Ban on sales of new petrol and diesel cars as of 2025

Norway

- All new passenger cars and vans sold in 2025 to be zero-emission vehicles

Republic of Korea

- 200 000 EVs by 2020

Spain

- Proposed law to ban sales of fossil-fuel cars by 2040 and their circulation by 2050 (Sauer and Stefanini, 2018)

UK

- Ban on sales of new petrol and diesel cars as of 2040
- 60% share of EV sales by 2030 and 100% by 2040 - 1.55 million EVs on the road by 2020

CHARGING INFRASTRUCTURE INCENTIVES: CASE STUDIES

European Union (ICCT, 2016)

A regulation on the deployment of infrastructure for alternative fuels that was enacted at the EU level in 2014 requested Member States to provide implementation plans and goals for the construction of infrastructure, including electric charging stations. Also, between 2013 and 2015, around EUR 35 million was spent on the construction of roughly 600 fast-charging stations throughout the major road networks of Northern Europe as part of the EU's TEN-T initiative.

Ireland (Gallagher, 2018)

A new policy was put into place in 2018 to support the government's objective of 30% of zero-emission vehicle sales in the automotive market by 2030. Under this policy, owners of electric vehicles can apply for a grant of up to EUR 600 to cover the cost of buying and installing residential charging stations[3].

Amsterdam, the Netherlands (BNEF, 2017b)

In order to establish public charging stations, the city signed a deal with the energy provider Nuon in 2016. EV owners may request the free installation of a public charging station under specific circumstances. For instance, EV owners should not have their own site or access to private parking, and they should have a parking permit at the desired location or be qualified to get one. In return, the Municipality of Amsterdam is permitted to use the charge information for study, even if it has been anonymized.

UK (UK Government, 2016)

Grant programmes are offered by the Office of Low Emission Vehicles to help with some of the installation costs of EV charging infrastructure. The end users of the charging systems determine the funded amounts and conditions. In accordance with the Electric Vehicle Homecharge Program, home customers may receive subsidies that account for up to 75% of the overall expenses of installation and procurement. Only "smart" home chargepoints will be eligible for this government assistance beginning in July 2019. The definition of a smart chargepoint is a chargepoint that can receive, comprehend, and act on signals supplied by energy system operators or other parties to suggest when is a good moment to charge or discharge in relation to overall energy supply and demand (RECC, 2019). For municipal governments that want to put up residential charge points on the street, a similar programme is created. Businesses, nonprofits, and public sector organisations may apply for a voucher worth GBP 300 per socket up to a maximum of 20 under the Working Charging Program.

California, US (Guinn, 2017)

In the US market, California has the greatest percentage of EVs. The state government, utilities, or municipalities have established around 15 programmes to encourage the construction of charging stations. EVSE rebates or tax credits are given to a certain group of clients' workplaces, multifamily homes, underserved neighbourhoods, companies, governmental facilities, etc. For instance:[4]

- Burbank Water and Power provides clients with a reimbursement of up to USD 500 (residential) and USD 1000 (commercial) when they install a Level 2 (240 volt (V)) charging station (commercial). Applicants must be paying the time-of-use power tariff in order to qualify for the refund.
- Southern California Edison (SCE), a regulated electric provider, works with regional "site hosts" of EVSE via its Charge Ready programme. SCE installs, maintains, and recovers expenses from ratepayers for site preparation and distribution system modifications. Site hosts agree to purchase qualifying EVSE at their own expense.
- The San Joaquin Air Pollution Control District provides assistance to local government entities and companies via its Charge Up! programme for the construction of public EV charging stations. The candidates are eligible for up to $50,000 per year or $5,000 per unit.

DISCUSSION

There are three key benefits of electric cars for the transportation industry: Secondly, they use a less expensive fuel, therefore the price of electricity per kilometre is often lower than that of gasoline or diesel. Second, no local pollution is produced by EVs. They assist in lowering noise and particulate matter emissions. Finally, compared to an ICE engine, an electric powertrain has a much superior energy efficiency. Pump-to-wheels fuel usage for an EV is around one-third to one-fourth that of an effective ICE car (EPRI, 2018).

Even when mostly "using fossil fuels," EVs often release less greenhouse gas than ICE cars (Creara, 2017). The mix of grid supplies affects how much CO2 is produced by EVs. For instance, EVs still produce less CO2 than ICE vehicles on average in China, but EVs produce more CO2 than ICE vehicles on average in India and Australia. In comparison, EVs generate almost no emissions in Iceland[5].

Even if EVs are not powered by electricity generated using a combination of renewable energy sources, the fact that they immediately reduce the amount of air pollution in cities, which results in millions of preventable lives each year, is a significant first step. According to the World Health Organization, nine out of ten people on earth live in areas with high levels of air pollution, which is thought to be the cause of an estimated 4.2 million yearly deaths from heart attacks, strokes, lung cancer, and chronic respiratory illnesses (WHO, 2018). Yet, the power needed to charge the EV battery packs must be generated from renewable sources in order to achieve genuine decarbonization of transportation via electrification.

Due to low renewable energy percentages in the power mix of the nations with the biggest percentages of EVs on the road, such the US, there is a significant opportunity to decarbonize transportation via the usage of EVs charged by renewable electricity. The growing electrification of transportation may also help nations with substantial renewable energy contributions. Electrification of transportation must coexist alongside decarbonization of the electricity sector in order for both to fully benefit society. The potential for using clean power to charge the present fleet of EVs is examined in the following graphs[6].

In developed nations like the US, the demand for power would increase by 24% if all light-duty cars were electric. Even if "renewable energy" could theoretically meet all of the demand for light-duty automobiles, it would not be possible given that the amount of electricity generated from renewable sources overall in the US is only around 18%. This would also be true, if to a lesser extent, in nations like Germany and Japan, among others. This unmistakably indicates that these nations' decarbonization activities must be stepped up.

The correlation between three variables in the same 10 nations examined in Figure 1: the percentage of electric vehicles in the fleet of light-duty vehicles, the proportion of renewable energy in the production of electricity, and the fleet size as of the present. The nation most likely to be able to provide clean energy for a full-EV national fleet is Norway. Almost 98% of the nation's power is produced. Renewable energy sources are used for generation, although Norway has less EVs overall than China and the US. The Norwegian energy mix is also more adaptable than energy systems based on variable renewables like solar and wind since it is hydropower-based. Although having a small percentage of renewable energy, France's nuclear-based energy mix is mostly low carbon.

When hydroelectricity is unavailable and the transportation sector must be powered by intermittent solar and wind energy, charging EVs using renewable energy becomes more difficult. Although the nations with the largest percentage of EVs China, France, Japan, and the US—have a tiny amount of wind and solar power in their generating mix, wind power accounts for practically all of the renewable energy produced in Denmark and the Netherlands. Denmark, which generates 51% of its energy from wind farms and has a small EV fleet, is the nation that comes the closest to matching the demand for EV electricity if solely wind were used to power them[7].

When the output of renewable power exceeds the demand, EV fleets may build up a sizable electric storage capacity to hold the extra supply. The balance of renewable energy sources will determine the best charging patterns, however. In a system with significant proportions of solar production compared to a system where wind generation predominates, EV integration tactics in the power system are considerably different. Separately, the wind and sun contribute to the production of power. It is important to note the examples of Japan and Sweden. Whereas Japan's VRE is entirely solar-powered, Sweden's is entirely wind-powered. In this way, Japan could store extra solar PV energy using its 26 GW of pumped storage hydro and utilise that energy to charge EVs at night. To better fit the wind availability patterns, charging of EVs might be spread out further throughout the day and night in the Swedish scenario.

When maximising the synergies between EVs and VRE and the decarbonization of the transportation fleet, three factors the kind of VRE electricity sharing, driving patterns, and charging needs need to be taken into account together. The effect of EV integration into high-solar or high-wind isolated systems is discussed in further detail. Since that electric mobility is a power-dense, movable, and controlled load, the adoption of smart charging is anticipated to create a positive feedback loop with the integration of renewables. According to studies, EVs and other vehicles are often parked for roughly 95% of their lives. This might make EVs an appealing flexibility option to support system functioning, especially when paired with their storage capacity. They have the potential to develop into grid-connected storage units that might provide the system a variety of functions. Future EV battery capacity may much exceed stationary battery capacity, according to IRENA study. Compared to 9 TWh of stationary batteries, about 14 TWh of EV batteries would be available to provide grid services in 2050.

An EV typically uses roughly 3000 kWh of power per year when travelling 15 000 km. Even with sluggish charging (i.e., charging at low power, let's say 3.7 kW), the entire time required to charge the annual energy is just 10% of the time the automobile spends at a standstill. The annual "flexibility window" for charging corresponds to around 85% of the time, assuming that an EV is linked to charging infrastructure the whole time it is parked. Ideally, each automobile would produce roughly 3000 kWh of flexible energy annually. So, EVs may be charged in a small portion of the time it takes to park them. A key potential for the power grid and EV owners is to encourage charging at the cheapest periods of the day. Due to drivers' time restraints, quick charging, or when the car is parked but not plugged in, flexibility may actually be less in reality. The many elements that affect how much energy is available for flexible discharge from EVs in the system are compiled.

Now, there is a very tiny EV fleet, and the batteries on the vehicles are still rather modest. EVs are already possible to increase the self-consumption of local renewable energy generation. The flexibility that EVs provide to the system is limited, however. From the standpoint of the power grid, their total storage capacity is now insignificant. The immobilisation period, which is based on the kind of vehicle and its usage, determines how long the automobile may be linked to the grid. Less flexibility will be available than single automobiles utilised by people in taxis or buses that cover a large daily distance. Passenger vehicles and two-wheelers may only utilise 40% to 50% of the battery capacity per day, compared to an electric bus or truck's daily use of 100% or more [8].

- Long-duration (> 4 hours) charging gives the system the greatest flexibility; the majority of charging occurs at home in the evening, as well as at night and at work during the day. EV owners without access to a home charging station need allotted office charging.
- Short-duration (15 minutes to 1 hour) or medium-duration (30 minutes to 2 hours) charging at retail or entertainment venues (movie theatre, gym, etc.) provide the least amount of flexibility for the system and are unsuitable for grid services: Now, rapid charging on highways is quite unusual since most people do not use EVs for lengthy journeys (due mainly to the limited range issue and the lack of appropriate charging infrastructure).
- Depending on the business models, the charging patterns of shared and commercial vehicles (such as taxis and other vehicle fleets) may be less predictable. Yet, because the money from the transportation service is so important, the amount of time spent stationary should be kept to a minimum. This will result in less time spent connected to the grid and more charging power than with individual automobiles. Although commercial services like taxis may still be in more demand during the day, freight transit may take place mostly at night.

1. Electric bus charging patterns depend on the place of charging:
2. Long duration (> 4 hours) at the bus depot
3. Medium duration (10 minutes) at the bus end-of- line
4. Very short duration (flash charging) (30 seconds) at the bus stop.

The usage of the vehicle should be anticipated, including the timetable and travelling distance. This requires communication with the vehicle owner. The distribution of charging places may vary depending on topography, particularly availability to private parking at the home level. The majority of charging cycles take place at home or at work in less busy places. A greater percentage of charging might be done in public areas in crowded cities when there are no charging stations at homes or places of employment. Dispersed charging spots don't have as many technological options or incentives to contribute to energy flexibility as large parking lots or bus terminals do. Nevertheless, owing to individual car ownership and the cheap cost of charging this manner, the majority of charging is now done at home and at work. Whatever charging infrastructure is used depends on it:

- The majority of chargers in use today are sluggish chargers placed in private and semi-public locations. The International Energy Agency estimates that in 2016, private chargers outnumbered public charging stations by a ratio of more than six to one, supposing that each automobile had access to a private charger in the majority of cases. However in recent years, the number of fast-charging installations has increased more rapidly than the number of slow-charging installations (IEA, 2017).

- Smart charging capabilities may not yet be present in automobiles and charging stations. Not all technological prerequisites have been completely realised, including the capacity of charging stations and automobiles to interact with one another and provide variable power via discharging.

Depending on the battery capacity of the vehicle and the demands of the drivers, the amount of battery capacity that may be made available for smart charging:

- The battery capacity: electric 2-3 wheelers will offer less energy flexibility than premium cars with bigger batteries. A few orders of magnitude are given as follows (EAFO, 2017):
- Entry BEVs: 20-40 kWh in 2017 (e.g., Renault Zoe, Nissan LEAF), 40-60 kWh in 2018-2019 (e.g., Renault Zoe, Nissan LEAF, VW eGolf)

1. • Premium BEVs: 60-100 kWh in 2017-2018 (e.g., Tesla Model S)
2. PHEV cars: about 8-16 kWh
3. BEV buses in 2017: 100-400 kWh (some models up to 600 kWh)
4. E-motorcycles: typically 3-20 kWh
5. E-bikes: typically 500 Wh.

A sufficient level of charge, or the battery's capacity at the time of departure, should be ensured. The battery must be fully charged (usually between 70 and 80%) at the time of disconnecting in order for the automobile to continue to give enough range. With bigger batteries in EVs and more penetration of charging stations, the significance of this metric will, however, decline[9].

If an EV is V2X-enabled, the capability that it can provide flexibility services will improve (e.g., about three to four times as compared to V1X). Before widespread deployment, it is also necessary to assess the influence of charging and discharging patterns on maintenance costs, efficiency, and battery longevity (guarantee, range anxiety, etc.), since these issues still need to be resolved despite some encouraging test findings (De Vroey, 2016). The number of EVs on the road will significantly enhance the flexibility's availability in the future, but advancements in the power system and trends in mobility will also have an impact. By 2030, automobile ownership by an individual will probably still be more prevalent than car sharing. As a consequence, more flexibility may be anticipated:

6. More EVs are accessible to the grid owing to dropping costs: As mentioned in the preceding section, EVs become more affordable due to falling battery costs and government programmes.
7. More EVs with bigger batteries will be linked to the grid, which will help alleviate range anxiety. Battery packs will be larger, expanding from 20 to 30 kWh to 40 to 60 kWh, with ranges of around 300 km becoming more common during the next two years and then further increasing.
8. Vehicles, charging points, and smart charging and discharging functionalities: As standardisation moves forward and as the need for better control of the charging power rises, vehicles and charging points will have smart charging options, including discharging as a common feature (provided by auto manufacturers), and technically enabling the provision of ancillary services to the grid. The entry cost

for consumers would be significantly reduced by a series-produced EV with alternating current (AC) charging and vehicle-to-grid (V2G) functionality.

9. More workplace charging options for EV drivers.

Given that there is sufficient range and as long as charging at home is still less expensive, fast charging will only be used for long-distance excursions and essential top-ups. Although increased nominal charging capacities often make uncontrolled charging more difficult, daytime rapid charging may be able to meet grid demands in regions with significant daytime solar generation. This scenario may drastically alter between 2030 and 2050. Fleet management may replace individual vehicle ownership as a result of the emergence and widespread adoption of mobility business models like mobility-as-a-service (MaaS), or seamless multimodal transportation[10].

According to studies, "ride-sharing" may increase the amount of miles travelled as more people switch from using public transportation to shared private transportation. But, it should also result in less usage of private vehicles with few passengers, which might mean a decrease in the net emissions of the transportation system. Nonetheless, in this case, downward pressure on the available flexibility is likely to happen, as:

10. MaaS will ultimately have an influence on the quantity of EVs in the system by lowering the length of time that idle vehicles are connected to the grid and increasing the distance that individual cars drive. Assuming that the EV revolution will occur before the development of a sophisticated MaaS ecosystem, new business models in MaaS would translate to downward pressure on individual vehicle sales after around 2030, after years of growing market growth.
11. Once charging is concentrated in hubs, zones of pressure on the regional power system may be produced. Although transportation service optimization will strive for maximum utilisation, these hubs may be significant for centralised flexibility management at night, but their importance will still likely be smaller than with individual automobile ownership. In order to achieve the objectives of EV grid integration and optimal renewable energy consumption, vehicle fleets will need to be directed towards optimised fleet charging and routing[11].

CONCLUSION

Due to significant growth in urbanisation in densely populated cities in developing nations, 60% of the world's population is predicted to reside in urban regions by 2030 and 70-80% by 2050. The layout of the city will also affect the adoption of MaaS and completely autonomous driving. Outside of metropolitan areas, the private ownership model will continue to be dominant, and EVs will provide distant regions more freedom. The availability of infrastructure and supportive legislation will have a significant influence on how quickly fully autonomous cars are adopted. For these reasons, even if dependable technology may be accessible much earlier, a significant uptake of these vehicles is not anticipated until the 2030s, and in most places, maybe later. The two different tones of blue represent two different adoption scenarios for autonomous vehicles. The light blue initial scenario shows the early arrival of autonomous cars and the early flattening of EV flexibility. Under the second scenario, shown in dark blue, use of autonomous cars rises until 2040, then declines.

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CHAPTER 15

IMPACT ON GRID INFRASTRUCTURE

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ABSTRACT:

This section reviews the different smart charging approaches and the status of smart charging infrastructure and provides an outlook based on the lessons learned from existing pilot projects and research in the field.If EVs were charged simultaneously in an uncontrolled way they could increase the peak demand on the grid, contributing to overloading and the need for upgrades at the distribution level. The extra load may even result in the need for upgrades in the generation capacity or at least in an altered production cost profile. The extent of possible impacts would depend on the power system's electricity mix, grid typology and penetration of EVs, as demonstrated by various trials and studies conducted globally.

KEYWORDS:

Charging, Electricity, Mobile,Networks Wireless Charging.

INTRODUCTION

On the effects of EVs on the electrical grid and how these affects might be reduced, the research agrees on three key points: Effect on the demand for power will be minimal:

1. In a situation where Europe only uses electric vehicles, the energy requirements of EVs may not exceed 10% to 15% of overall power generation. Yet, with rising EV quantities, EV grid integration may cause local power problems.
2. Just 5-6% of Norway's annual hydropower production would be used if all 2.7 million automobiles were electric vehicles (BoA/ML, 2018a).
3. Ten million EVs by 2035 in a Germany with a 25% electric mobility scenario would result in a consumption rise of just 2.5–3%.
4. In 2016, the overall power usage in the US would have been around 24% lower if all light-duty cars were electrified[1].

If the increased demand is not dispersed carefully, the effect on peak demand might be significantly larger. Smart charging is crucial in this:

A. Evening peak demand would grow by 3 GW in a scenario in which there are 10 million EVs in the UK by 2035, but only by 0.5 GW under a scenario in which charging is managed. Smart EV charging might result in a 7 GW demand surge during low pricing times (AER, 2018).

B. According to EV modelling in New England, a 25% share of EVs in the system charging in an unregulated manner would result in a 19% increase in peak demand, necessitating a large investment in grid and generating capabilities. Nevertheless, the increase in peak demand might be reduced to between 0% and 6% by distributing the load during the nighttime hours. Also, charging just during off-peak periods might prevent any rise in peak demand.

The impact on local distribution grids might also be significant if not managed with smart charging:

1. Colorado-based Xcel Energy has shown that if charging coincides with peak demand periods, 4% of distribution transformers might be overwhelmed at a market penetration of 5% for electric vehicles.
2. The UK's My Electric Avenue Project found that 32% of distribution circuit modifications are required, along with a 40–70% proportion of electric vehicles (EA Technology, 2016).
3. In a scenario with 10 million EVs by 2035, "dumb" charging of EVs in Germany would result in a 50% increase in low-voltage grid and transformer expenses, while optimized peak shaving with smart charging would prevent these investments [2].

Impact on grid infrastructure

The investments made in the distribution system will be impacted by EV charging. The following factors, at the very least, will determine the extent of grid expenditures in terms of cables and transformers that will need to be done in a certain location:

1. **Congestion:**For instance, in the neighbourhood distribution network before any EV deployment.
2. **Simultaneity factor:** According to how each distribution grid's size is used. The possibility that one piece of equipment will need to be turned on at the same time as another is determined by the simultaneity factor or co-efficient. Every distributor takes a different simultaneity factor into account.
3. **Load characteristics:** For instance, areas with large percentages of electric heating will be more affected by unregulated EV charging thus leading to higher grid reinforcement. Yet, since the local grids are sized for greater peaks, smart charging may be implemented in these regions with less grid reinforcement than in locations that do not utilise electric heating.
4. **Generation assets connected at low voltage level:** Smart charging, for instance, might help the integration of significant shares of solar PV connected at low voltage level for instance, in Germany, although EVs could put more demand on local grids in areas with no or very low shares of solar PV.
5. **Grid code limits and other regulations:** National grid rules set physical restrictions in terms of both voltage and frequency changes that distribution system operators have to follow, and investment in grid reinforcement if these country-specific limits are exceeded due to EV charging[3].

The effect of EVs on potential bottlenecks is quantified in the case study of Hamburg, Germany, in Box 4 along with the distribution system operator's response plan. Grid infrastructure development faces a hurdle from fast charging. The distribution grid's capacity must increase as electricity increases. Moreover, the car and locally installed charging station/cables must be able to handle this power. While both of them are technically possible, they also have a cost:

A. Electronics and safety equipment for vehicles must cost more.
B. Larger cables and transformers are needed for fast-charging station grid connections.

C. Such charging stations need more costly cooling and protection equipment in addition to electronics.
D. If very heavy wires are to be avoided, the charging cable needs active cooling. While increasing voltage from the current level would reduce the requirement for heavier cable and/or active cooling, this is not the best option when taking into account the compatibility with the current infrastructure (and with the existing EVs). Cars may use both technologies to be compatible throughout the changeover. Porsche is developing an 800 V capable version of the Taycan that is backwards compatible with the existing 400 V charging infrastructure, for instance.
E. Last but not least, the charging capacity for EVs is dependent on a variety of factors. For instance, highway charging stations use numerous charging points, whose power consumption will rise in tandem with the number of EVs[4].

A comparative illustration of a motorway charging station and a traditional gas station. In the medium future, a highway station with 30 charging outlets would be well within the range of a 6 MW capacity. A huge windmill currently has a nominal power of this amount. Moreover, an electric vehicle would need 6 MW of electricity to charge energy at the same rate as a traditional ICE vehicle (e.g., typically 100 km charged in 15 seconds). With the battery technology we have now and in the next several years, this is not practical nor economically viable. However, the new EV models' declining consumption would effectively balance out this potential necessity. Diesel uses roughly 10 kWh per litre. This indicates that 500 kWh are required to fill a 50-liter automobile tank. This equals around 6 MW (500*12) if the charging time is to be the same as filling a tank (roughly five minutes). Power does not remain constant during a charging curve; instead, it drops off towards the conclusion of the cycle. As a result, to start the charging cycle, a specific average power level (such as 4.8 MW) needs a higher level (such as 6 MW).

EV CHARGING IMPACT ON HAMBURG'S DISTRIBUTION GRID

Currently, Hamburg has the most charging stations per capita in Germany (several hundred charging points in households and 810 public charging points as of November 2018). By the start of 2019, the city planned to set up 1000 public charging stations. The most important factors influencing load growth in the city are the electrification of public buses and the expansion of EVs. The bulk of EVs will be found in Hamburg's outskirts, where the grid is less reliable. With charging point loads of 11 kW and 22 kW, the local distribution system operator Stromnetz Hamburg conducted a load development study to identify key circumstances for uncontrolled charging of EVs. 15% of the feeders in the city's distribution network will experience bottlenecks due to the 9% EV share, or 60 000 EVs loading in private infrastructure.

In order to prevent these dire circumstances, Stromnetz Hamburg estimated that the local grids would need at least 20 million euros in investment. Other approaches to solving the issue are also being considered by Stromnetz Hamburg. The secret is to reduce simultaneity, or the number of EVs being charged simultaneously on the same local grid. In order to do so, a clever solution based on digital technologies is being tried. It consists of a real-time communication system that allows the distribution system operator to lessen the burden on the charging stations required to solve the issue. For instance, the 11 kW charging stations may lower their load from 16 amperes (A) to 8 A, which enables EVs to be charged more slowly[5].

Siemens and Stromnetz Hamburg collaborated on this project, and Siemens will set up 30 control units and monitor the loads on the private charging infrastructure. They will be better able to predict congestion problems and design the network based on the load profiles thanks to this. This method is expected to cost roughly EUR 2 million, which is only 10% less than the price of strengthening the wires in a typical manner. The story of Hamburg demonstrates not just the potential effect of EVs on municipal grids but also possible solutions to it, which may call for a mix of digital technology, new business models, and market regulation to include all necessary participants.

Managing EV loads may be done via smart charging utilising vehicle-grid integration (VGI) technology. Customers may respond to pricing signals, the EVSE can automatically respond to control signals that adapt to grid and market conditions, or a mix of the two can be used while still honouring customers' demands for car availability. It entails delaying certain charging cycles or adjusting power output in response to limitations (e.g., connection capacity, user needs, real-time local energy production). Hence, smart charging is a method of optimising the charging process in accordance with local renewable energy supply, distribution grid limits, driver preferences, and EVSE site hosts. If charged properly, EVs may not only save the local grid from being overworked but also provide services to fill flexibility gaps at both the local and system levels. Intelligently (dis-)charged EVs might lessen the need for grid reinforcement, boost local consumption of VRE output, and save investment in peaking generating capacity.

The EVs have the ability to function as grid-connected storage units with the capability to provide the system a variety of services. By varying their charging levels, they might enable real-time grid balancing, flatten peak demand, fill load troughs, and change their charging patterns. The major emphasis of section 6 is quantitative modelling of isolated VRE-based systems, which provides a more thorough illustration of the breadth of potential synergies. The section also provides case studies that serve as examples of how local distribution grid effects might be reduced.

Smart charging reduces EV-related demand spikes while also flattening the load curve to better incorporate VRE at the system level as well as locally during the near term. To be more precise, changing charging habits that now spend 90% to 99% of their time idle in parking spaces might help with: Peak shaving (system level/wholesale): flattening the peak demand and filling the demand "valley" by encouraging late morning/afternoon charging in systems with high solar penetration and night-time charging that could be adjusted in response to night-time wind production as cars are parked for longer than they need to fully charge. This would postpone early evening charging that may otherwise boost peak consumption.

DISCUSSION

Support for real-time grid balancing is provided by ancillary services system and local levels/transmission and distribution system operators, which modify the EV charging levels to keep the voltage and frequency constant. Despite the large number of demonstration projects that have been carried out and the intense regulatory discussions that have taken place in several countries, distribution system operators are generally not yet equipped with flexibility from distributed energy resources for operating their grids. Transmission system operators have developed flexibility at the system level well mainly in Europe and the US. Behind-the-meter optimization and "back-up power" (local level / consumers and prosumers): this entails raising self-consumption of locally produced renewable electricity as well as reducing reliance on the electricity grid and lowering the energy bill by purchasing inexpensive electricity from the grid during off-peak hours and using it to supply home during times when the electricity tariff is higher during evenings.

Putting aside their effect on the performance of the vehicle, EV batteries' capacity to provide certain grid services is crucial in this context. Depending on the application under consideration, the grid's service-providing capabilities and accompanying technology will vary. High depth of discharge tolerance, or the degree to which the battery may be depleted, is required, for instance, to balance renewable energy sources. If the battery is to be utilised to assist system-wide balancing or the absorption of extra renewable energy into the battery behind the metre, 300 complete cycles may be necessary per year. It is necessary to discharge at a lower depth for supplementary services. The optimal standby level of charge for batteries is around 50%, meaning that the chosen batteries should be able to function in lower states of charge. This is necessary because batteries must be able to inject power when frequency is too low and consume power (when frequency is too high)[6].

Lithium-ion (Li-ion) batteries are the most used EV battery technology today. Several mobile batteries are compared to stationary batteries to show that Li-ion can compete with other stationary storage technologies like lead acid and redox flow. For a variety of grid functions today, Li-ion technology continues to be the most developed. With V2G and battery switching, the battery deterioration caused by increasing the number of charge/discharge cycles has been a long-debated topic. The discharge current, depth of discharge, and operating temperature have the most effects on battery deterioration. Recent testing, however, have shown that battery deterioration using V2G is restricted if the battery maintains a level of charge between 60 and 80%. The effect is comparable to regular AC charging. When employing a V2G system, EV battery life may be increased by adopting profiles that are V2G friendly, according to the Warwick University deterioration battery model that forecasts capacity and power loss over time. This project's "smart grid" algorithms enable drivers to monitor how much energy may be drawn from the battery of the car without harming it or even extending its life[7].

A testament to the faith built up over many years in the industry is the fact that original equipment manufacturers (OEMs) with vehicle-to-everything (V2X) technology continue to honour their battery warranties for cars with rapid charging and/or V2X. This was validated by a year of rigorous testing at ENGIE Laborelec, which revealed that V2X had no discernible effect on battery ageing. Battery manufacturers nowadays, however, often refer to the worldwide market for their technology as either mobile or stationary, and some even name a particular application. It is difficult to determine without testing whether a technology is appropriate for a particular application. For instance, even though it is claimed that lithium-metal-polymer (LMP) chemistry is now primarily utilised for mobility, certain providers allow stationary applications, despite the fact that this appears illogical given the high operating temperature. As a result, in the future, there may be a difference in how battery technologies are used in mobile and utility-scale applications.

Consumers are encouraged to shift their charges from peak to off-peak hours via the most basic incentive time-of-use pricing model. It is technically simple to implement (smart metre built into the EV or EVSE), and it works rather well to postpone EV charging till off-peak times at low EV penetration levels (ICCT, 2017a). On the other hand, clearly defined rebound peaks in the total residential demand may be produced via simple time-varying power pricing structures. In order to supply near-real-time balancing and supplementary services at greater penetration levels, direct control mechanisms made possible by the EV and the charging station will be required. These techniques vary from simple turning on and off of the charging system for automobiles or EVSE (also known as V1G) to more complex bidirectional vehicle-to-everything communication (V2X).

Two particular settings are especially important for V2X:

A. Vehicle-to-home (V2H) and vehicle-to-building (V2B) interactions seldom have a direct impact on the efficiency of the grid. The EV is used to increase self-consumption of energy generated on-site to reduce demand charges or as a backup power source for homes during power outages.
B. The term "vehicle-to-grid" (V2G) designates the discharge manner of service delivery to the grid. During times of peak demand, the utility or transmission system operator might be willing to buy energy from consumers. They might also be willing to use the EV battery's capacity to provide ancillary services like balancing and frequency control, including primary frequency regulation and secondary reserve[8].

Another option is V2Tool or V2Load, which uses the EV battery to directly power a neighbouring load (without the need of a power network or system). what separates unidirectional V1G from bidirectional V2G Only by altering their rate of charging up and down in relation to the starting charging power can the driver, the host of the EV charging station, or the aggregator get rewards under the V1G. (3 kW is assumed for illustration). Electric vehicles (EVs) may use V2G to charge and discharge power to and from the grid, respectively. The size of the "bids" for grid services is in accordance with the needs of the specific market and the capabilities of the EV.

To provide a more effective response, these methods may be coupled. For instance, time-of-use tariffs may be used with V1G automation. V1G and V2G capabilities are available on some of the new charging stations. With the exception of Japan, where commercial V2H solutions have been offered since 2012 as backup options in case of an electrical blackout in the wake of the Fukushima disaster, V2X has not yet been deployed on the market, in contrast to more established V1G alternatives. Pre-commercial options are available in the US to sustain the grid in areas with shoddy electrical infrastructure. With a focus on local energy management, various pilot projects are being conducted around Europe, including in Denmark, Germany, the Netherlands (Amsterdam), and Spain (Malaga). As of the beginning of 2019, various automakers (such as Nissan, Mitsubishi, Toyota, BYD, and Renault) were actively engaging in V2X programmes[9], [10].

Time-of-use tariffs

With EVs, dedicated time-of-use charging has the greatest experience. It illustrates that the rate design is more successful the bigger the price disparity between the peak and the off-peak is. The peak and off-peak (or even "super off-peak") settings are in accordance with the features of the local electrical system. An illustration of prices from Pacific Gas & Electric (PG&E) in California, a state with low solar PV penetration, where the peak comes in the late morning owing to heavy air conditioning, might alter in the future as solar PV penetration rises.

CONCLUSION

Most of the time, drivers may use an app or the car's on-board technology to schedule charging during off-peak times. Consumers either have a dual metre or a single metre for house and EV charging. Dual metering, or metering that allows for the distinction between EV consumption and other usage (by having one metre for the EV plug and one for other use), has shown to have a more positive influence on consumers' charging habits. Basic command 100 homes are being tested by My Electric Avenue, Scottish and Southern Energy Power Distribution, and EA Technologies in the UK.

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CHAPTER 16

SMART CHARGING IN ISLAND SYSTEMS

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ABSTRACT:

Alternative methods are available on the market that can facilitate the implementation of EV-specific rates without adding the cost of secondary utility meters. The Minnesota Public Utilities Commission permitted Xcel Energy to undertake a pilot that aims to reduce the upfront cost burden for customers looking to opt into EV tariffs by implementing the tariff directly with an "embedded metering" in EVSE.As the penetration of both VRE and EVs increases further, appropriate market signals will be needed to incentivize loads including EVs to adjust their consumption patterns. V1G may be combined with dynamic pricing prices reflecting the real-time cost of energy and the grid at hourly or even smaller time intervals supported by automated solutions on the consumer side.

KEYWORDS:

Electricity, Mobile,Networks, Smart Charging, Wireless Charging.

INTRODUCTION

Although the majority of charging stations, for instance, in the Netherlands currently support V1G, it is still uncommon in other nations. According to Box 5, San Diego launched a test concept integrating VGI and dynamic pricing. The experience with V2X is mostly restricted to pre-commercial installations, similar to dynamic pricing. An example of V2G improvements is shown in Box 6. One country that stands out as an exception is Japan, where Nissan released a kit that is compatible with the LEAF and can provide backup power for a Japanese house utilising CHAdeMO technology, the sole global standard that supports V2X. A total of 7 000 units of such V2H systems based on the CHAdeMO protocol have been sold to date. This is because several systems makers and OEMs adopted the V2X protocol as it was standardised by CHAdeMO. Given that the typical Japanese household uses 12 kWh per day, the 40 kWh battery capacity of the LEAF might last for more than three days.

V2G is often considered to have more potential economic value than V2B or V2H in applications (Kempton, 2016). It may be utilised for peak shaving in addition to provide auxiliary services and backup power. The utility may not need to set up a peaking plant or add more peak capacity if EVs could be charged during off-peak hours and discharged selectively to "shave the peak." V2G is especially important for sluggish charging in places with a lot of EVs, such big parking lots. Flexibility from a single EV often has to be pooled to offer flexibility services. A minimum of 1 MW to 2 MW of capabilities would need to be transferred in each V2G transaction for the wholesale supply of EV services (peak shaving and ancillary services) to be economically feasible. This is about comparable to 500 EVs connected to a typical 3.7 kW European circuit. The number of regulated EVs would have to be considerably more numerous given that these EVs are not constantly accessible [1].

VGI with fast charging

While it is theoretically conceivable, fast charging, or charging at high power, typically has relatively little promise for VGI. There is no real flexibility available for quick charging times when fast charging is required, and peak demand at highway stations does not and will not correspond with traditional peak load. Installing charging stations in locations with little effect on local peak demand and congestion while attaining a high utilisation rate for profitability will be necessary to reduce the impact of rapid charging on the grid.

But, quick charging could take place at different times in certain particular apps. A driver of an electric bus, for instance, who has access to numerous bus stops for charging, may decide not to do so if the flexibility offers value and has no effect on the driver. The four-year EU project ASSURED, which began in 2017, will look at the flexibility associated with rapid charging of electric heavy-duty vehicles. Using several interoperable charging infrastructure designs that will be converted into business cases, taking into account both commercial and social costs and benefits, the project will test novel heavy-duty and medium-duty vehicle solutions. Combining rapid charging with stationary batteries and locally installed VRE is another method for achieving local optimization. The EV user is not anticipated to authorise considerable latitude in terms of time or power when fast charging is necessary; nonetheless, combining fast-charging.

EXAMPLES OF VEHICLE-TO-GRID PROJECTS

The "ELBE" initiative, which seeks to finance the construction of EV charging stations at buildings and on business premises, was introduced by the City of Hamburg in February 2019. The initiative makes use of load-dependent tariffs and V2G technology, with electric vehicles (EVs) being treated as a kind of regulated consumption. Nissan and Enel collaborated to put into place an energy management system that makes use of V2G charging devices and enables energy consumers and car owners to function as independent energy hubs that can draw, store, and feed power back to the grid. In order to test the solution, two pilot projects were started in the UK and Denmark (Parker Project). Via Enel's bidirectional chargers, Nissan EV customers made money during 2016 by delivering electricity to the grid, while the Danish and UK transmission system operators profited from main regulation grid services. Per car, the annual frequency response income was around EUR 1 400.

A V2G pilot project using the battery packs of more than 25 000 PHEV Outlanders was announced by Mitsubishi at the end of 2017 and would take place in the Netherlands. The EV smart charging solution supplier NewMotion, the grid operator TenneT, and the V2G technology and grid-balancing services provider Nuvve will all work together to accomplish the project. Mitsubishi's involvement will be to supply capacity reserves by connecting PHEV Outlanders to the grid, similar to how Nissan did it in Denmark[2].

In contrast to the other pilots, which concentrated on direct current (DC) V2G, Renault, Elaad, and Lombo Xnet tested AC V2G in Utrecht, the Netherlands. Other charging stations than CHAdeMO would be able to integrate V2G features according to the proposed standard ISO 15118 Ed2. Nevertheless, this would need cars with bidirectional power flow capabilities, as well as communication-capable charging stations, and both the charging stations and the vehicles would have to adhere to ISO 15118 Ed2. The experiment included the first bidirectional, solar-controlled AC charging station in history. For each owner of an EV, the provision of backup power generated financial advantages ranging from EUR 120 to EUR 750 yearly.

SMART CHARGING IN ISLAND SYSTEMS

For a number of reasons, island power systems have been pioneers in researching cutting-edge uses of distributed energy resources, such as VGI. With petroleum-derived fuels accounting for a significant portion of all primary energy usage and the inclusion of other conventional sources being constrained, islands are often heavily reliant on fossil fuels.

The response to power system shocks in island regions is typically "tighter"; that is, the loss of a few electricity supply units has a bigger impact than in interconnected systems, and the effects of voltage drops are more pronounced. However, each isolated system varies in terms of weather, population, and economic activity. As a consequence, it is more challenging to balance the grid, there is a greater chance of load shedding and blackouts, and more reserves are needed. So, introducing substantial shares of VRE on their own poses a risk to the stability of the system. In addition, many tourist islands currently run rental vehicle fleets that serve as distributed energy storage systems and are an appropriate use case for electrification just a small number of chargers are required around the island.

Many research has shown the synergies to exist:

- A 2030 EV scenario in Barbados with solar and wind power providing 64% of demand and more than 26 000 EVs in the system showed a five-times cheaper production cost with the most effective smart charging method compared to uncontrolled charging. Even though lower than the reference case without EVs, that is, while EVs are still partly charged with VRE, uncontrolled charging would still result in a greater amount of curtailment.
- Tenerife (Canary Islands, Spain) modelling revealed that the impact of 50 000 EVs would increase the share of renewable energy in the island's electricity mix up to 30%, decrease CO2 emissions by 27%, lower the overall cost of producing electricity by 6%, and decrease the internal market for oil by 16%.
- Modeling of So Miguel in the Azores archipelago (Portugal) revealed that EVs might aid in boosting the generation of renewable energy.
- Sams Island in Denmark would let EVs and other wheel-to-wheel zero-emission vehicles to generate up to 100% renewable energy.

By buffering, infrastructure with stationary energy storage may boost the station's adaptability to the grid. As a support for the usage of normally high-power charging stations, a solar canopy and stationary storage may be included in a charging infrastructure or even in the charging points themselves. Increasing self-consumption, avoiding expensive demand fees, and allowing greater charging peaks with less grid effect are all aided by this. For instance, joint projects in the US between the energy storage company Green Charge Networks and the charging station provider ChargePoint use on-site batteries and EV-charger scheduling to control and smooth out the grid demand of charging stations, assisting their hosts in avoiding exorbitant demand charges[3].

With the help of its Supercharger stations, which serve as a "grid buffer," Tesla is collaborating with utilities on grid energy storage. The automobiles may be immediately charged from a 0.5 megawatt-hour (MWh) battery pack located adjacent to the Supercharger station without the power system seeing the rise. To balance out the demand for power, Fastned in the Netherlands equips its fast chargers with a solar canopy and storage [4].

EV batteries need DC power, while AC power travels via the electrical distribution system. Hence, an AC/DC converter (or charger) is always required. This converter may be found in the car or at the charging station ("on-board charger"). The cost of the charging station (on-board is less expensive) and the cost of the vehicle must be considered when deciding between an off-board or on-board charger (off-board chargers reduce the weight and cost for the converter in the vehicle). If all else is equal, an on-board charger indicates that there are more sites accessible for charging since AC current (the kind of power coming from the socket) is also more readily available. The most popular EVSE power output levels and charging configurations, as well as the many communication protocols that may be used between the car and the charger.

- In the majority of situations, on-board chargers are used for low power (usually up to 22 kW), which includes Level 1 and Level 2 chargers in North America and "slow" or "regular" chargers in Europe. They make it possible for EVs to be charged using standard connections or inexpensive AC charging stations.
- The AC option was used for deploying the intermediate power range (from 22 kW to 50 kW), which was originally not utilised much (e.g., Renault up to 43 kW AC). Yet, a growing number of companies who provide charging solutions advocate DC charging (off-board charging) in this middle power range. The implementation of AC charging methods may be significantly impacted by this new trend. From the standpoint of car Makers, there is currently no agreement.
- Off-board chargers are often used for high power "rapid chargers," which typically start at 50 kW. The AC/DC converter is then installed at the charging point and shared amongst the cars, becoming larger, heavier, and more costly with increasing power. When charging at intermediate stops or end stops, heavy-duty vehicles, particularly urban buses, often employ pantographs at 150–300 kW.

Several electric vehicles can now charge at 50 kW. Tesla, for instance, has its own 140 kW charging infrastructure. As charging demands rise, ChargePoint's Express Plus is a modular, scalable DC fast-charging infrastructure that can produce 62.5 kW to 500 kW. Power capacities used to charge electric buses generally range from 22 kW to 300 kW. Electric buses and automobiles are charged at high rates using direct current (DC).

The three primary venues for charging are at home, at work, and in semi-public or open areas. The majority of the time, AC charging is used. At home, AC chargers are used and modest power is often enough (e.g., 3.7 kW on a 240 V circuit). Intermediate power AC or DC charging stations are placed if more power is necessary or if the goal of maximal self-consumption is adhered to (for example, using local solar PV generation) (7.4 kW to 11 kW). While DC high-power charging is often used for street charging, it is also frequently used for motorway charging (e.g., Belib in Paris)[5].

Smart charging infrastructure outlook

Cable charging will probably continue to be the most popular charging method for light-duty cars for years to come as battery ranges expand. Battery cycling and EVSE infrastructure advancements will be under additional strain as EVs gradually match the ICE cars' range in terms of driving distance. Yet, because to their high cost, high ranges will only be utilised sparingly, indicating sparse demands for ultra-fast charging even with the growth of autonomous cars and mobility-as-a-service (MaaS). Home and hub charging that is slow (up to an intermediate power range) will be the norm. Between 2030 and 2050, alternatives to conductive charging will emerge for buses, trucks, and light-duty vehicles driven by MaaS and autonomous driving. Constant static charging is expected to result in significant innovation, but with little to no effect on the flexibility of the grid.

Outlook for charging infrastructure moving towards more charging power Electric vehicles with 600 km of range might become ubiquitous by 2020, moving from the niche to the mainstream. An EV uses roughly 20 kWh of electricity per 100 miles (less for a small car at slow speed). A battery of around 200 kWh would be needed to achieve the next Tesla Roadster's stated 1000 km range. Battery capacity has greatly improved from the initial generation of electric automobiles in the early 2010s. Batteries in the 20 kWh range were first made available. In less than ten years, this capacity has at least quadrupled and the operating range has increased by up to five times. Luxurious vehicles with batteries of 80–100 kWh include the Jaguar I-PACE (available in 2018–2019), the Audi eTron (on sale in 2018), and the Porsche Mission E (planned for 2019). About 2020, even bigger batteries will be feasible, such as 120 kWh with the BMW iNext platform.

Theoretically, EVs should be able to go further than today's diesel vehicles by the years 2030 to 2050. The practical requirement for such ranges, however, as well as the associated increase in charging power, could still be rather small. Initially, EVs were mostly utilised in cities, with annual driving lengths of less than 10,000 km. Electric vehicles now go 15,000 km annually, or even more, than standard vehicles. Yet, the typical daily driving distance, for instance, in Europe is about 30–40 km, and 95% of yearly journeys are less than 110 km, indicating that the existing driving range is already enough.

Yet, as EVs with greater battery capacities are utilised more often for extra-urban travel and as daily mileage increases, the necessity for quick charging along roads will increase. Users may experience novel problems, such as long lines at the public charging infrastructure (which are already a concern in Norway). Even the anticipated 2018-2019 models will need far greater charging power than is typically utilised now (> 200 kW) in order to complete a rapid charge in 15-20 minutes. As can be seen in Box 9, the industry is making significant efforts to create ever more potent chargers[6].

If the driver wanted to charge a 200 kWh battery so rapidly, 600 kW of electricity would be required. Considering the chemistry of today, a battery may charge at 3C, taking 20 minutes to get from 0% to 100% assuming the power level is maintained. A 3C rate indicates that the battery will be completely discharged in 20 minutes. With improved battery chemistry, charging times of under 15 minutes for 80% of battery capacity may be feasible. Batteries may make advances, such as raising the C-rate in the next decades, which might potentially double the C-rate.

What "speed" of fast-charging stations will really be required, however, is still debatable. Seldom would most automobiles go more than 600 or 1000 kilometres per day. Also, if there are human drivers behind the wheel, they will take breaks. Even while autonomous vehicles with greater ranges increasingly employ EVs, it may not be necessary to go beyond that range. Even with MaaS, travelling 1,000 miles in a city would need 20 hours of driving time at an average speed of 50 km/h (a very high speed for an urban area). Even if they drive 16 hours per day, today's cabs that go 200 km per day are already regarded as having excessive mileage.

If so, despite anticipated battery evolutions, the trade-off between battery size (and accompanying weight and cost) will be crucial. Due to the proliferation of MaaS, the battery sizes may continue to be restricted based on their intended purpose, particularly in fleet management optimization. Overall, despite potential advancements in fast-charging power and battery chemistries, slow(er) charging at night will continue to be the most desirable for the grid and light-duty car owners. But, improvements in battery technology will reduce the price of common-use batteries and thus the price of EVs as well. Nevertheless, the actual patterns will vary for various kinds of transportation such passenger automobiles, freight, taxis, and buses. Last but not least, PHEVs and other sources like environmentally friendly hydrogen-fueled vehicles should also be taken into consideration as alternatives, not only for passenger cars but also in other applications like industrial and commercial trucks, buses, and taxis.

The investments made in the distribution system will be impacted by EV charging. The characteristics of the local distribution network, such as bottlenecks to EV deployment, the methodology of distribution grid sizing by each distribution system operator, the presence of solar PV connected at the low-voltage level, etc., will determine how much grid investment in terms of cables and transformers will be required in a given location. For instance, if smart charging is used in these areas, grid reinforcements may be cheaper than in areas with no electric heating. Smart charging might assist the integration of large shares of solar PV linked at a low voltage level, however EVs could put more burden on local grids in areas with no or very low shares of solar PV.

Impact of transport patterns on charging needs in different cities and regions

Varying city transportation patterns will affect charging requirements as well. These trends are mostly influenced by the interaction between population density and economic growth. Low-quality road infrastructure and traffic may limit a substantial adoption of shared mobility in growing, heavily populated regions. More and more people will live in cities that are conducive to two-wheelers as a result of the projected urban boom in Africa and Asia (and cities may also focus on those, as we already see with motorbike-sharing businesses in Asia). When infrastructure is in excellent condition and established, highly inhabited places, shared mobility may prosper.

DISCUSSION

Private ownership could yet continue to be the most relevant means of transportation in high-income areas with sparse populations. The topography of cities and discusses how the characteristics of each will influence future demand for transportation. It describes the billing patterns and requirements in three different sorts of big cities. These traits will also influence how MaaS and autonomous cars develop. Theoretically, as the EV market grows, public charging infrastructure should become more economically viable thanks to business models that include grid services, power or retail sales, and other sources of income like advertising. In order to target challenging market segments including curbside charging stations, multi-unit residences, and intercity fast charging, funding programmes will still be required in developing EV markets .

Initially, to jumpstart the market, developing economies with low penetration of EVs may need early incentives for charging. For instance, Costa Rica gave incentives in the form of a significant decrease in the import duties on EVs, but due to a lack of infrastructure, only fewer than 1000 EVs were sold. Second, housing and demographic variables will have the most impact on the financial feasibility of public charging and the consequent requirement for charging infrastructure incentives. One public charger for every five EVs is found in denser cities like Amsterdam, according to data analysis of charging in major EV markets across the globe, compared to one public charger for every 25 to 30 EVs in California (ICCT, 2017a). Public charging coverage will continue to be crucial and may need to be developed as a public service for some time in the future in some regions of Europe and some megacities in Asia where population densities are high and where most people might not live in buildings with garages and off-street parking. 40% of European drivers lack access to off-street charging stations.

The majority of drivers will still desire access to "their own" on-street charger, at least if private EV ownership prevails, even if that were the case. There are less expensive alternatives to installing brand-new full-fledged charging stations on the market, such as adapting the current street light system. In order to create these charging stations, the London city government and the German startup ubitricity have been working together. Unfortunately, the long local processes (permits, etc.) act as a barrier to these developments. An important portion of the power expenses at a fast-charging facility may be accounted for by the present grid pricing structure. Higher proportions of demand charge are often applied since greater voltage levels are needed for quick charging. Hence, simultaneous charging activities at fast-charging locations raise peak demand and raise the demand prices. Demand charges may account for more than 65% or even 90% of the expenses (RMI, 2016)[7].

Nevertheless, owing to the small number of cars on the market that will utilise these stations in the near future, DC fast-charging stations now exhibit a low load factor and intermittent instances of significant energy demand. Fast-charging site hosts may be subjected to large demand-based fees as a result of poor utilisation, making the supply of fast-charging solutions during the crucial early adoption period unprofitable. In order to fulfil the demands of the developing EV industry, the next generation of DC fast chargers with a 500 kW charging capacity are required. But, this problem will only become worse, particularly when transit buses and other medium- and heavy-duty vehicles also switch to electric propulsion.

By building energy storage on-site to regulate peak demand and offer extra network services, or by colocating stations at locations with high power demand, this problem may be solved locally. In the evening or at periods of surplus renewable energy production, energy may be charged during times of low demand or tariff and discharged at periods of high demand. Peak demand fees may remain constant even when the connection is used more often in terms of kWh.

In order to lower costs and the need for capacity upgrades, regulation in some countries/regions promotes the use of energy storage and local renewable energy sources, primarily solar PV, for fast-charging sites. One example of this is through power purchase agreements for renewable energy for charging providers in some US states. The added high capital costs of storage, however, may restrict this method's ability to reduce demand charges. Numerous American jurisdictions, like California and New York, have either introduced alternative rate design alternatives or are contemplating doing so: [8]

- To provide charging station operators with low utilisation more security, demand fee might be substituted by or combined with higher volumetric pricing. As the use of EVs increases, charging behaviour may alter over time, and this rate may be adjusted dependent on utilisation or load factor.
- A credit on a business customer's monthly bill each month equal to a portion of the nameplate demand associated with the installed charging infrastructure that supports their metered service.
- For commercial customers with dedicated EV charging stations, a retroactive and variable credit calculated as the difference between the effective blended per kWh distribution charge, including demand charges, and an established target blended rate, multiplied by the volumetric energy throughput in each billing cycle (e.g., Long Island Power Authority in New York).

With rising demands for charging power, lower grid fees resulting from higher voltage connection levels and the ability to charge electricity at fast charging stations at wholesale prices rather than end-consumer/retail prices charged at homes or offices may also become more relevant over time and may eventually drive down the cost of fast charging. Overall, regulation will need to strike the correct balance between allowing utilities to recoup expenses in a fair and responsible manner and encouraging locations to install and use DC fast chargers. The importance of incentives for multi-level home charging infrastructure cannot be overstated. Pre-cabling for EV charging equipment of a specific level may be included in any new construction to significantly reduce such obstacles since wiring of the building can account for up to 50% of the cost of installing charging stations.

Building code regulations allow nations and towns to impose a requirement that a certain proportion of newly constructed or modified parking spots be "EV ready." Cities may control where and how many EV charging stations can be erected in each region via zoning restrictions. This is a crucial lever that may affect the accessibility of charging infrastructure in the future, when the absence of multi-level workplace and residential charging might become a major adoption hurdle and could limit the electrification of transportation[9].

In several American locations, such regulations have already been put into effect. For instance, the 2015 California Green Building Standards Code, which has subsequently been expanded, mandates that 6% of all parking spots in commercial buildings have infrastructure for EVs. Every new building in Los Angeles must include a 240 V outlet and circuit capacity for Level 2 charging (ICCT, 2017a). According to a new regulation in Atlanta, new residential buildings must have electrical infrastructures that can support EVs and 20% of their charging places must be EV ready. In Ontario, Canada, all new non-residential buildings must have 20% of their parking spaces equipped with full circuit capacity to facilitate EV charging.

Many projects have been initiated to expand the number of charging stations in key cities around Europe (e.g., Amsterdam, London, Paris). In this regard, the EU offered bold suggestions. Although though they were ultimately significantly scaled down, the new EU-wide construction regulation mandates that at least one charge point be installed in every parking spot in non-residential buildings, as opposed to the 10% that was first suggested. Moreover, pre-cabling is required for residential buildings that have been newly constructed or remodelled and have more than 10 parking spots, in order to facilitate the future installation of EV charging stations in each parking place.

Alternatives to cable charging

A number of charging technology improvements with significant potential are currently developing and will be accessible in the future, in addition to the development of cable charging power. The development of static wireless charging has begun. This technology is being used in certain small-scale applications for vehicles and buses. It suffers from a lack of standardisation, greater costs, and a little poorer efficiency, nevertheless. It's also necessary to handle certain potential problems with electromagnetic compatibility and security. With traditional charging (by cable or pantographs), the maximum power of wireless charging is currently lower: 200 kW for buses (such as the Bombardier PRIMOVE) and 11 kW for automobiles (e.g., WiTricity).

Current battery technology for long-distance trucks and buses prevents long-distance travels without regular charging perhaps every 100–200 km for trucks and every 100–300 km for buses with technology available in 2017, which reduces the appeal of electrifying them. New charging techniques will also be necessary for autonomous cars. These factors have led to research on continuous charging and battery switching. Because to the uncertainties surrounding the long-term cost reduction and density rise of battery technology, it is difficult to estimate their emergence.

Continuous charging

Continuous charging that is both conductive and inductive has the potential to be appealing:

- Conductive power transmission is used in conductive charging. A charging board must be used as the power transmitter, and a charging device with an integrated receiver must be used as the power receiver.
- Electromagnetic induction, commonly known as inductive charging or wireless charging, transfers energy between two things.

Metal-to-metal interaction is required for conductive charging. The static ground-based system with conductive plates, for which Alstom is creating a product based on its tram expertise, may be used to do this. Using catenaries on certain tracks is an option that Siemens is trying with the "eHighway." By reducing the size of the battery, these technologies may enable more affordable, lighter, and heavy-duty vehicles with increased passenger or cargo capacity (such as buses) (trucks). Yet, they are still less developed than conventional pantographs that transmit electricity from overhead wires[10].

Also, they need additional money to convert the roads for catenaries, which is projected to cost EUR 1-2 million/km. Wireless continuous charging has also been attempted, for instance in Belgium and the Republic of Korea in a trial project involving buses and the Renault Kangoo. Mass-market uses for static wireless inductive charging may increase, starting with premium automobiles in the near future, around 2020. For instance, the 2018 BMW 530e should have a WiTricity system. Dynamic wireless charging on electrified roads might be used to continually draw electricity from the grid in real time, thereby increasing the amount of flexibility. More research is required to determine how wireless charging indefinitely affects flexibility. Automated charging makes autonomous cars more practical, and among those technologies, static wireless charging is the most developed. If so, the primary factors to take into account while evaluating the grid effect will be the autonomous car driving range and the available charging time.

The ongoing standardisation efforts in this area include:

- International standard IEC 61851-23-1: Electric vehicle conductive charging system – Part 23-1: DC Charging with an automatic connection system: this norm will cover the implementation of pantograph charging for electric buses.
- International standard IEC 61980 series a work in progress, covering the wireless charging topics.
- Charging standards for electric buses as discussed in, for example, the EU project ASSURED.

CONCLUSION

In order to avoid having to wait at the station for the EV to charge, battery swapping entails replacing an EV's exhausted battery with a charged one. The pay-as-you-go or leasing/renting/subscription business model is based on the utilisation of battery-swapping stations or EV batteries. In order to reduce the cost of purchasing the automobile, the battery may either be purchased separately or the owner can keep ownership of the battery. Individuals or fleets might use this strategy (e.g., public transport). Better Place, an Israeli startup with a business plan for automobiles directly influenced by mobile phone schemes (subscription or pay-as-you-go scheme (per kilometre)), pioneered battery switching for passenger vehicles. Consumers wouldn't own the battery; instead, the business would only promise a certain minimum capacity for each battery it offers. Only Nissan and Renault adopted the Better Place paradigm, and both companies received lukewarm consumer response despite having an integrated battery and a battery switching system. Yet, it seems that this design is returning for fleets and two-wheelers.

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CHAPTER 17

BIG DATA AND ARTIFICIAL INTELLIGENCE

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ABSTRACT:

Battery swapping is better suited for captive fleets that return on a regular basis to the same place where the empty batteries can be replaced by full batteries, and that are composed of a small number of different vehicle and battery models. Pros and cons of battery swapping are presented. Because of technology development, in the future charging providers could operate battery swapping stations or wireless charging roads. Battery swapping may proliferate together with fleet development and automation. Reducing a car (taxi, e-rickshaw) or bus' downtime with a swapping station and reducing the total cost of ownership (if the battery is separate from the car/fleet ownership) may help with accessibility and productivity in common models are leasing, renting or pay- as-you-go. Battery swapping for trucks (small delivery as well as long haul) also may be developed in emerging markets: the Indian truck maker Ashok Leyland announced a partnership with the transport solution start-up SUN Mobility for the development of interchangeable battery stations powered by renewable energy.

KEYWORDS:

Charging, Electricity, Mobile,Networks Wireless Charging.

INTRODUCTION

No of the battery size, recharging takes very little time. The grid may be balanced using the batteries that are kept in the exchange hubs. No universal batteries: complex logistics for automobiles. High capital expenditure: battery swap network must be established immediately. Vehicles still need conductive charging "just in case"; this adds complexity and increases the number of components used. There are currently battery-swapping stations for buses, mostly in China and the Republic of Korea, as well as for two-wheelers, notably the successful start-up Gogra.

Such ideas for the Model S were previously made public by Tesla, with the driver owning the battery and the switching station not functioning as a storage station. The durability of battery packs and the standardisation of batteries, which would enable the station to offer batteries for diverse car types with automated battery switching, continue to be significant entry obstacles for this business. It may only be successful when provided to captive fleets as a full solution (vehicles + exchanging stations). Another possibility is the operation of wireless charging roads, if the potential of dynamic EV charging technology materialises, or even of smart motorways, if systems like flexible security rail and smart signals allow the number of lanes in each direction to be adjusted in accordance with traffic needs[1].

There may be a significant difference between the expectations of mass market consumers and those of technology aficionados. The former are the leaders who are open to trying new things and who want to individually contribute to a sustainable society, even if they have to pay more for it, while the later choose comfortable and inexpensive solutions. By enabling smart charging, digitalization will ultimately assist to close this gap and break down barriers between power and energy systems. Despite the limited number of sales to yet, customer acceptance of EVs has been steadily rising thanks to their expanding variety. Although though several studies have indicated that a current, reasonably priced EV could already today meet the energy needs of 87% of vehicle-days, this has been a problem for a very long time. The acceptability of this technology, especially among millennials, is far from certain, despite some studies suggesting that first-time drivers may be more interested in purchasing an EV. Yet, millennials' propensity for shared services and preference for access over ownership are anticipated to spur the uptake of mobility-as-a-service (MaaS) and create synergies with electric driving.

The theoretical availability of flexibility must be adjusted to individual drivers' preferences even when significant EV adoption is achieved. A priority will always be given to transport services. In order to fully use flexibility, the user must be motivated to plug in as much as possible. Afterwards, it will be up to individual consumers using smart charging to guarantee that they always have access to a fully charged car for commuting. Moreover, charging behaviours won't be uniform, for instance in terms of price sensitivity. There may be differences in current travel patterns, parking availability, attitudes about refuelling, and views of various EV charging choices. Dynamic pricing must be thorough and provide appropriate incentives for client engagement[2].

Thus, it is necessary to keep an eye on variables like charging speed, EV battery health, possible shortening of battery lifespan, and others. While choosing the EV business model, these should be considered. As an instance, offering operation services would need the battery acting "on call," while offering sTable profits just for being accessible. On the other hand, frequent charging and discharging is required for power price arbitrage, which significantly shortens battery life.

Big data and artificial intelligence

Using digital technologies may aid in increasing consumer acceptance of EVs, navigating the complexities of the market, and connecting with the grid to raise renewable energy contribution percentages. There are certain products on the market that do just that. For instance, the WallBox home charging solution is a smart charging system that manages recharging using intuitive sensing technology and charges EVs automatically when energy prices are the lowest.

To better meet the demands of EV consumers, even artificial intelligence (AI) algorithms may be used. As an example, the cloud computing platform Azure from Microsoft analyses sensor data to identify trends, then uses artificial intelligence (AI) to decide whether to remotely monitor or perform maintenance on various assets. Microsoft and EnBW AG have partnered to create smart street lights in Germany that can track pollutants and charge electric vehicles. Also, Microsoft will introduce the subsequent generation of EV fast-charging technologies in partnership with ABB Ltd.

The Innovation Centre for Mobility and Societal Transformation and Schneider Electric worked together to build a micro-smart grid with AI and machine learning capabilities that actively optimise EV charging at the EUREF site in Berlin. Based on dynamic pricing, it manages charging demand to align with network capacity and delivers energy excess back to the grid[3]. New business models will also be made possible by digitization. The described "charging provider" model will go further in the direction of a "as-a-service" approach. New capabilities like remote repair and administration of charging stations will be made possible by advancements in information and communications technology (ICT), including data management and analyses of charging trends. There are existing services that allow for smart charging and efficiency optimization across several charging outlets.

For instance, the SMATCH B2B solution by ENGIE, seen in Figure 20, enables the user to specify their charging requirements and optimise the usage of the charging station, maximising the use of local renewable energy production and decreasing peak shaving. SMATCH enables a 30% reduction in electrical infrastructure since it lowers the overall power needed for charging.

Lastly, digitalization will be crucial to the planning and execution phases of grid service and transportation service optimization. To match mobility demand with power supply patterns, to be as compatible as feasible, and to pinpoint the best sites for charging stations, digital technologies and data analytics will be used. An analysis of Boston transportation data on the ideal position for charging stations revealed that, without expanding the number of charging stations, a potential energy savings of 20–30% for reaching the nearest station is attainable.

Big data-derived transport analytics may enhance the calculation of grid load, electricity cost, and V2G in addition to locating the optimum EV charging locations. While generic load curves may not show differences in parking loads for lots that are near to one another but have highly distinct profiles, time-of-day information is essential for V2G.

Blockchain technology

Similarly, the development of new technologies, such as blockchain, might significantly simplify the payment and invoicing for EV services as well as the offer of flexibility by EVs to the grid. Distributed ledgers that are secure called blockchains allow for transactions. They function as distributed databases with an ever-expanding set of data records, or "blocks," that are stored in them. Computers controlled by the network's users, or so-called nodes, verify transactions. Consequently, there is no requirement for a third party to confirm that a transaction was completed successfully. In addition to being decentralised, their main benefit is the ability to conduct safe and affordable transactions, especially for charging.

In November 2017, seven companies, mostly utilities from five different nations, introduced the Oslo2Rome experience: blockchain-based Share Charge App from MotionWerk for EV cross-border travel in Europe. German-based Share Charge has 1 200 public and private stations with this approach installed. In order to allow service providers to access the product and include it in their toolkit, it is transitioning from a business-to-customer (B2C) to a business-to-business (B2B) and a larger public charging network solution[4].

This technology may also be used to customer-to-customer (C2C) charging systems, which include renting out a private charger to another person while it is not in use. Home charging is currently done with simple plugs that, unlike public charging, are not equipped with a software back-end that verifies the identity of the user, establishes a connection, and grants permission to charge. This would require hardware for home plugs with a functionality to connect to the blockchain (a current pilot between MotionWerk and WallBee).

Blockchain-based solutions may disrupt or at least have an impact on the platform-as-a-service (PaaS) paradigm for billing and roaming. By connecting various parties and facilitating financial transactions between aggregators and customers through a form of open-source standards, blockchain could facilitate smart charging and V2G (real-world transactions take longer and charge higher fees). This would replace the proprietary solutions currently being developed. IBM, TenneT, and Vanderbron are investigating the use of blockchain technology in smart charging to deliver grid services in the Netherlands.

DISCUSSION

Widespread EV adoption necessitates the development of new business models for EVSE (electric vehicle supply equipment). An overview of the current strategic stance of the various e-mobility players is provided in this part, with an emphasis on the infrastructure. In this developing industry, there are several established and up-and-coming players from the energy and transportation industries. New independent providers include e-car sharing service providers (like Zen Car and BlueIndy by Bolloré), dedicated charging station developers, operators, data managers, e-roaming platform providers, as well as providers and aggregators of advanced grid services, in addition to Tesla, with its vision of an integrated mobility company igniting change in the sector.

Automakers are searching for new avenues to enter the e-mobility sector and are increasing customer confidence in the product by concentrating on lowering range anxiety. As they evaluate a move towards charging infrastructure development and operation as well as the provision of new smart energy services, energy utilities are searching for alternatives to selling "kilowatt hours-only" in addition to finding ways to provide charging stations with power. Even energy firms in the oil and gas industry are getting ready for a move to sustainable transportation[5].

Partnerships between these entities that span the whole value chain are becoming more common in this sector. They search for workable business models that capture and provide value to the client throughout the whole value chain. The key categories of business models and illustrations of market participants functioning in each area. Sales of EVs together with transportation and charging services are the most advanced business concepts. The logos that businesses give. This does not imply that IRENA is endorsing or recommending any particular service or product. Smart energy services, EV flexibility aggregation, battery swapping, and the utilisation of second-life batteries are some of the business models being explored for the EV-grid nexus but have not yet reached full commercialization or broad use.

Smart energy services provider and aggregator

With higher loads and dispersed generation, the business concept of managing and controlling several resources together by grouping them and selling their energy or capacity in the wholesale or ancillary services markets has matured. The market has not yet completely commercialised the collection of EV batteries or the provision of services that EVs can provide. Yet, there is growing interest in this paradigm. Investments in energy management and aggregation services are being made not just by utilities but also by many major automakers and charging service providers. To offer grid balancing and energy management services, for instance, the JuiceNet platform from eMotorWerks, which Enernoc, a subsidiary of Enel, bought, may aggregate dispersed storage facilities, including but not limited to EV batteries. The economics of EV flexibility and its ability to compete with other sources of flexibility at the system level, however, continue to be major problems:

- First, if the system is flexible enough, price spreads may be reduced (for example, by midday solar PV output) and may not increase again (low price spreads are anticipated in the German and Spanish day-ahead markets, while significant ones are anticipated in the UK market).
- Second, in certain areas, profits from auxiliary services could not provide enough flexibility. Studies from different markets may indicate substantially lower values, as

opposed to the high estimates from pilot programmes described in section 3. Using Germany as an example, the computation was based on a market volume of primary and secondary control of EUR 265 million for 2015, assuming 10 million EVs with 90% availability, or € 29 per EV year. Interestingly, the current demand for these services is just 660 MW, and these 10 million EVs would represent a volume of around 30.000 MW, which would result in much cheaper rates.

- Lastly, EVs will face competition from alternative decentralised flexibility options including demand-response resources and the old EV batteries. The cost of used EV batteries will be low, and manufacturers are already using them.

Locally, the EV argument could be stronger, which might minimise the need for low- and medium-voltage grid expansion initiatives. For EV users and service providers, this prospective business case would need to be monetized. This is not the case at the moment, since there are no local flexibility markets to reduce grid congestion, as was previously suggested. Various parties are testing various business models because they believe their expertise in various EV-grid nexus niches will work well together. A charging station manager might handle unidirectional V1G. This might be done remotely using a software-as-a-service (SaaS) architecture, which could control several loads and charging stations on a site. Instead, it may be done locally as part of the infrastructure for charging (e.g., local EV-PV synchronisation)[6].

An aggregator is needed for the functioning of V2G and second-life batteries. The initial "niche" supplier and aggregator model for energy services will evolve into a platform provider of energy services, merging various VGI income streams with other energy goods and services. Instead of concentrating on a single application, as is the case now, smart energy services and home and building energy management (smart charging, V2X, and V2G) will be regularly combined as part of a bigger portfolio of aggregated distributed energy resources and second-hand batteries. An international pilot project that uses EV batteries to deliver secondary control reserve to TennET, the transmission system operator in the Netherlands, has been launched by Next Kraftwerke, the operator of the virtual power plant, and Jedlix, the aggregator of electric vehicles (EV) and a provider of a smart charging platform.

The Jedlix platform can coordinate user charging preferences and create a live link with the EV by connecting the EV, ensuring that they are charged effectively. Each EV may provide either positive or negative control reserves, depending on the charging choice. For a continual projection of the capacity, Jedlix will be able to integrate customer preferences, vehicle data, and charging station information. Then, Next Kraftwerke uses this in TenneT's grid service procurement bidding procedure. The present VGI is mostly centred on the supply of charge management software to utilities and fleets, sometimes run by OEMs, by creators of proprietary solutions like AutoGrid or Nuvve. The paradigm of the supplier of energy services platforms is no longer B2B but instead incorporates software and offers a range of B2C services. This newly developed business approach is shown from the utility and OEM viewpoints, respectively, in the case studies of Nissan and Enel.

Yet platforms for energy services might also be incorporated into other platforms and by other players from different subsectors. For instance, smart building "as-a-service" integrating energy management is gaining steam, and although if it isn't the present emphasis, gathering data from users, aggregation, and VGI back to the grid might be the next step. Electronics industry juggernauts Schneider Electric, Siemens, and Panasonic presently rule this market. Siemens is doing research on integrating EVs into the building's energy management system using its building automation system Desigo.

FUTURE ENERGY SERVICES PLATFORM PROVIDERS: ENEL AND NISSAN STRATEGIES

Enel has invested in the development of an accessible DC V2X home charging station that charges and discharges at 10 kW in addition to building up the necessary infrastructure and bundling offers for both home and public charging. Enel has taken part in a number of pilot projects, such as the one with Nissan in the UK where they served as the aggregator, the software provider for charging at the charging point, and the power supply at the charging station.

In this pilot, EV clients were compensated by having their electricity bills reduced in exchange for the provision of grid services, and as a result of the smart energy service, they were able to locally optimise their energy use by using more of their own locally generated solar energy and paying less for network fees. Enel included the acquired V2G power into its wider portfolio of aggregated auxiliary services, acting as a "buffer" for any schedule irregularities in individual vehicles without having direct control over them. Operators of transmission and distribution systems pay Enel, which then splits the profit with the customer.

Enel has bought the JuiceNet platform from eMotorWerks via a subsidiary called Enernoc, which will enhance the business's capacity to provide smart energy services like EV-PV storage. It can plan EV charging for times when household solar rooftop systems are producing the greatest power. Moreover, by aggregating charging and discharging operations via JuiceNet, EVs, V2G charging stations, and other storage facilities may be utilised to react to network signals and balance power flows in the grid as required[7].

Nissan, a car manufacturer, also sees aggregated flexibility valuation as a potential new source of income. Nissan introduced a new solar generating and energy storage system for residential usage in the UK in January 2018. The manufacturer claims that their solution would enable homes in the UK to enhance the rate of self-consumption from on-site PV and reduce energy costs by up to 66%. Solar panels are now installed in over 880.000 UK households, and the industry is expanding. This new item is an expansion of xStorage Home, which Nissan and Eaton created together using used EV batteries[8]. In October 2017, Nissan announced a cooperation with OVO Energy to provide a new product. The agreement will enable the development of an OVO SolarStore and a V2G offering for private consumers purchasing the most recent Nissan LEAF (OVO Energy, 2017)[9], [10].

CONCLUSION

Reconditioning and reusing spent EV batteries in stationary applications is an alternative to recycling them. This is known as "second-life storage applications." Solutions for used batteries could potentially provide energy storage capabilities. As an EV battery's capacity drops to 70–80%, it needs to be changed since it can no longer be utilised as an energy storage system but is still suitable for everyday driving. This provides a battery lifespan extension of up to 10 years at a price that is attractive even now; it is estimated to be approximately EUR 150 (USD 180) per kWh. It may be utilised for grid-to-battery (G2B) pre-charging during low price times and battery-to-grid (B2G) discharge during high price periods, depending on the application.

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CHAPTER 18

MARKET DESIGN AND REGULATION FOR VEHICLE-GRID INTEGRATION

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ABSTRACT:

Renault Zoe can provide the same power as two Tesla Powerwalls, and at a much lower price.Pros and cons of using second-life batteries for stationary storage are summarised in Table 14.In addition to pilot projects, a number of OEMs have started exploiting the re-sale of recycled batteries. Offering stationary storage allows auto companies with large battery manufacturing capacity to reduce exposure to fluctuating EV sales, reduce inventory, and increase manufacturing utilisation rates and monetise the battery after the initial use. Several products for residential customers (smart home optimisation) based on second-life batteries are already commercially available, while more advanced applications are in demonstration phases.

KEYWORDS:

Charging, Electricity, Mobile,Networks, Vehicle, Wireless Charging.

INTRODUCTION

After serving the primary function of an EV, the battery may be further capitalised on. Cost savings while producing fresh battery cells. Delaying the possibly wasteful recycling of a battery with 70% of its original capacity would also delay any associated legal obligations. When a battery ages and becomes worn out, its performance and remaining cycle life decrease. EV batteries that have been in use for ten years or more may be technologically out of date and would be better suited for recycling than for second-life usage.

Similar uses for battery switching stations are possible across a wide variety of applications. Studies show that while the multiple battery swapping requirements of EV fleets like taxis, which would swap batteries several times per day, will significantly affect the charging behaviours of battery swapping stations, growing EV fleets and battery swapping stations could limit load fluctuation and peak-valley load difference[1].

As technological prices drastically decline, the obstacles to EV adoption are gradually being removed. Deploying and expanding EV charging infrastructure, however, will continue to be crucial for the EV revolution as well as for maximising the synergies with VRE-based power systems. Smart energy service providers and aggregators will need to be able to stack value to include EVs in their demand-response programmes in order to transition new VGI business models from pilots to full implementation, which may be particularly important for fleet management.

Market design and regulation for vehicle-grid integration

Without the proper incentives in the form of dynamic pricing signals, smart charging will not "simply happen," and V2G will not take off without the ability to "stack income" from various revenue sources, allowing for flexibility at both the system and local levels. Without properly functioning electrical markets, this will not be possible. Even in the developing e-mobility industry, there are not necessarily competitive wholesale and retail marketplaces. In certain nations, competitive auxiliary services markets and retail markets are often absent when wholesale energy markets exist. As a result, these services are nonetheless regulated and are still carried out centrally by a transmission system operator.

Even in existing markets, their design and regulation must be developed to create incentives for the value of EV grid services, including:

- Modification of market thresholds and access criteria for various wholesale segments: Even in markets that expressly permit aggregation access, key grid services still have minimum capacity and availability standards that are intended for large-scale power plants.
- Avoiding duplicate charging of storage for the grid, which penalises V2G and second-life batteries: EU lawmakers have already identified payment for injection to the grid as a barrier, and the so-called Clean Energy Package (CEP) intends to do away with it.
- To take into consideration EVs, an outdated legislation that forbids the selling of power from the grid without a provider has to be changed.

Local grid operators are often restricted from managing grid congestion at the distribution level in any manner other than by tightening copperplate. Even though it hasn't been implemented globally yet, investment in smart grids and smart metres will be crucial. To assign a monetary value to smart charging's assistance to distribution grid optimization and the elimination of distribution bottlenecks, local flexibility markets must be developed. This is presently not the case in almost any market, with the possible exception of specialist applications (but the CEP also proposes addressing that). Distribution system operators want incentives to exploit EV chargers as distributed energy resources rather than expanding the capacity of existing lines and transformers[2].

At some point, EV users could be able to provide flexibility to both the wholesale and balancing markets and at the distribution level. It would be made possible by local price signals and geographic information in bids. The power capacity of EV batteries is limited, therefore a single EV cannot offer these services for the length of time required by the power system. But, EV batteries can provide the quick reaction needed for certain auxiliary services. Yet, EVs may complement one another when they are combined, creating a virtual power plant with a quick reaction and the capacity to supply services for the required amount of time.

Dynamic pricing plans that incentivise smart charging and synergies with VRE

Prices are not always permitted to change at the retail level in accordance with the system's supply and demand. In nations that restrict power costs, often keeping them below market value, this is both a technical and politically difficult problem. Even if that is not the case, "fixed" rates are often more preferred since customers can easily grasp them in liberalised retail marketplaces. With flat costs, however, there is absolutely no incentive for smart charging.

Prices and rate structures that encourage smart charging are an excellent idea that have already been adopted in a number of nations. In essence, these proposals treat electric vehicles as a different load category. High-peak and off-peak prices often vary more than those provided by conventional time-of-use tariffs. In order to avoid contributing to peak demand, EVs must be charged during off-peak hours. Several utilities, mostly in the US, have introduced EV home charging tariffs, providing charging rates that are up to 95% less expensive at night than they are during the day [3]. To capitalise on the fact that 28–40% of EV owners also have residential solar, compared to roughly 1% solar penetration among the general population, several utilities and merchants have now begun selling "green EV charging" programmes. For instance, Great River Energy, located in Minnesota, charges its member customers nothing more beyond ordinary and off-peak rates to power their electric vehicles with 100% wind energy. EV owners in the UK can get 100% renewable power from OVO Energy for both their house and their car. With a planned reform for 2020, the British regulatory body Ofgem has also started a discussion about altering regulated network rates for homes and smaller companies that wish to use a lot more energy during peak hours.

Presently, relatively few automobiles support V2G, and very few charging stations both private and public are smart grid equipped. The need for standardised charging infrastructure and interoperable solutions between charging stations, distribution networks, and the EVs themselves will grow as the prevalence of EVs rises. In addition to protecting against vendor lock-in for charging infrastructure, interoperability is essential to enabling cost-effective connection of EVs with a variety of charging infrastructure and metering. For these reasons, standardisation is essential to easing EV uptake, the interaction of EVs with the electrical grid, and the infrastructure for EV charging.

The International Electrotechnical Commission (IEC) and the International Organization for Standardization (ISO) together established a number of regulations that were later adapted into supranational and national versions. summarises the key international standards and the areas in which they are applicable to electric vehicles. For light electric cars, the IEC 61851-3 series, which was released, focuses on the specifications for AC and DC conductive power supply systems, battery swap systems, and communications. The IEC, ISO, and their regional representatives' work is ongoing. New rules are being prepared, and the current requirements are modified often to reflect the development of electric transportation. In addition to the official standards, a number of protocols are being established by private parties that want to create industry standards via collaborations. Although while several industry standards could coexist, this often makes it easier to achieve standardisation more quickly. This is especially true for interactions among the many actors at a charging station.

The following features need to be present on charging stations in order to enable unidirectional smart charging (V1G): A charging system that permits varying charging current and a certain degree of control, ranging from programmable relays (local open-loop control) to charging points with current modulation capabilities, including basic charging points with Open Charge Point Protocol (OCPP) communication (charging stations to get signal on grid capacity) and remote start/stop. The installation of OCPP, which governs the exchange between the charging station and the charging station operator, could assist overcome the fact that many of today's charging stations are unable to alter the charging current. Moreover, communication between the EV user and the smart charging operator, as well as between certain energy metres and an aggregator, may be feasible. The position of OCPP and the other most significant protocols in the communication chain, including Open Clearing House Protocol (OCHP), Open InterCharge Protocol (OICP), Open Charge Point

Interface (OCPI), Online Certificate Status Protocol (OSCP), and Open Automated Demand Response (OpenADR). They are combining with a number of established rules [4].

- **Energy measurement systems:**Smart metres, current clamp metres, and other metres with autonomous reading and data transmission features.
- **For closed-loop energy management:**Communication between a charging point and an energy management system - local solution using a standard (e.g., Zigbee, Modbus, Bluetooth) or dedicated protocol, or distant solution (e.g., OCPP) for control by the charging stations platform.
- **User interface:**For the EV user and/or the site manager, a local screen on the charging station or a remote online or mobile application.

Standardization will also help V2G and V2X technologies, whose interface costs are now three to five times greater than those of unidirectional smart charging. Such more intricate types of smart charging need:

- **Bidirectional charging stations:**Currently, only a small amount of (dis-)charging infrastructure is offered commercially (e.g., Nichicon, IKS, Magnum Cap).
- **Cars that can discharge (not only charge):**The majority of V2X projects use an off-board solution (an AC/DC converter housed in the (dis-)charging station). This is because the Japanese CHAdeMO Association produced the first bidirectional (charging/discharging) communication protocol as an addition to its DC charging standard, which is used by companies like Nissan and Mitsubishi. The IEC/ISO 15118 Ed2 for on-board discharging solutions is the subject of worldwide standardisation activity (expected finalisation by 2019). IEC 61851-23/24 Ed2, which is based on the V2H guideline in Japan, also includes the off-board solution developed by the CHAdeMO Association (EV conductive charging systems). Renault and BYD have either already developed or planned on-board discharge. As a result, V2X may be utilised in more places as AC charging outlets, which are more accessible and less expensive, could also be used for discharging. To comply with the IEC/ISO 15118 standard, this would, however, need certain technical changes to charging systems. Moreover, it would necessitate that EVs carry extra components, which would increase the cost and weight of the vehicle.
- **A standardised way to know the state of charge of the vehicle:**Since this is now unavailable, smart charging and V2X are more difficult to use. There are workarounds available, such utilising a proprietary app from a car provider, however doing so necessitates the implementation of an ad hoc smart charging software adapter.
- **IEC 63110:**This international standard specifies a protocol for the administration of EV charging and discharging infrastructure, and it is currently under development. It is a series of standards for electric industrial trucks and electric road vehicles that attempts to harmonise other international standards and normalise the OCPP communication standard (e.g., CCS, CHAdeMO).
- **IEC 61850:**It is developing the communication standards for electrical substations and intelligent devices. Vehicles have not yet been equipped with it. A proposed upgrade to the standard will allow for more uniform smart charging and V2X.

DISCUSSION

For this technology to proliferate outside of the most established European and American markets, where the majority of new charging stations are currently being bought with this technology, international approval of these standards will be crucial. As an example, the Living Lab Smart Charging partners in the Netherlands (325 municipalities, Allego, ChargePoint, EVBox, etc.) decided to only build smart charging-ready stations at new public stations. Older stations are gradually being smartened up. Semipublic charging stations with smart charging capabilities numbered 7,500 as of November 2017, and bids were being accepted for a further 7,000 such stations. Smart Charging at the Living Lab, 2017. This is often not the situation in other markets[5].

Implementation of international EV standards or national requirements based on international standards will be necessary in other countries of the globe (such as India). This section gives a general summary of the electric vehicle industry, its development, and the transportation patterns that have an impact on how well EVs integrate renewable energy sources. Any automobile that can be recharged using outside electrical sources is considered a plug-in electric vehicle (EV):

- The single source of power for a battery-electric vehicle (BEV) is the grid.
- The plug-in hybrid (PHEV) motor combines an internal combustion engine with a rechargeable battery.
- The range extender (REEV) is initially an electric vehicle; but, in the absence of a charging infrastructure, the battery may be charged and the driving range can be increased using a tiny combustion engine. PHEVs and REEVs are sometimes included together as one category.

Up until this point, the fall in battery pack prices has been the most important aspect that has contributed to a significant cost reduction for EVs in the previous several years. The average cost of battery packs has dropped from USD 1000/kWh in 2010 to around USD 200/kWh in 2017. This is due to advancements in battery technology (UCS, 2017). According to analysts, prices will continue to fall until they reach USD 100/kWh in 2025 (McKinsey, 2014), making EVs competitive with ICE cars. As a general rule, battery pricing of around EUR 175/kWh will result in total cost of ownership parity between EVs and traditional gasoline cars.

The growing range of models on the market is another noteworthy aspect that has contributed to EV price reductions over time. Early EV purchasers in 2010 had just a small number of alternatives to pick from, including the Nissan LEAF and the Citroen C-Zero, but today's model selection is much wider, giving consumers more options in terms of price, driving range, powertrain, battery pack, and consumption. The market has become more competitive and EV costs have decreased as more models are added to the selection. For customers to not see EVs as inferior to or equivalent to ICE cars, EVs will need to attain near parity on a first-cost basis with ICE vehicles and to provide enough amenities like driving range and convenient recharging.

Total cost of ownership comparison

Total cost of ownership (TCO) measures all expenses a vehicle owner incurs throughout the course of ownership. It covers the price of buying the car, the price of using it, and the price at which it may be sold again. Taxes and purchasing incentives unique to the research area are taken into account each time a TCO analysis is conducted. Based primarily on their yearly fuel usage, economic comparison shows that both gasoline and diesel are now more cost-effective than EVs for the majority of customers. As demonstrated in Annex 4, the decision between an EV and a diesel car may be changed by the effective deployment of financial incentives, such as tax reliefs, in an area. By 2030, EVs will probably have a TCO that is equal to that of both fuels, depending in part on oil prices. In the years to come, it is anticipated that the TCO of EVs would significantly reduce. The location, yearly mileage, and vehicle usage will all affect how quickly TCO parity is reached.

The primary driver will be a further decline in the capital expenditure (CAPEX) of batteries. Battery prices are reducing quickly while all other EV expenses remain practically flat. The average battery cost is USD 275/kWh in 2016. The most optimistic projections see it falling to USD 100/kWh in 2025 and USD 60/kWh in 2030. Up to 2050, the TCO of diesel and EVs may change. The graph, however illustrative, intends to emphasise that even without subsidies and taxes, EVs will ultimately be more affordable than diesel cars in the medium term the second half of the 2020s. If so, EV fleet penetration might be as high as 7% globally.

The same patterns mentioned previously continue to support the ongoing decline in TCO, and two more findings might add to this picture. On the one hand, there will be a transition from privately owned automobiles to shared vehicles due of new mobility business models focused on car-sharing practises that are anticipated by 2050. This will unavoidably boost the EV's utilisation rate to between 40 000 and 55 000 km per year, which will enhance the fuel savings of the EV in contrast to a diesel vehicle travelling the same annual miles. On the other hand, how rapidly the TCO of EVs will decrease relative to diesel cars is an unknown variable. The current and incoming wave of nations that have banned the sale of fossil fuel vehicles by as soon as 2025 in the Netherlands or by 2030 to 2040 in France and the UK may have an impact on this topic. Annex 4 contains a case study of the 2030 TCO projection for EVs and diesel passenger vehicles, which are most prevalent in Europe.

Evolution of vehicle-related policies

Local factors will determine how policy incentives for EVs change. Direct financial incentives could become less significant as EVs are priced similarly to ICE cars. The requirement for subsidies will decline by the time EVs reach cost-competitiveness in many countries between 2025 and 2029, even without subsidies and before accounting for fuel savings (BNEF, 2017a). Another explanation for the elimination of incentives might be because governments have completed their intended goals, making the use of policy incentives unnecessary[6]. The timeframe of the phase-out of incentives will be impacted by large regional variances. While it is anticipated that EV sales would rise quickly in the major car markets, the worldwide growth is not evenly distributed. As pockets of development with high penetration rates have formed in nations like China, the Netherlands, Norway, and the US, such divergences have already begun to show[7].

It may also be necessary to provide ad hoc assistance for electrification in certain systems, such as islands. By decreasing tariffs on these technologies, Fiji and Sri Lanka have already been encouraging the use of hybrid vehicles. Similar EV incentive plans have been discussed in Jamaica. Governments may be inclined to depend more and more on other means of supporting electric mobility as EV market share rises and conventional incentives, namely tax exemptions and tax credits, generate less money over time. Transport objectives will likely continue to be important for accelerating the decarbonization of the industry [8]–[10].

CONCLUSION

In the next decades, batteries will be one of the biggest problems that EVs will have to deal with. There might be significant advancements in non-lithium-ion battery technology and their usage in grid applications between the years 2030 and 2050. The progress of battery chemistry will have an impact on not only mobility-related factors like driving range but also charging speed (which is connected to the demand for grid infrastructure augmentation) and the capacity of batteries to support the grid. Li-ion technology has constraints in terms of safety and the future supply of this element (and presumably also cobalt), as well as associated potential cost consequences. This is true despite its high energy density and appropriateness for both grid and mobility applications. Any Li-ion subchemistry's performance would decline with an increase in safety standards, especially with regard to energy density. During the next years, the price is anticipated to decrease. But, it will eventually reach a sTable value, much as lead-acid did in the past. Although while Li-ion has many benefits today and would be difficult to replace, these difficulties can only be resolved by a shift in technology, such as with sodium-ion for cost or redox flow for safety.

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CHAPTER 19

SHARED E-MOBILITY: MOBILITY-AS-A-SERVICE

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ABSTRACT:

To address the challenges of electric mobility such as power, distance travelled and charging time new battery technologies are necessary. Despite ongoing major research on Li-ion, other technologies present high potential and are also being developed. The outlook for battery technologies up to 2030 and 2050. While Li-on will probably remain the prevalent technology until 2030, potential breakthroughs in other technologies may lead to its replacement in the long-term horizon. Two technologies that have already been commercialized for example, as minor technologies in e-buses for around 10 years are Zeolite Battery Research Africa (ZEBRA) and lithium-metal-polymer (LMP) battery technologies.

KEYWORDS: Charging, Electricity, Mobility,Networks Wireless Charging.

INTRODUCTION

New business models that potentially revolutionise mobility systems over the next decades will emerge as a result of shifting mobility requirements. Getting rid of the problems that travellers encounter might prove to be a vital chance for new enterprises to attract clients. The transition from a mobility choice that is consumed as a service to an ownership-centered approach is already laying the groundwork for these economic possibilities to arise. Mobility as a Service is the name given to this service-oriented mobility (MaaS).With mobility as a service, you may effortlessly mix different providers' transportation options (including shared mobility providers but beyond). MaaS provides a one-stop shop for everything from payments to optimised travel itineraries, going beyond just finding the shortest route between two points. Trip planning, booking, payment, and ticketing/billing are the four complementing capabilities that make up a MaaS package. Mobility as a service has not yet been fully realised, however. MaaS will need substantial analytics, mobility modelisation, data purchasing, coupled with the construction of a complete transport operators' portfolio to guarantee that all users find a ride in a timely manner. This is necessary to address the mobility demands of thousands of consumers[1], [2]. New actors must arise if this goal is to be realised. Other, less developed technologies, which are now being developed (only cells, not systems, are commercialised), have the potential to be disruptive if their problems are resolved:

- Li-ion systems with silicon (Si) as a negative electrode
- Lithium-sulphur system (Li-S)
- Sodium-ion batteries (Na-ion), which are raising interest due to the potential low cost and environmental friendliness
- Metal-air batteries including aluminium-air (Al-air) and zinc-air (Zn-air)
- Redox flow batteries for mobility applications.

Four primary characters play essential roles in the MaaS offering and are at the centre of the MaaS design. Customers, MaaS providers, data suppliers, and transit operators are some of these players. Although consumers have gradually embraced new mobility options over the last 10 years and many nations currently have transport operators in place, MaaS providers and data providers are still essentially nonexistent.

Customers will first be able to schedule and organise door-to-door excursions using a single app thanks to the MaaS suppliers. They will achieve this by offering software that includes a cashless payment engine, a ticketing feature, and a travel planning tool. MaaS providers will need to develop a robust analytics engine to decide how to distribute resources at peak times and to forecast demand in order to provide these services. In order to provide solutions that best meet their consumers' mobility preferences, it will also be essential to establish a sizable network of transport providers, both public and commercial.

Thousands of consumers' real-time information would need to be collected in massive quantities in order for MaaS to become a reality. Data suppliers are thus required. They will gather data from different sources, analyse it, and then sell it to the MaaS supplier. The intricacy of each activity and the sensitivity of concerns like data privacy and antitrust rules may preclude a single participant from doing all of these activities on their own, even if a MaaS provider might theoretically also serve this role.

Transport operators will finally give the MaaS providers with the transportation capacity, which is essential to any MaaS ecosystem. These service providers are a small portion of the new mobility ecosystem, despite being well-known and numerous. Public trains and bike-sharing programmes are only two examples of transport providers. Most of the transport companies that we now use are among them. The most important change in the business model may be a change in the ownership of the connection with commuters, since they now interact with the MaaS provider rather than the transport operator[3], [4].

Included in the new MaaS business models are integrated MaaS providers that handle booking the trip, locating the optimal route based on the customer's request, and then invoicing everything in a single bill. Data providers allow MaaS providers to create completely customised experiences, and transportation companies may expand on current fleet management practices.

Autonomous EVs

Technology-enabled services for carpooling and ridesharing are setting new standards for how to transport large groups of people. It is anticipated that the adoption of shared mobility and ultimately MaaS would pick up significantly as a result of vehicle electrification and the development of autonomous vehicles.

Transport providers shouldn't only purchase the cheapest cars; they should also take into account those that are not too costly in the long term since the switch from private ownership to corporate ownership entails greater daily mileage. Fleet managers will most likely prefer EVs over ICE vehicles because electricity will continue to be much more affordable than diesel or gasoline over the next ten years and because EVs emit fewer greenhouse gases and particulate matter in a situation where regulators want to ensure air quality in cities.

The arrival of autonomous cars will accelerate MaaS advancements in addition to the expansion of EVs. While they are not necessary for the expansion of MaaS, autonomous cars have the potential to be a significant growth driver in the ecosystem of seamless mobility. The following are some of the primary benefits that autonomous cars may provide:

- Why having more autonomous cars would provide end users more time since the passengers could concentrate on other activities while "driving."
- The emergence of autonomous vehicles will most likely reduce the operating expense of fleet operation, as the driver's salary represents a significant portion of this expense.
- Autonomous vehicles would increase traffic efficiency because they would be permitted to drive at a higher speed, closer to one another, while having a lower risk of accident.
- Lastly, the trend towards autonomous driving would help free up parking spaces since these cars would be used more often and would spend less time parked.

Evolution of vehicle DNA: Towards autonomous vehicles

Automobile, bus, truck, and to a lesser degree, two-wheeler manufacturers are working hard to produce connected and autonomous vehicles. The anticipated timetable for the commercial launch of autonomous vehicles. For instance, Daimler has openly said that it would concentrate on the CASE (Connected, Autonomous, Shared, and Electric) strategy.

Since running expenses for EVs are lower than for equivalent gasoline or diesel cars, sharing vehicles makes more sense because the more miles driven, the faster the cost of the vehicle is recouped. According to the Society of Automotive Engineers' taxonomy, several levels of autonomy include:

- Level 0 (hands on, eyes on): no active assistance system
- Level 1 (hands on, eyes on): longitudinal or transverse guide
- Level 2 (hands temp off, eyes temp off): longitudinal and transverse guide (traffic control)
- Level 3 (hands off, eyes off): takeover on request (awareness for take over)
- Level 4 (hands off, mind off): no takeover request (no driver intervention)
- Level 5 (hands off, driver off): no driver.

Google's Waymo autonomous vehicle project has already begun testing autonomous vehicles in the US city of Phoenix, providing free self-driving taxi trips. Vehicle-to-infrastructure (V2I) or vehicle-to-vehicle (V2X7) communication is possible between connected automobiles and the driver and other vehicles (vehicle-to-vehicle, or V2V). With services like pre-heating the automobiles, the experience is made easier for the driver by connecting with them. Also, capabilities for smart charging the capability to set the charging at more convenient times and to view the level of charge of the automobile) are also feasible. V2X and V2V collect data on the traffic and roadways to enable autonomous driving. There are a number of autonomous vehicle pilots. For instance, Renault is using both V2V and V2X in the SCOOP project to allow autonomous driving by alleviating traffic congestion and enhancing safety. The project began in 2014, and in 2017 it reached the deployment phase with 1000 Renault Megane cars that were properly outfitted[5], [6].

Navya and EasyMile have previously proposed tiny shuttles that can operate independently at low speed in a predetermined region as an alternative to buses. Daimler and Proterra, two bus manufacturers, have also shown interest in autonomous vehicles. While they are at a younger stage of development, autonomous and electric trucks may follow a similar pattern. For instance, Tesla's electric semi was unveiled in late 2017 and will also have improved autopilot. Embark is also developing technology for autonomous vehicles. Tesla is aggressively working on creating autonomous vehicle technology, so its technology can also be used in its trucks.

Regarding autonomous cars, there have been optimistic developments so far, and the price of the technology is predicted to fall. Because of technical advancements and increased demand, Aptiv anticipates that the price of the essential hardware and software package will drop from a range of USD 70 000 to USD 150 000 now to USD 5 000 in 2025. The gear comprises graphical processing units (GPUs) to operate the cars based on inputs from sensors for instance, the Tesla Model S has eight 360-degree surround-view cameras, twelve ultrasonic cameras, and radars that can "see" even in inclement weather like torrential downpour. Data from other vehicles or the infrastructure, such as reports of accidents or traffic congestion, may also be used. Autonomous vehicles need sophisticated software, often based on artificial intelligence methods like deep learning [7].

With large grid demands from the charging hubs in a world of MaaS and driverless cars, the necessity for AI-based software will only grow. Public and commercial stakeholders will be able to carefully introduce this technology to the market in a manner that benefits constituents, while addressing major mobility concerns and optimising the grid, with the use of data analytics and greater knowledge of mobility. Based on current travel trends, INRIX has selected the best markets for the deployment of autonomous vehicles by using hundreds of millions of trips, parking availability and constraints, and demographic data. Cities will be able to proactively use highly autonomous cars to solve important transportation and social concerns by using these data-driven insights to improve public planning as opposed to reactively dealing with the effects of this technology.

Addressing the issues with completely autonomous driving and regulatory obstacles. Autonomous vehicle legislation has a direct influence on the EV industry. Many governments are not yet prepared for the operation of this sort of fleet of vehicles on public roads since the market for autonomous car technology is less developed than that for electric vehicles or shared mobility. The first nations to permit the testing of driverless cars and to adopt technical standards mandating that fully autonomous systems adhere to traffic laws are Germany and Japan. Some US states, including Arizona, California, and Nevada, permit autonomous vehicle testing on public roads. In 2017 China released its first road test regulations, and in 2018 it granted its first road test permits.

Concerns about liability, privacy, and security are significant obstacles to the adoption of autonomous vehicle technology. For regulators, determining fault in accidents is a particularly touchy subject. Dealing with the damage might provide ethical dilemmas. V2X in this sense refers to the transmission of data from the infrastructure to the vehicle. V2X refers to energy transfer from the vehicle to the infrastructure caused by autonomous cars damage to property or to persons, with decision-makers needing to determine who would be accountable. This term is used in the context of charging and discharging. Several projects are already underway; Germany, for instance, is thinking about mandating a black box that would record whether a person or a piece of technology was operating the vehicle at all times. Even if the car is driven autonomously, the owner and driver are still responsible.

To overcome these problems, regulators should cooperate with other stakeholders including manufacturers, drivers, and passengers. This would ensure that moral choices are intentionally made. Before fully implementing autonomous cars, there is a critical need for a legislative framework that would control data access, exploitation, and security. Job losses will become another issue. Workforce and industry displacement will result from technological advancements. In order to prepare for such losses, governments will need to take action. To control the long-term reallocation of labour, policymakers should limit the number of taxi licences they issue. In addition, a kind of compensation for lost wages due to unemployment and job retraining might be offered.

DISCUSSION

Smart charging, as previously discussed in the sections, will be essential to maximising the synergies between EVs and VRE production. Depending on the features of the energy grid, various EV charging procedures may have relatively varied effects. The system's major source of VRE and evolving mobility trends have an influence on the methods for integrating EVs into the grid. The first is the analysis's geographic scope. Compared to linked systems, the effects of EVs on system functioning are more pronounced in isolated systems with a large proportion of fluctuating renewable energy sources that are more challenging to balance.

Since interconnector-based sources of flexibility are either few or nonexistent in these systems, the effects of uncontrolled charging are more severe. Understanding the effects of various grid integration solutions requires evaluating the additional value of V1G and V2G smart charging in such severe situations. The immediate and long-term local effects of EV charging and renewable energy sources on distribution systems were also evaluated. The second is the analysis's time span. It is necessary to evaluate both the immediate effects on operational planning in the system and the long-term effects of various EV charging options on system development.

Modeling of discrete systems serves as the foundation for the examination of system-wide impacts. The model's approach, including its assumptions and restrictions. The evaluation of regional effects is based on third-party case studies. The exercise offered insightful information and could motivate more research beyond the purview of this study. This might include battery swapping systems, smart charging systems, isolated systems using EV batteries as stationary batteries, and modelling of linked and isolated systems. Future research may concentrate on hybrid systems made up of renewables solar PV and wind) battery storage, and charging infrastructures that are close to being used in industrial parks and on remote islands with an abundance of renewable energy sources, such as those in northwest China systemic effects. For the system-wide effect evaluation, two different kinds of isolated systems are modelled, as will be discussed below. The following key performance measures, reported in annual values, are used to evaluate the effect on these separated systems:

- Renewable energy curtailment (%)
- Peak demand reduction/increase (%) compared to business as usual
- CO2 emissions reduction (%)
- Average electricity cost (EUR/MWh) calculated as the average short-run marginal cost of electricity generation.

In this simplified modelling, the cost of the grid, communications, and losses are not evaluated. Four scenarios that allow for an evaluation of the major EV advancements impacting the integration of renewable energy into power systems were established. They are used both independently, isolating the impacts, and together to evaluate the consequences of two improvements on the power system side, and one on the mobility side (synergies).

The first three possibilities presumptively include no advancements in mobility. Mobility as a service (MaaS) adoption is still mostly at its present levels. Private auto ownership is still common; as a result, economic growth in each nation has an impact on the number of automobiles. The overall cost of ownership continues to decrease as the quantity of EVs increases at the same time. The potential costs of not pursuing lost transportation service income are minimal:

1. Under the BAU (business as usual) scenario, there will be few breakthroughs in the electricity industry and existing trends in EV adoption will continue until 2030. As a result, there will be a significant rise in the number of EVs, although their load and charging patterns are still unpredictable.
2. The "partial smart charging" (also known as V1G) scenario assumes that only unidirectional V1G smart charging will be used to integrate EVs into the grid.
3. The "fully smart charging" scenario (referred to as V2G) presupposes considerable innovation in terms of technology and commercial models on both the EV and power system sides. For renewable-based power systems, EVs are used as a source of flexibility. To do this, EV-grid integration has advanced to include both unidirectional smart charging (V1G) and V2G, and used batteries are now a competitive source of flexibility for the grid, used for peak shaving as well as for grid balancing in close to real-time.

The end scenario, nevertheless, presupposes significant adjustments to mobility patterns: The "completely smart charging" scenario used in the MaaS[ive] smart charging scenario implies full innovation on the power system side and high innovation on the mobility side. As a result of significant advancements in ICT, very effective vehicle sharing, intermodality, and the development of EV technology towards completely autonomous driving, individual automobile ownership has significantly decreased[8].

The instance studied here shows a remote area with significant solar radiation and an annual load factor for solar PV of 31%. In the BAU scenario in 2030, this system's installed capacity is around 2 700 MW. Almost 27% of the generating mix is solar, with the remaining 60% coming from combined-cycle gas turbines, 9% from biomass, and 2% from wind and other sources. The site will attain a 50% EV fleet penetration rate by 2030, or 100 000 EVs with an average battery capacity of 80 kWh. The area's peak demand is around 900 MW. As compared to uncontrolled charging in the BAU scenario, they amply illustrate the advantages of smart charging:

When V1G and V2G are implemented, curtailment steadily decreases to zero levels. V1G changes the EV demand to better match the availability of solar electricity, which lowers curtailment. This is made increasingly clearer by the use of EV batteries for V2G services, which enable full use of solar resources and allow consumers to change when they consume energy by storing it in EV batteries and reintroducing it to the grid during periods of high demand. As a result of using more solar energy to meet the demands, the system's CO2 emissions are slightly decreased. Peak load is decreased in the V1G scenario compared to BAU because the cars are not charged during the peak demand as a result of the daytime charging being spread out. Since the car battery sends power back to the grid during periods of high demand, peak load is considerably more decreased in V2G. Finally, the cost of power might decrease on average. Given that EVs are assumed to be utilised as free batteries in the modelling, the V2G scenario exhibits a significant cost savings. Prices in auxiliary services markets may fall in addition to the short-run marginal cost if the little demand of this market segment is satisfied by an abundance of flexible EVs or other flexible loads.

Also, it is to be anticipated that properly charged EVs would respond quickly, which is necessary for shorter operating time periods. Nevertheless, some of the advantages may be lost if high levels of innovation on the mobility side are combined with sophisticated innovation on the power system side via smart charging. The MaaSive scenario modelling, in addition to V1G and V2G, envisions a significant transition towards mobility-as-a-service that will happen concurrently with the broad deployment of autonomous cars. This will result in a significant decline in private automobile ownership. Compared to today's privately owned automobiles, there will be fewer cars that will be driven a lot more[9].

Due to reduced charging flexibility for heavily utilised cars, there will be less total EV battery capacity for the grid compared to situations without MaaS, less availability of these batteries to deliver grid services, and even an increase in demand during certain periods. In Annex 5, the specifics of how EVs were modelled in this scenario. The MaaSive scenario's modelling implicitly assumes that no alternative flexibility technology will develop to replace the car batteries that are no longer accessible, such as stationary storage, demand response, etc.

Because of these developments:

Solar curtailment may continue to be at zero levels. The available battery capacity from V2G may still be sufficient to store extra clean power and to shift its use in time, as in the simulated case, even if the sizes of accessible EV batteries have decreased in comparison to the V2G scenario. Yet since EVs add more load to the system each year, peak demand in the system rises. There will be fewer cars on the road, but they will drive much more than in the other scenarios, increasing the demand for charging. Despite having smart charging capabilities, [2], [10]EV batteries' storage capacity is severely limited since they spend the majority of the day driving and cannot be used to provide grid services. The average power price could continue to be less than in the BAU situation. The cheapest option to meet the additional demand is to raise the load factor of gas-based generation, which involves deploying combined-cycle gas turbines more often than in BAU as baseload since solar was already fully used (zero curtailment in the V2G scenario). The most costly units sent out determine the hourly short-run marginal cost. Even though the MaaSive scenario's system peak is greater than BAU's, the average system costs may be lower if the dispatch favoured less expensive baseload units more often than peaking units (which bring up the marginal cost). This is the situation in the modelling experiment, when baseload units run more and gas peaking units operate less than BAU. Yet, growing use of resources based on fossil fuels results in higher emission levels.

CONCLUSION

The same scenarios and key performance metrics that were used to evaluate the short-term implications may be used to highlight the long-term effects of EV charging on the renewable-based power system. This time, however, two separate systems were modelled: the same solar-based system as in the short-term example (2 700 MW) and a wind-based system with an installed capacity of 5 800 MW under BAU and an average annual wind load factor of 51%. The outcomes for both model-based examples are summarised in this subsection. The influence of several vehicle-grid integration techniques on system operation was evaluated in the short-term study, along with how they would affect the key performance metrics from the time of installation. On the other hand, short-term market signals have an effect on the system's long-term development, and this is what is examined in this subsection: how various VGI techniques affect the system's long-term expansion and how such future systems will function. The modelling software was modified to "freely" determine the ideal capacity mix and to invest in new assets in order to take this influence into account. It determines the best dispatch by technology type with an hourly precision, optimises the entire system costs, and satisfies demand for the year 2030. The system growth would be impacted by different VGI strategies or the lack of VGI strategies in a BAU scenario, modifying the ideal capacity mix. To develop additional generating capacity and fulfil demand in 2030, the model may choose the four technologies solar PV, wind, combined-cycle gas turbines, and open-cycle gas turbines in the best possible way.

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CHAPTER 20

LOCAL DISTRIBUTION GRID IMPACT

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ABSTRACT:

EVs are expected to impact renewable energy investments, and particularly for isolated systems using wind and solar energy. There is a high match between wind power production and EV charging profiles even with uncontrolled EV charging (BAU), and the implementation of smart charging will not significantly improve this match the incremental change will be small. This is presented in, which shows the EV charging profiles matched with the solar and wind availability. EVs mostly charge when wind blows. However, the exact match will depend on concrete wind production profiles that are more volatile than solar profiles. As an example, illustrates regional variation of load factors in a country with high wind potential.

KEYWORDS:

Charging, Electricity, Mobile,Networks Wireless Charging.

INTRODUCTION

Likewise, land availability difficulties in certain regions might limit the growth of wind investment. Like in the modelled example, the wind case exhibits a comparable capacity growth in all situations. Under the BAU scenario, the model decides to invest in wind to the fullest extent possible. The somewhat varying renewable energy percentages that were shown in the wind scenario are a result of the various load factors of the technologies. For less isolated or networked systems, this could not apply.

The solar generation profile varies depending on the orientation of the panels, with production from eastward-oriented panels peaking in the morning and from westward-oriented panels peaking in the afternoon. The solar generation profile also varies depending on the weather, with less irradiation occurring during cloudy weather and in the winter. With the exception of workplace charging and, to a lesser extent, public charging throughout the day, solar PV production profiles often do not coincide with uncontrolled EV charging, in contrast to wind. Therefore, the additional advantages of smart charging in terms of their influence on renewable capacity could be even greater with solar, particularly in the V2G case with affordable batteries that can store excess renewable energy that is not immediately consumed during the day and then dispatch it later[1].

The table provides a detailed breakdown of the additional capacity needed by the model in 2030 for the solar case for each scenario. Due to improved load factors, cost competitiveness, and compatibility between solar profiles and intelligent charging patterns, a significant amount of solar investment is selected over wind in the V2G scenario of the solar case, and no wind investment is made. The V2G scenario's capacity growth is also highly crucial since the modelling relies on the EV batteries' free energy return to the grid.

The renewable share, however, may be anticipated to cancel out and revert to reference levels under the MaaSive scenario (BAU). This is a result of increasing the annual load of EVs while not providing the system with adequate storage capacity to allow for the economically viable integration of additional renewable energy. In this instance, the model determines that base load combined-cycle gas turbines are more economically advantageous than large-scale solar installations, which will ultimately need to be scaled down due to batteries' inability to incorporate them. Keep in mind that the simulated area has little seasonality. As EVs only function as short-term storage and cannot be used to compensate for seasonal changes or maintain the advantages of integrating renewables, more long-term storage may be required in places with greater seasonality[2].

We may anticipate that till 2050, the same developments will be available. Yet, other technological developments, like the digital revolution in electricity and transportation, will have an impact on their intensity. As a result, it is anticipated that the percentage of renewable energy will increase compared to 2030 as more fossil fuel units are shut down and investments in renewable energy become a more attractive alternative as capital costs for both producing and enabling technologies continue to decline. A higher proportion of renewable energy sources will balance out daily changes in the system together with an increasing percentage of smart-charged electric vehicles.

The generation profile of wind energy might operate in a similar manner to that of solar energy, with the exception that it is less predictable. The maximum wind capacity was already established in BAU, and expanding the wind capacity was not feasible because of the restricted acreage available in our "wind scenario," hence this does not apply. The little variations in curtailment levels explain the modest variations in wind production across the various scenarios. The development of the power mix then has an impact on the various key performance indicators, generally in accordance with the patterns shown in the short-term study and enhancing the advantages noted, such:[3]

A. In the short-term study, the impacts on annual peak load are comparable; that is, smart charging scenarios result in peak decreases, while the MaaSive scenario results in peak increases, with little to no change for solar- and wind-powered systems.
B. In both the solar and wind smart charging situations, increased renewable system shares result in lower CO2 emissions. As compared to the short-term effect, more renewables may also be able to reduce the emissions growth in the solar MaaSive scenario. Nevertheless, the solar V2G scenario's amount of emission reduction is fairly optimistic in the model owing to the oversimplified assumption that the system's batteries would be free, as previously mentioned. In the wind situation, if impediments to more wind investment are not removed, emissions may increase dramatically under a MaaSive scenario.
C. The short-run marginal cost reduction likewise closely tracks the growing percentage of renewable energy sources. In contrast to the short-term MaaSive instance, where the cost actually decreased compared to uncontrolled charge, the long-term pricing is comparable to BAU.
D. When V1G or V2G are modelled, high fluctuations of curtailment are shown (for solar curtailment in the solar case and for wind curtailment in the wind case). Generally, although still under control, curtailment is a little bit greater than in the near term. When it is more economically advantageous to do so than to add additional capacity, the model ideally

decides to increase the quantity of installed renewable capacity in the system.

Other studies have also evaluated the effects of uncontrolled EV charging vs smart charging on power networks, many of which focused on power systems that already have substantial proportions of VRE today, such California or Germany. They have observed a positive effect of smart charging on peak load mitigation in the system, as well as associated CO2 emissions and renewable curtailment reduction, in keeping with the situation studied for the purposes of this research. Studies on the German power industry also shown that the proportion of renewable energy utilised for EV demand may be more than quadrupled by using wind- and solar-oriented charging options. It will still be important to carefully consider the consequences for EV flexibility, which may be less available in a future transportation system based on shared autonomous cars than in a system based on private EV ownership [4].

Local distribution grid impact

High VRE penetration and unchecked EV penetration enhance the unpredictability of local residual demand even in linked networks. Due to overvoltage and transformer overload, local curtailment may be very high if there is a significant local penetration of variable renewable energy sources. Voltage at the grid injection point is raised locally by the local injection of active power from VRE. Transformer loading capacity and critical line loading set a limit on the hosting capacity of lines. If these boundaries are often crossed, "saturated" transformers and wires need reinforcement. Also, if local supply is greater than local demand, the produced power would raise the distribution grid's voltage levels.

Additionally, improperly charged EVs pose a serious problem for the distribution system, which is built to support unidirectional power flows and is characterised by lower voltage levels and a mostly radial grid topology. Solar PV feed-in may be utilised to charge EVs in the best possible way using smart charging. The PlanGridEV project, which is co-financed by the EU, aims to provide operational principles and planning guidelines for the best integration of EV in various municipal network architectures. Simulations conducted for this study showed: When more EVs are charged using traditional methods, the transformer saturation rises. Yet, for the same number of EVs, smart charging increases transformer saturation.

This is due to the fact that the peak in EV demand does not coincide with the peak in conventional consumption. Reverse power flows from dispersed generating to the transformer may be reduced with smart charging. The voltage curve is smoothed in smart charging mode, which allows for the reduction of overvoltage and the maintenance of sTable grid voltage in a low-voltage distribution network. By workplace charging or public charging, this benefit may mostly be realised throughout the day. Just unidirectional smart charging (V1G) may minimise solar PV curtailment by 20% annually, according to a simulation of a site with three distribution feeders. Curtailment may be decreased by 83% annually if used in conjunction with a fixed battery as opposed to an uncontrolled charging situation [5].

DISCUSSION

The infrastructure of the electric grid is impacted by the widespread use of EVs. When the current transmission and/or distribution lines, or transformers, are unable to support the entire required load during times of high demand, such as when thousands of EVs are being charged simultaneously, or during emergency load conditions, such as when an adjacent line is taken out of service, bottlenecks or grid congestions may occur. Two distinct case studies from two medium-sized European distribution grids, Stromnetz Hamburg (Germany) and Endesa, may be used to highlight the effects of EV charging on grid congestion (Spain)[6].

The effect of EV charging on Hamburg's power system

Currently, Hamburg has the most charging stations per capita in Germany (several hundred charging points in households and 810 public charging points as of November 2018). By the start of 2019, the city planned to set up 1000 public charging stations. The most important factors influencing load growth in the city are the electrification of public buses and the expansion of EVs. The bulk of EVs will be found in Hamburg's outskirts, where the grid is less reliable. With charging point loads of 11 kW and 22 kW, the local distribution system operator Stromnetz Hamburg conducted a load development study to identify key circumstances for uncontrolled charging of EVs. Stromnetz Hamburg evaluated two possibilities:

A. **Scenario 1:**200 bottlenecks will result from a 3% EV share, or loading of 20.000 EVs in private infrastructure. Problems would arise in the low-voltage grid as a result.
B. **Scenario 2:**800 out of 6 000 feeders, or 15% of the feeders in the city's distribution network, will experience bottlenecks with a 9% EV share, or 60 000 EVs loading in private infrastructure.

Stromnetz Hamburg evaluated the expenditure requirements for strengthening the local grids in order to prevent these dire circumstances. Under Scenario 2, it would be necessary to reinforce around 10,000 km of 0.4 kV cable lines, which would cost at least 20 million euros, or about 200 euros each cable metre. The replacement of overloaded transformers, which would be considerable as well, is not included in this investment estimate.

Finding the workforce capacity to reinforce the grid, obtaining the necessary permits, and gaining public acceptance of work that necessitates closing numerous city roads for the replacement of underground cables for periods of several months or even years would be additional challenges, perhaps more complex than the financial implications.

Stromnetz Hamburg is looking at another approach to solve the issue given the size of the task and the expense required to strengthen the local grids. The secret is to reduce simultaneity, or the number of EVs being charged simultaneously on the same local grid. A clever solution based on digital technologies is being tried for that and includes:

1. Every home with a charging station must notify the operator of the distribution system. There hasn't been a need for this information yet.
2. Measure the loads on the 0.4 kV wires, which the city of Hamburg does not now demand. As a result, the bottleneck issue will be easy to see as it develops.
3. A real-time communication system that allows the operator of the distribution system to lessen the burden on the charging stations required to solve the issue. For instance, the 11 kW charging stations may lower their load from 16 amperes (A) to 8 A, which enables EVs to be charged but over a longer period of time [7].

Siemens and Stromnetz Hamburg collaborated on this project, and Siemens will set up 30 control units and monitor the loads on the private charging infrastructure. They will be better able to predict congestion problems and design the network based on the load profiles thanks to this. This method is expected to cost roughly EUR 2 million, which is just 10% of what it would cost to reinforce the cables conventionally without factoring in transformer expenses. Also, they want to begin working closely with charging station owners to create a robust IT and communications infrastructure that will connect the charging station operators to the grid.

Even if the technical solution is workable, its full implementation would necessitate the involvement of consumers as well as the more than 400 electricity retailers in the City of Hamburg. For instance, the distribution system operator might use a time-of-use price incentive to let it control its charging points based on the needs of the local grid. The example of Hamburg demonstrates both the possible effects of EVs on municipal grids and potential ways to address them, which may call for a mix of digital technology, new business models, and market regulation to include all necessary parties [8].

EV charging impact on the Spanish distribution grid

Under two scenarios, the study evaluated the possible cost of distribution grid reinforcement at various degrees of EV adoption in the transportation industry and various densities of charging stations inside low-voltage networks. The likelihood that local overloads will happen if numerous cars start charging at once increases with the density of charging sites, such as in a big parking lot.

The two scenarios included:

A. The first case in which smart charging is not used. In this case, the only method to prevent local congestion is to heavily fortify the overburdened portion of the network (also known as the "copperplate" approach).
B. The second option involves the use of smart charging, which is a kind of charging system that allows for some degree of control, including changing the charging current.

When too many vehicles are attempting to charge at once, the system rotates them to distribute capacity. This is the fundamental distribution of charging capacity under V1G. By evenly spreading the available power among all the cars and charging them one after the other without overloading the local feeder, this technology enables the charging of all EVs. When there isn't enough electricity to charge every car, network reinforcement is anticipated (e.g., overnight)[9]. These illustrate the scope of cost avoidance in the distribution network: Smart charging enables significant savings of more than EUR 1 billion compared to business as usual at 15% of EV uptake [10], [11].

CONCLUSION

According to the outlook analysis, there will be a significant increase in EV potential for VRE integration between now and 2030/2050 as a result of the anticipated acceleration of the transportation sector's electrification, technological advancements allowing for larger batteries, and ongoing adoption of smart charging capabilities for V1G, V2G, and V2X on the part of both the vehicles and the charging infrastructure. Digitalization may help people accept and connect with brands, as well as open up new commercial options.

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CHAPTER 21

NON-MONETARY INCENTIVES FOR EVS

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ABSTRACT:

At the same time, a number of obstacles might hinder the realisation of this expanding potential. The absence of a charging infrastructure is currently one of the major obstacles to EV adoption. Public assistance (regulatory incentives, policy objectives, etc.) is often required for the construction of such infrastructure since there is currently no obvious economic model for doing so. In order to minimise the effect of this additional load on the power system and to take use of the synergies between EVs and renewable energy sources in the system, which calls for greater flexibility, VGI policies should be implemented in conjunction with the adoption of EVs. Even with the right hardware and software in place, it may be difficult to make the promise of V2G and V2X that was shown in pilots a reality. It is necessary to encourage smart charging that follows renewable energy production patterns via suitable market design and automated regulation.

KEYWORDS:

Power, Renewable, Mobile, Monetary,Networks Wireless Charging.

INTRODUCTION

To overcome these obstacles, policy assistance and regulation will be required. The following types of policy levers are available to governments: financial and non-financial incentives, regulatory actions, lobbying and public relations, and public procurements. The development and testing of them should also be spearheaded by local administrations. Also, they must avoid creating silos between the energy utilities running the networks and delivering power and the mobility providers by facilitating contact between them.

On the one hand, reduced well-to-wheel emissions of EVs and, therefore, the decarbonization of the transportation sector, are guaranteed by a decarbonized power system with a large percentage of renewable power production. On the other hand, by using their synergies at both the system and local levels, intelligently charged EVs will enhance the integration of high proportions of renewables in the power system. EV prices must further drop to parity with ICE car costs in order to make this source of flexibility widely accessible. For mainstream adoption to occur and to alleviate range anxiety, charging infrastructure has to be improved.

Set challenging transportation goals the ambition in e-mobility at the national level should increase, in addition to maintaining high aspirations in renewables or putting them in place where they are currently lacking. Governments should take notes from early adopters who have already put mobility objectives and assistance into place. They should concentrate on various types of road transportation, such as public transportation, in addition to only passenger automobiles. To encourage the development of a premium market, cities and regional public authorities can set an example by reviewing processes and may even establish goals for public procurement for buses and work vehicles[1].

To be successful, road transport objectives should be kept apart from those for other modes of transportation like aircraft or the military. CO_2 reduction objectives for transportation would be important in addition to mobility goals and CO_2 standards that are currently in place in certain nations. Governments and municipal authorities in developing EV markets should provide incentives for the installation of charging infrastructure while adhering to accepted best practises. The complicated market categories, such ultra-fast charging and multi-unit housing, should be addressed by all governments. The application process for installing charging infrastructure has to be simplified.

Between 2025 and 2030, EVs are anticipated to reach cost parity with ICE cars in the majority of situations and for the majority of vehicle types. While it is anticipated that EV sales would rise quickly in the major car markets, the worldwide growth is far from even. Direct financial incentives for EVs should thus be implemented and then gradually tapered off in accordance with regional demands and conditions. Non-monetary rewards should eventually be increasingly common. For instance, local governments need to draw inspiration from the most effective indirect incentives, such emission-free zones. Where this is not presently the case, nations and international organisations should set aggressive renewable energy objectives. If such policies currently exist, they need to be constantly updated and kept aspirational[2].

Even if EVs are charged in an unregulated manner, wind production profiles may sometimes fit well with EV charging profiles in certain places since wind may blow more in the evening and at night, when EVs often charge. Hence, solar-based systems will benefit most from the incremental advantages of smart charging. Increased shares of solar might be integrated at the system and local grid levels by switching charging to more effective solar PV generating and deploying V2G, which would reduce the requirement for distribution infrastructure investments. Nevertheless, as most house charging occurs at night and most fast charging that will be produced has typically limited potential for VGI, the advantages of smart charging with solar may not be simple to attain without incentives.

Keep up with the international standardisation process (IEC) so that when EVs hit the general market in the middle of the 2020s, these standards may already be used to enable smart charging on a large scale. They need to be created with data security and privacy in mind. Standardization by itself won't provide solutions that are compatible for recharging EVs. To prevent the duplication of standards, assure compatibility, and promote effective communication, interoperability is essential. For smart charging to take off, there must be interoperability and common standards across EVs, the grid, and the charging infrastructure. For "roaming" customers those who wish to charge their car outside the service area of their home operator interoperability of data transmission is also essential.

Start deploying smart charging in remote locations and areas with strong renewable energy penetration. Prioritize remote systems like islands where there is less connectivity and hence less competition for EVs from other forms of flexibility. In consequence, early adoption of smart charging may benefit the growth of the power system, particularly in solar-based systems. Priority should be given to areas with significant local penetration of distributed generation, mostly from solar PV, and high local potential for synergies with intelligently charged EVs. This has to be supplemented by increased commercialization and display of smart charging solutions, which will allow real-world validation of field-related research, development, and innovation[3].

Create intelligent charging techniques while considering the power mix. Network solutions that go beyond the conventional fit-and-forget strategy should be permitted by regulation that prioritises long-term investments. It is important to build smart charging while taking into account the unique characteristics of each power system. Pay special attention to workplace charging and other business charging methods in solar-powered systems. For EV charging to complement solar, charging must occur throughout the day, which also necessitates the installation of charging stations at offices and other commercial locations where EV owners park their cars. Companies may provide renewable power for free charging for their staff, who can then use it later at home. Pre-cabling and smart chargers should be pushed in business buildings in order to achieve this.

Focus primarily on home charging to occur at night and modify it dynamically to fluctuations in wind output in those wind-based regions/systems where wind blows more in the evening and at night. Choose a charging location that is ideal for mobility and power systems. Support the best grid and mobility solutions at the planning stage: developers must have access to information regarding local grid congestion from the distribution grid in order to place charging stations in the best grid locations. To save costs and the requirement for fast-charging station capacity improvements, smart charging will need to be further supplemented by incorporating energy storage and local renewable energy sources (mostly solar PV)[4].

Create a smart charging power market design and modify legislation. It will be necessary to promote the development of V2G and other EV battery business models with multiple income streams (revenue "stacking" of batteries). To prevent batteries from being charged twice for network usage, taxes, and levies, tariffs will need to be modified. It will be necessary to implement market incentives that will provide the proper signals to drivers as well as other market participants like aggregators, notably:

A. Encourage the use of appropriate pricing signals across all regions to educate and empower consumers.
B. To tell the automobiles when to charge and discharge, the distribution grid tariffs will need to be updated and dynamic pricing implemented. At the same time, more automation will make it possible for service providers and drivers to control this system.
C. The best way to do this is to create retail markets that support price volatility and wholesale markets that give access to pooled resources.
D. More means for distribution system operators to purchase flexibility locally will need to be developed, as well as flexibility platforms that coordinate sources for both system-wide and local usage.

Use alternatives to grid charging Grid charging might be supplemented by redundant battery storage at the stations or battery swapping with additional battery storage that can take electricity from the grid when it is most efficient and then use it to charge EV batteries. EVs will continue to be used largely for transportation and just incidentally as "batteries for the system." In addition to spurring the development of new technologies like wireless charging, mobility-as-a-service (MaaS) and the ultimate transition to completely autonomous cars, particularly in metropolitan areas, will also transfer charging from homes and offices to hubs. Encourage comprehensive research and development in batteries and charging (R&D) to simultaneously take into account the demands of the grid and of mobility, battery and charging research should be encouraged. Batteries that are currently suitable for grid purposes will preserve their capabilities in this fashion.

DISCUSSION

More widespread use of e-mobility will increase system adaptability. It is important to carefully consider the consequences for EV flexibility, which may be less available in a future transportation system based on shared autonomous cars than in a system based on private EV ownership. Rural locations may be less affected than urban areas in major cities. In order to maximise the use of renewable energy and optimise the relationship between the grid and mobility demands, planning for charging (e-hubs) should be carefully coordinated with plans for mobility. Via one-time subsidies and lower ownership costs, financial and fiscal connected to government income and taxes financial incentives seek to promote the purchase of EVs. The most typical forms of fiscal and financial conduct are: [5]

- **Purchase subsidies or grants:**Direct financial incentives are offered via this sort of incentive to encourage the purchase of EVs, the replacement of commercial or public fleets with EVs, and the building of EV charging infrastructure. The grants or subsidies are often extended and updated annually as part of the government budget to support sustainable mobility.
- **Scrappage schemes:**Many varieties of these government-sponsored incentives exist across the globe, but their fundamental premise is the same: you destroy an old, environmentally destructive vehicle in return for a discount on a new one with improved environmental performance.
- **Electricity rates:**The overall cost of EVs is reduced because utilities provide business or residential customers with discounts on power tariffs for charging their BEVs or PHEVs.
- **Tax exemption or reduction:**This entails a variety of incentives designed to lower the financial burden of getting a new car. In this regard, EVs may be free from taxes such as value-added tax (VAT), purchase taxes, registration taxes, road circulation charges, and others.
- **Income tax credit:**In this type of incentive, companies or private clients who have purchased new alternative fuel vehicles or installed electric charging equipment may be qualified to receive an income tax credit equal to a specified percentage of the investment's total costs, or else the same as a specified calculated credit. The idea is comparable to purchase subsidies, but the manner the money is received is different. At the time of the beneficiary's yearly tax declaration, the credit is repaid in this instance.

Since 2008, France has used a bonus-malus system, which grants grants for the purchase of low-polluting vehicles and imposes fines on the purchase of high-polluting vehicles. For a BEV, the subsidy covered 27% of the purchase price, up to EUR 6 300, and for a PHEV, it paid 20% of the price, up to EUR 4 000. As sales rose year after year, the incentive proved to be successful. Sales of EVs in France increased in April 2015 and went over and above the 1% market penetration rate. This resulted from the addition of a scrappage programme worth EUR 3,700 to the bonus-malus system. Starting of April 2015, consumers may take advantage of a tax credit of EUR 10,000 for a BEV and EUR 7,700 for a PHEV when they trade in their diesel vehicle for an electric vehicle.

Under the Electric Vehicle Subsidy Scheme (EVSS), which was established in 2009, the Chinese central government has throughout the years provided significant financing to assist the purchase of EVs. Prior to an extension in 2010, the funds were formerly only available for public purchases. However, now private customers are now eligible. The programme encompassed a variety of vehicle types, including passenger vehicles, freight trucks, and buses.

According to the rated power, electric range, and battery energy density, China's inaugural EVSS for the most recent category granted up to CNY 50 000 for a PHEV and CNY 60 000 for a BEV until the end of 2012. The programme was extended for the years 2013 to 2015, and the current subsidy amounts for PHEVs and BEVs are CNY 35,000 and CNY 35,000 to CNY 60,000. The programme was once again extended in 2016 for the years 2016 through 2020, with the phase-out date for the subsidy programme set for 2020. In addition to the one-time incentives, the Chinese government declared in 2014 that EVs will be free from the 10% purchase tax[6].

Non-monetary incentives for EVs

The most typical non-monetary incentives used by local governments, in addition to the e-mobility objectives and collective agreements led and supported by national governments and organisations, include:[7]

A. **Driving permissions:** EVs may benefit from road toll exemptions or reductions since they are low-pollution cars, and they can also be permitted to travel in dedicated reserved lanes for public transportation.
B. **Parking permissions:** When requesting a parking permit, EV users may be given preference or get free parking.
C. **Free charging:** EV users can be entitled to recharge their batteries for free in indicated locations.
D. **Emissions test exemption:** A common practice in the US is to exempt BEVs and PHEVs from emissions inspections[2], [4], [8].

CONCLUSION

Municipalities have the right to provide additional incentives to electric or low-emission cars under the federal electric mobility rule, which was enacted in 2015. Free or preferred parking, use of high-occupancy vehicle lanes, and entry into restricted traffic areas are examples of privileges. While the law is applicable to the whole nation, it is up to the local governments to create and execute the incentives. For instance, Stuttgart offers free EV parking in designated areas for the general public (ICCT, 2016).

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CHAPTER 22

POWER CHARGING LEVELS AND MODES

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ABSTARCT:

The Netherlands: There are no non-fiscal incentives planned at the national level in the Netherlands, although some municipalities have developed their own indirect incentive plans. For instance, EV drivers in Amsterdam enjoy preferential access to parking permits and designated parking spaces close to charging stations. Norway has been providing non-monetary advantages to EV users for many years as the nation with the highest EV penetration rate in the whole globe. While these benefits are administered by municipalities and may vary from one city to another, the government oversees the subsidies on a global scale. BEV drivers get free access to toll highways, discounted ferry fares, the ability to drive in bus lanes, and free parking and charging at public locations. Moreover, EVs are marked with a unique registration plate.

KEYWORDS:

Depth of Discharge (DOD), Lithium-Metal-Polymer (LMP), Mobile,Networks Wireless Charging.

INTRODUCTION

For a battery to offer system-wide balancing or behind-the-meter optimization via the absorption of surplus renewable power and for minimizing volatility, around 300 complete charging cycles per year are required. It is necessary to have a high depth of discharge (DoD) tolerance. Nowadays, any kind of lithium-ion battery will work just well. Yet, because to its extended cycle life and ability to withstand high DoD, redox flow battery technology may provide this function. While it may be suitable for DoD, lithium-metal-polymer (LMP) has drawbacks because of its high temperature and significant self-discharge. As ZEBRA technology cannot be expected to cover the whole DoD, it cannot be envisioned here[1].

Energy is more crucial than electricity in time-of-use applications because the user may be requested to change how much they consume. Redox flow batteries would be suitable in this kind of circumstance since energy and power may be scaled separately. For this purpose, lithium-ion technology is also well suited. The energy grid is balanced using ancillary services, which maintains the grid frequency close to the reference (50 hertz in Europe and 60 hertz in the US). When available, these services may be purchased via reserve markets, which are further broken down into primary reserve, secondary reserve, and tertiary reserve.

- Compared to renewable energy balancing, DoD and battery engagement in main reserve is more seamless. The battery must provide power when the frequency lowers and vice versa. In order to do this, the referenced battery's state of charge must stay close to 50% and only vary within a small range. For instance, it is necessary to take into account around 1.5 complete equivalent cycles every day in Belgium. These many cycles with low DoD, which are more cautious for the

advancing of technology, make up these whole comparable cycles. Less often do frequency gaps occur, and batteries may be charged and discharged at C-rates lower than 1C.
- Compared to frequency containment reserve, the secondary reserve requires a shorter response time and fewer cycles (FCR).
- Even when compared to automated frequency restoration reserve, tertiary reserve requires a longer response time and fewer cycles (aFFR). Compared to FCR and aFRR, the energy required is more (lower C-rate) [2].

Although this application is less demanding on batteries, Li-ion and redox flow batteries are suitable for usage in this scenario. LMP has the same problems as renewable storage in terms of maintaining a high temperature environment, hence its suitability for this application needs to be established. The usefulness of a battery for backup applications that reduce reliance on the electrical grid and cut energy costs by drawing power during off-peak times has been established. Long standby lengths with a full state of charge are also conceivable. The frequency of cycling is based on the grid's stability, but the profile stays the same: the battery must handle extended state of charge durations and sustain deep DoD, as for renewable balancing[3].

While these batteries age more rapidly in a charged state than lead-acid batteries (which are more stable), Li-ion is often not the best option in these circumstances. To maintain the chemistry stable and avoid any runaway or sudden capacity drop while still utilising Li-ion as a backup for a long period, the battery would need to be kept partly charged rather than fully charged. This would allow the battery to operate at just a percentage of its potential. Frequency Containment Reserve (FCR), Automatic Frequency Restoration Reserve (aFRR), and Manual Frequency Restoration Reserve (mFRR) are also known as R1, R2, and R3 in Europe. While not cycling as effectively as Li-ion, lead-acid can be kept at a high state of charge for a very long period without deteriorating [4].

Power charging levels and modes

The three commonly distinguished levels of power output (terminology used mainly in North America) are:

- Level 1 chargers (AC ≤ 3.7 kW) are devices installed in private households, the primary purpose of which is not recharging EVs.
- Level 2 chargers (AC > 3.7 kW and ≤ 22 kW) are installed mainly in public or private places.
- Level 3 chargers (AC or DC > 22 kW) are installed mainly along highways.

Levels 1 and 2 are known as slow chargers in Europe, whereas Level 3 is known as a rapid charger. The three levels are described in SAE J1172 in North America. Mode is a standard notion that largely relates to the necessary electric protection system, which is connected to power range. There are four different charging "modes" for cable charging that are specified in IEC61851-1:2017. The technical details of the various charging methods, including the kinds of connections and sockets used. Connecting an electric vehicle to a typical AC supply network outlet. A permanent connection between an EV and an AC supply network is made by the EV supply equipment. No auxiliary or backup pilot connections Cable with pilot control and electric shock protection for the user The EV's control pilot function is integrated into the AC EV supply equipment[5].

DISCUSSION

The construction and upkeep of customer-use public and/or private charging stations is part of the charging service provider paradigm. Several sub-models include the production and/or supply of the actual charging stations as well as the delivery of ancillary services. The cost of the charging station and the energy are covered by the contract for private charging. Public funding has shown to be effective in limiting the high initial capital cost for public charging, with recharging serving as the primary income source. Power utilities, technology corporations, and specialised independent enterprises are the main market participants: Utilities firms that specialise in charging station setup and management.

Examples include Fortum's Charge & Drive initiative in Finland and German utilities E.ON, Vattenfall, innogy, and EnBW holding over 35% of public charging infrastructure in Germany. 140 DC fast-charging stations are part of Norway's national network operated by utility-owned Grnn Kontakt, with Statkraft as a significant stakeholder. Operators of distribution systems may sometimes construct and manage charging stations (e.g., the Elaad association in the Netherlands). State Grid of China, which had a monopoly on managing and supplying charging stations, is in charge of the biggest charging network in the world (Wenyu, 2017). More recently, however, the company has allowed private firms to compete on the market (BusinessWire, 2016). More large-scale roll-outs of charging stations are planned, for example by Enel in Italy and by E.ON and Clever, a partnership of five Danish utilities, with numerous new EV models set to hit the market in 2018/19 [6].

1. Major technical firms (like Bosch and Schneider Electric), for which the production of charging stations accounts for a very minor portion of their overall business.
2. Independent, specialised businesses that produce, install, and run charging stations as well as provide associated services including maintenance assistance and cloud data services.
3. The "own and operate" approach, which is often paired with a software-as-a-service (SaaS) offering, is the most prevalent. As an example, regular software upgrades and subscriptions for smart charging are often provided (e.g., by the two biggest European charging station operators EVBox and NewMotion).
4. ChargePoint established an alternate approach that serves around 70% of the US market. ChargePoint offers a comprehensive solution that includes hardware, little in the way of permanent assets (they lease their stations), and money derived from services (SaaS). All ChargePoint charging stations are Internet linked (3G or 4G), which is unusual, and allows for real-time management of the stations from anywhere in the globe. There are additional sub-models depending on different sources of income, such advertising (e.g., California-based Volta).

Recently, there has been significant market consolidation. In 2017, ENGIE purchased EVBox, and numerous oil corporations have shown interest in EV charging while first seeking synergies between conventional gas stations and ultimately new business models. 2017 saw Shell acquire NewMotion, the leading provider of electric charging stations in Europe with an 80 000-site network. Due to their higher upfront expenses, which are brought on by the current high cost of batteries, EVs are currently not cost-competitive with identical ICE cars[7].

Unsubsidized total cost of ownership (TCO) parity is anticipated to materialise in the medium future and make electric vehicles (EVs) viable on a lifetime cost basis. The margin will still be small, and the competitiveness of any option will be highly dependent on its annual mileage. In 2016, the cost of a diesel car was 31% less than the cost of an identical EV without subsidies and tax benefits[8].

This development is being driven by three key trends and variables: a decline in EV capital expenditure (CAPEX), an increase in diesel price, and an increase in average vehicle mileage. To provide a complete picture, it is also necessary to look at the regulatory framework. The economics of total cost of ownership for EVs are mostly influenced by their higher purchase price. A typical EV passenger vehicle cost around 25% more in 2016 than a diesel-powered counterpart (CEEME, 2016a). Even if an EV costs less to run than a diesel vehicle owing to the lower cost of energy per kilometre, the fuel savings presently do not make up for the higher CAPEX. A significant portion of the 30% reduction in the EV total cost of ownership may be attributed to lower EV CAPEX, which is in turn a result of lower battery CAPEX[5].

Considering that batteries made about 40% of the price of a new EV in 2016 (CEEME, 2016a), this dramatic drop in battery prices significantly reduces the EV CAPEX as a whole. The CAPEX for diesel cars is anticipated to remain a mature technology in the meantime. Two elements will be crucial to consider when analysing a vehicle's operating costs: the development of fuel prices and the vehicle's mileage. Figure 40 illustrates how the average price of electricity is anticipated to rise by 2030, whilst the average price of diesel is anticipated to rise by more than half. This trend does indicate to making EVs more competitive by 2030 than they are now, even if the effect of fuel expenses on a vehicle's overall cost of ownership will depend on the distance travelled by the vehicle - and hence the quantity of gasoline bought. The total cost of ownership comparison in Figure 40 was calculated using a 20 000 km/year driving average [9], [10].

CONCLUSION

Last but not least, there may come a time when the growing economics of EVs are muted by declining subsidies, depending on how quickly and aggressively governments decide to reduce their support for EVs. Even though EV economics have been continuously improving and are expected to be competitive by 2030, subsidies and financial benefits will alter the situation. Moreover, diesel will probably be subject to increasingly tougher regulations, which would lessen its appeal. This estimate implies that EVs will become competitive substantially sooner than 2030 when compared to a scenario without subsidies. Governments could decide to speed up their existing attempts to reduce restrictions, however, if EVs start to gain popularity. If governments reduce their support for EVs, a transitional phase may arise during which EVs and diesel cars are equally competitive. The total cost of ownership for EVs may begin to decline after all subsidies has been phased away in the future.

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CHAPTER 23

MODELLING IN PLEXOS

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ABSTRACT:

Mobility-related uses account for a significant portion of worldwide battery output, and this trend may continue in the years to come. The best battery technology for various mobility applications depends on a number of factors, including cost, degree of safety, and necessary energy and power output. Among the most important elements affecting the availability of EVs are the capacity and other technical characteristics of batteries. The quantity of energy stored in a specific system or area of space per unit volume, or battery energy density, has grown throughout time. The main cause of this phenomena is the kind of material employed as the battery's electrode, while cell and pack design optimization (such as improving temperature dissipation by modifying the cell shape) also plays a role.

KEYWORDS:

Business-As-Usual (BAU), Mobile,Networks, PLEXOS, Wireless Charging.

INTRODUCTION

Regardless of the subchemistry, lithium-ion technology is widely used nowadays. It is appropriate for grid and mobile applications, and the economics are becoming better. Today's Li-ion batteries only use a small number of different battery subchemistries. The choice of battery technology is a trade-off between performance, cost, and safety. The positive electrode type is primarily responsible for the markedly increased energy density of the cell performance. LFP (lithium-iron-phosphate), NMC (nickel-manganese-cobalt), and NCA are the three main sub-technologies that may be employed for the positive electrode (nickel-cobalt-aluminium). Although while NCA has far higher energy and power densities than the other two, it is less safe since it cannot withstand high temperatures. A thorough technical comparison of the two mobility-related chemicals, LFP and NMC. NMC provides more capacity and power whereas LFP is safer, less expensive, and has a longer lifespan. A contrast of the Li-ion battery chemistries used in most light-duty car models.

China dominates the market for electric buses, and 75% of the batteries used in buses are made there. LFP subchemistries are the most often utilised kind. The majority of NMC batteries are produced and utilised abroad. The optimum balance between safety, performance, and price seems to be LFP. Even if NMC is less harmful than NCA), the possibility of banning it from mobility applications in China for safety grounds was discussed in favour of LFP (Deutsche Bank, 2016). Yet, other reports reported a proposal to subsidise NMC batteries for electric vehicles. At the level of the cell to the pack, energy density falls. Although the energy density of the pack is only 140 Wh/kg, a cell put in a vehicle today may attain 250 Wh/kg (FEV, 2017; TBC, 2017). A vehicle with such a battery may travel around 400 kilometres and be fully recharged in 30 minutes (with fast charging that accelerates ageing). The goal for academic initiatives like the French project Helios (L'Agence nationale de la research, 2016) is to reach an energy density of 200 Wh/kg for battery packs and 300 Wh/kg for individual cells by the year 2020. This expansion may result in ranges of around 550 kilometres[1], [2]. Icreases system size to get energy that is equivalent to NMC [3]. A lower level of safety than LFP greater susceptibility to extreme temperatures. LFP has a shorter lifespan. After repeated cycling, the battery's capacity declines. When a battery reaches 70% of its original capacity for any mobility application, it must be replaced (reaches its "end of life"); beyond this point, the decline may accelerate significantly. Manufacturers of cars and buses have given the issue of batteries ageing for mobility a lot of attention. The battery will survive longer if it is cycled under more controlled settings (cycling rate/charging speed, temperature, depth of discharge, and state of charge utilised) than if it is required to perform at its full capacity.

An effective cooling system is required to keep the area surrounding the battery at a consistent temperature, ensuring safety and maximising battery longevity. Compared to LFP, NMC is more sensitive to temperature, and if the temperature is greater throughout the course of its lifespan, it will age more quickly. Moreover, NMC is more sensitive to the cycle rate used (this subchemistry has a lower nominal cycling rate). The modeling's purpose was to examine the effects of integrating EVs in high-renewable energy systems in several scenarios that varied not only in the degree of growth in the power and transportation sectors but also in terms of the dominant renewable source in the electricity mix. The seven provide an explanation of the modelling process[3].

For the research, two isolated systems were chosen, one with a high percentage of solar energy output and the other with a high share of wind energy. Four separate scenarios that include varying degrees of innovation in the electricity sector (uncontrolled charging, V1G and V2G scenarios), as well as the transportation sector, were used to model these systems (so-called MaaSive scenario). The number of EVs in the system, the makeup of the EV charging demand, and the size of the accessible EV battery are the three main EV modelling factors that are used in the research to simulate the effects of adopting the innovations associated with these scenarios. These situations are described in depth in Box 14 along with how they were modelled. According to the innovations presumpted in the four scenarios, the modelling of EVs in PLEXOS differs. The next three modelling parameters reflect these variances:[4]

1. Number of EVs in the system
2. EV load profile of charging needs
3. Mobility patterns and available battery capacity for flexibility services.

The structure of the EV load profiles and the potential use of EV batteries to offer grid flexibility services are reflections of the advances on the power system, i.e., V1G and V2G. Adoption of MaaS affects the availability of EV batteries, the quantity of EVs, and mobility patterns. Current levels of vehicle ownership and annual miles will be maintained. 90% of the time, cars will be parked, and just 10% of the day will be spent driving. To illustrate this:

5. Ownership rate of 0.4 cars per capita
6. Cars drive 20 000 km per year
7. On average, 60% of the EV will be available, and grid connected

The use of private automobiles will drop as car sharing and automated driving become more prevalent. When available and linked to the grid, cars will have better utilisation rates and, as a result, less idle time. To illustrate this:

8. Ownership rate of 0.25 cars per capita

9. Cars drive 60 000 km per year
10. On average, 20% of the EV will be available, and grid connected

DISCUSSION

PLEXOS was the modelling programme of choice for this project. A depiction of the electrical system that takes into account demand profiles, the current capacity mix by source (i.e., installed capacity and technical and economic attributes), fuel pricing, and renewable profiles may be made using this commercially available software. To reflect the overall amount of EV batteries available for flexibility services to the grid, EVs were simulated with an extra EV load profile and as a single-system battery. The programme determined the ideal capacity mix to satisfy demand in 2030 while reducing system costs overall. It also determined the ideal dispatch by technology type with hourly precision. Moreover, it computed system indicators such local power costs, energy availability, generation, and fuel offtake.

The results of the simulations were compared to a set of important performance metrics, allowing us to quantify the contributions that V1G, V2G, and MaaS provide to the integration of EVs into highly renewable energy systems. Results from the modelling exercise are shown until 2030. A qualitative perspective on how the major performance metrics could change and be viewed in 2050 completes this. Finally, a sensitivity analysis is performed for the system with a high share of solar in a business-as-usual (BAU) scenario to evaluate just the adoption of the innovations in the system and their impact on the remaining key performance indicators (e.g., curtailment, average yearly electricity cost), etc. In order to do this, the model is exogenously compelled to retain the capacity mix in 2030 at the same levels as the growth originally predicted under the BAU scenario.

Modelled cases

As the selected geographic areas are unconnected to any national or surrounding systems, they must use their own producing resources to satisfy demand. Moreover, no exports to nearby systems are taken into account, and all of the power generated inside the systems is used locally. The high-solar isolated system is representative of an equatorial locale with one of the greatest annual sun irradiances in the region and close to a 24% solar share in power production. Both in terms of the land available for large-scale PV plants and in terms of integrated PV in building roofs, façades, or windows, there is a great potential for installing PV in the system.

The high-wind isolated system is an area where wind energy accounts for 40% of the total energy generating mix. While the location benefits from significant wind resources, the land availability for wind farms might constitute a barrier for future system capacity improvements. In addition to fitting the criteria listed above, the specific locations for the two cases were chosen based on the data that was readily available for system modelling over the long term, particularly a long-term view of future load demand, the availability of solar and wind load profiles, projections of the technical specificities of the technologies (such as CAPEX, OPEX, efficiencies, etc.), and a good representation of the actual electricity system in terms of existing infrastructure. The PLEXOS tool was used to do the modelling and technical simulation. The two stated situations are modelled using PLEXOS, which also simulates them under four distinct scenarios over a predetermined horizon. The outcomes of the simulations will allow us to evaluate how important EV-related developments may affect the grid's integration of renewable energy sources [5].

Modelling in PLEXOS

A tool for simulating power systems called PLEXOS can create integrated energy models. Long-term expansion and/or short-term unit commitment models are solved using stochastic approaches, mixed and linear integer programming, and optimization. A model of the electrical systems in the two situations was created for this investigation. In terms of capacity mix, demand, renewable profile, and fuels, the models depict the system's current status.

The simulation of the models begins with long-term capacity growth and investment planning (long term). For this, the models take into account the currently installed capacity in the systems and will determine the best investment choices needed to meet the demand in 2030 and that minimise the net present value of the system's total costs over the planning horizon (Energy Exemplar, n.d.). This entails simultaneously resolving a generation and transmission capacity expansion problem as well as a dispatch problem from a long-term, centralised planning perspective. The following technologies are available to the models: combined-cycle gas turbines, open-cycle gas turbines, solar photovoltaic systems, and wind. The economic and technological characteristics for 2030 are used to model these technologies. The models will be run in a unit commitment and economic dispatch mode once the capacity mix needed to satisfy demand in 2030 is understood (short term). This hourly, chronological phase will make it easier to analyse the Effects on the system.

Moreover, PLEXOS models the existence and integration of EV using two components.

1. EV load (MWh): To indicate the additional power demand that EVs will bring to the system when they are linked to the grid for charging, in the form of a profile. Future mobility patterns, the quantity of EVs on the road, smart charging technology, and the load profile will all have an impact on it.
2. EV battery (MW + MWh): To symbolise the flexibility that EVs may provide the grid while they are being charged or discharged. This is modelled as a single-system battery that can accommodate all of the EVs' eventual grid-services-capable battery capacities.

The EV load is included into the demand-supply balance that PLEXOS solves by being put on top of the system load. Also, the model makes the best decision for how to distribute the EV batteries. The effect that the EV will have on the grid will depend on how the model balances the system, which will also be seen in the key performance metrics[6], [7].

After modelling, PLEXOS offers the best capacity investment options required to balance 2030's anticipated load. PLEXOS also offers the dispatch of the various technologies concurrently. Due to this, the primary outcomes for 2030 are:

1. Installed capacity by source (MW)
2. Generation by source (MWh)
3. Available energy by source (MWh)
4. Fuel offtake by source (terajoule, TJ)
5. Hourly marginal cost of electricity (EUR/MWh)
6. Hourly dispatch
7. Emissions (tonnes/CO_2).[8]–[10]

CONCLUSION

High EV adoption will result in a rise in peak demand, which will expand the generating and distribution grid's capacity. Peak load varies significantly between the two cases. As an example, in California If all EVs were charged in an uncontrolled manner, the peak demand would increase by 11.14%; however, if smart charging was used, the peak load would only rise by 1.33%. Smart charging may aid in grid resource optimization and assist eliminate the need to spend money on additional peak production capacity.

EV charging raises the requirement for peak power capacity and increases CO2 emissions since it is correlated with the peak load of the electrical system: If V2G is used, passenger EVs would smooth the net load curve in the Scandinavian and German energy systems such that the peak net load hour is lowered by 7%. If no V2G is used, the ERS would raise the peak of the net load curve in Scandinavia and Germany by 20% (from 127 GW to 152 GW) (from 127 GW to 118 GW).

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CHAPTER 24

ELECTRIC VEHICLE WITH MOBILE NETWORK

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ABSTARCT:

This research suggests an EV dynamic wireless charging control approach that adapts to speed change to address the issue of the electric vehicle (EV) charging quantity fluctuation caused by the variation in driving speed during dynamic wireless charging. In order to describe the charging power of each load in a multi-load scenario, a dynamic wireless charging model based on a long-track transmitting coil is first constructed. The impact of the maximum driving speed and the number of EV charging stations on the range of system parameters is then researched. The process for calculating the load resistance value in accordance with the vehicle's speed in a multi-EV charging scenario is then further detailed. A charging power management strategy that adjusts for speed variance through load modification is then suggested. The speed variation range of the variable-speed charging EV may be increased to 20–60 km/h by modifying the equivalent load, while the charging power fluctuation range of the other EVs can be maintained within 10%–15%. The experimental prototype is then constructed to test the previously specified control approach.

KEYWORDS:

Electric Vehicle (EV), Mobile,Networks, PLEXOS, Wireless Charging.

INTRODUCTION

The issue of global warming brought on by greenhouse gas emissions has become worse as human civilization has developed, making energy conservation and emission reduction even more crucial. The transportation sector has caught the attention of nations all over the globe as one of the sectors with the highest greenhouse gas emissions. Undoubtedly, the best approach to solve environmental issues is to replace dirty energy in the transportation sector first. Electrical energy may be produced from a range of renewable energy sources, which is a well-known clean energy source. Electric vehicles (EVs), which are propelled by electric energy, offer a distinct zero-emission advantage over conventional cars propelled by fossil fuels that fuel-powered vehicles cannot match. Because of this, EVs are without a doubt the ideal option for the transportation sector to encourage the optimization of the energy structure. Nevertheless, the marketing of EVs is now constrained by the high price, low capacity, and short cruising range of their battery packs. Wireless power transmission (WPT) is a potential energy supplement technique since it eliminates the need for a physical connection between the source and the load during the charging process, making it safer and more convenient than the conventional plug-in charging approach[1].

In order to efficiently minimise the size of the vehicle battery pack, enhance the cruising range, and further boost charging process flexibility, DWPT charging was created on the basis of SWPT charging. Currently, the allocation of coil segments and charging power are the major areas where the DWPT system is being optimised. Without communication networks, the authors of suggested an ideal power distribution mechanism for multi-objective WPT systems. A technique for determining the charging region for the double excitation unit wireless power transmission (DEU-WPT) system for EV dynamic charging is put forward in the literature. Based on this, a switching control approach was suggested to change the system's working mode when an electric vehicle (EV) enters a charging area. This method is advantageous for enhancing system power capacity without raising the voltage and current stress. To obtain constant current (CC) charging for the battery and to achieve zero voltage switching (ZVS) functioning of the main inverter, Jiang et al. developed a control method using a zero voltage switching angle (ZVSA) loop in the literature. A very effective nonlinear parity-time (PT)-symmetric model for wireless power transfer (WPT) was put out in the literature[2].

According to the theoretical study, the suggested system automatically maintains a constant output power and transfer efficiency despite changes in the coupling coefficient. Liu et al. found in the literature that the direct current (DC)-link voltage or the phase-shift angle may both be adjusted to regulate the transfer power. As a result, a combined control approach using phase-shift angle and DC-link voltage is suggested in order to increase system efficiency, dynamic responsiveness, and changeable power range. On the other side, several studies have looked into the segmented power transmission coil of the DWPT system's length optimization. In order to develop an EV speed profile and allocate a WPT system to a lane section simultaneously, the authors of suggested an approach based on mathematical optimization. By using the energy storage devices and the length of the power supply rail as constraints and using a particle swarm genetic algorithm, the authors of this study examined the driving characteristics of electric vehicles and the characteristics of supercapacitors with the goal of achieving the dynamic wireless charging system for EVs at the lowest possible investment cost[3].

The varying lengths of each segment rail, however, will result in variations in rail standards and make system administration more challenging. The driving pace of the EVs will have a significant impact on the charging time since they won't constantly be moving at the same speed, which also has an impact on the overall amount of charging power over a specific period of time. The charging power management system that adapts to speed variation is the main topic of this research. The DWPT system discussed in this work is suggested to combine the EV driving speed with the relevant energy consumption standard, and to modify the self-charging power in a targeted way by altering the EV's own characteristics, ensuring that the energy is evenly distributed among the EVs. The DWPT system's goal is to maximise the usage of the EVs' journey time in the wireless charging area. As a result, the aforementioned achievement of this objective is correct.

A circuit model is constructed with several secondary coils and a lengthy primary-side transmitting coil. The formulas for each EV's receiving power are developed. The range of the transmitting-side voltage and the corresponding load resistance value at the vehicle-side are examined in turn, followed by a discussion of how to calculate the load resistance value in multi-EV charging scenarios. A speed-variation-adaptive process control approach for EV dynamic wireless charging is suggested in Section 4. The theoretical analysis is supported by the practical findings once the experimental prototype is constructed using the aforementioned control mechanism. Introduction a long wireless power transmitting coil can be placed beneath the surface of the road to create a dynamic wireless charging area. A power receiving coil is mounted on the vehicle's chassis, allowing the electric power to be rectified and supplied to the battery of the EVs while the vehicle is moving through the charging area[4].

The long-track dynamic wireless power transmission (DWPT) system is shown in a schematic figure. IMN impedance matching network; AC alternating current; EV electric vehicle. In this diagram, U represents the output voltage value following rectification and inversion, Rp represents the transmitting-side equivalent resistance value, 1 2,,..., R R Rn represents the equivalent internal resistance of the power receiving coils of the first, second, and nth vehicles, respectively, Lp represents the transmitting coil inductance value, and 1 2,,..., LL We choose to omit the mutual inductance between the vehicle receiving coils when studying the circuit since the horizontal distance between the cars is much greater than the geometry of the vehicle-side power receiving coil. In other words, we solely take into account the mutual inductance between the power transmitting coil and the power receiving coil on the vehicle side (1 2 , ,..., M M Mn) 1 2 , ,..., RL The equivalent load impedance of the first, second, and nth EVs' receiving side is L Ln R R, and it may be changed via an impedance matching network (IMN)[5], [6].

DISCUSSION

The long-track dynamic wireless power transmission (DWPT) system is shown in a schematic figure. IMN impedance matching network; AC alternating current; EV electric vehicle. The equivalent circuit diagram of the previously mentioned long-track EV DWPT system is shown in Figure 2, where U is the output voltage value following rectification and inversion; Rp is the transmitting-side equivalent resistance value; R1, R2,...,., Rn are the equivalent internal resistance of the power receiving coils of the first, second, and..,.,.,.,.,.,. We choose to omit the mutual inductance between the vehicle receiving coils when studying the circuit since the horizontal distance between the cars is much greater than the geometry of the vehicle-side power receiving coil[7].

It may be assumed that the mutual inductance, M1 = M2 =... = Mn = M, between each power receiving coil and the transmitting coil is about equal. The analysis may be further streamlined by assuming that all EV models in the charging region are the same and that the starting value of the vehicle-side equivalent load impedance is equal to RL. In this case, the charging power of a single EV can be written as follows: P = [(R1 + RL)Rp + n2M2] = 2M2U2RL. (4) 2019, 12, 2214, 5 of 13 energies 3. Technique for Calculating the Corresponding Vehicle-Side Load Resistance Value Determining the Transmitting Side Voltage Range and the Corresponding Vehicle Side Load Resistance Value The ideal charging power control method should be that the system adjusts its own parameters in accordance with the EV driving speed in order to adapt to the driving state of the EV and thereby realise a flexible energy supplement. This is because the DWPT service system's target is an EV in the charging area. Hence, in order to accomplish the EV charging power management, this study proposes altering the system parameters in accordance with the lower limit of the charging power requirement associated with varied speeds. The size of the transmitting coil must be determined using the "two-second principle" before looking at the multi-vehicle charging scenario in the charging area.

A safety space of about 33.33 m should be maintained between adjacent cars at the 60 km/h speed limit. The BYD e5 is used as a reference to establish the EV settings in this article. The car is 4.68 metres in length and 1.765 metres in width. The length of the transmitting coil is about equivalent to l = (33.33 + 4.68) 3 = 114.03 m, and we choose an integer to make the length of the transmitting coil 120 m. This is assuming that the charging area can handle up to three automobiles for simultaneous charging. We adjusted the transmitting coil width to 1.5 m and the vehicle receiving coil size to 1 m 1 m in order to minimise the impact of the offset between the coupling devices and use the whole effective area of the vehicle chassis at the same time. In this study, the long-track DWPT charging system's required charging power is established in accordance with the vehicle's power consumption per unit of kilometres, denoted by Q, in order for the car to be charged in the charging area [8].

According to Joule's rule, Q = P • t, and t = L/v, where L is the length of the road segment (one kilometre), v is the speed, and t is the amount of time it takes for the car to traverse one kilometre. Thus, the critical charging power of a single vehicle has the formula P0 = Q•v L, which indicates that while the driving speed is v, the charging power cannot be less than P0 in order to balance the car's unit kilowatt-hour power consumption, Q. [9]Using the BYD e5 as an example, a single car uses 0.15 kWh of electricity every unit of kilometre. The range of the car's speed during dynamic charging is 0–60 km/h; the lowest allowed charging power for a single vehicle, which corresponds to a speed of 60 km/h, is 9 kW. As a result, P0i in combination with Equation may be used to calculate the range of the transmitting-side voltage and load value at various driving speeds. The DWPT system's precise parameters M[10], [11].

CONCLUSION

In order to achieve the goal of fully using the EVs' travel time in the wireless charging region, a DWPT charging control approach based on a long-track DWPT system has been developed in this study. This method involves regulating the load resistance in accordance with the EV driving speed. The analysis of the long rail type DWPT system's charging power comes first. The critical load resistance adjustment value for a given n and v0 is calculated by adding the kilowatt power consumption of the vehicle. Lastly, the effect of the load resistance variation on the maximum speed for EV dynamic charging is investigated. Experiments are used to confirm that the aforementioned control mechanism is practicable. The control strategy suggested in this study addresses the issue that, in the case of variable speed charging, the energy generated by two vehicles cannot satisfy the energy requirements of the vehicle. This control method's drawback is that it can only be used for single-EV variable-speed charging. Hence, the charging control technique under the condition of multi-EV variable-speed charging may be further researched on the basis of the suggested DWPT system control method in the case of single-EV variable-speed charging. In addition to the DWPT charging system based on a long-track transmitting coil, more research must be done on the control strategy for the DWPT system modified for EV variable-speed charging.

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CHAPTER 25

A COMPREHENSIVE STUDY ON HOME CHARGING

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ABSTRACT:

A synchronised development of infrastructure at home and in public places facilitates and supports the adoption of electric cars. Although public infrastructure enhances the electric car argument for potential purchasers, boosts the possible electric mileage from electric vehicles, and provides charge for individuals without home charging, home charging provides the majority of the charging required for most drivers. Prospective buyers of electric vehicles, manufacturers, legislators, and electric utilities all have concerns about how much charging infrastructure would be required and how much it will cost.

KEYWORDS:

Electric Vehicle (EV), Mobile,Networks, PLEXOS, Wireless Charging.

INTRODUCTION

A new charging gap study clearly shows the need for much additional electric car charging infrastructure across the United States until 2025. 1 According to that research, by 2025, there will need to be around four times as much public charging infrastructure as there was in 2017. According to the estimate, the 100 most populated U.S. metropolitan regions will need at least 100,000 public and workplace chargers between 2019 and 2025. By 2025, it is anticipated that these 100 places would have 2.6 million new plug-in hybrid electric vehicle (PHEV) and battery electric vehicle (BEV) sales combined. This study examines the capital expenditures for the infrastructure required for home, office, and public electric car charging in the 100 most populated US metro regions from 2019 through 2025. We examine pricing information for charging equipment, including hardware and installation, for chargers of different charging kinds and locations. The prices of the equipment are then applied to our most current estimates of the demands for public and workplace charging, as well as the needs for residential charging that are now being evaluated. In the end, we calculate the infrastructure expenses based on metropolitan areas[1].

The charging prices outside the 100 biggest markets, or in smaller cities and fast-charging corridors connecting the cities, are not included in this scope. Costing according to region and kind the infrastructure for electric car charging types is discussed in this section in relation to the charging site. In order to determine typical hardware and installation costs for both home and nonhome charging, cost estimates and research papers were employed. The next section builds estimates by metropolitan region using these installation and hardware prices. In this research, the following three types of electric car chargers are evaluated: Levels 1, 2, and rapid direct current (DC). Basic information about the various charger levels examined in this paper. The usual power in kilowatts (kW) represents the rate of energy transfer, and the voltage (V) column indicates the voltage at which electricity is given to the electric car. It also displays the common charging stations and the accompanying miles of range per hour of charging for electric vehicles. Level 1 charging is often used at home, whereas Level 2 charging is utilised in a range of charging scenarios and DC fast[2], [3].

They are based on the most up-to-date and thorough cost estimates from the many studies into the price of non-residential infrastructure. Using 1,294 Level 2 charging stations at 637 locations, the Electric Power Research Institute (EPRI) examined the costs of labour, materials, permits, and taxes. Also, the EPRI analysis illustrates how per-charger prices decrease when additional chargers are added per site, i.e., sites with 3-5 chargers and sites with above 6 chargers. Expenses are further broken down by California-based locations in comparison to those throughout the rest of the nation and are used as such in this research. Based on the EPRI report, we assume workplace charging costs for our analysis. The client often receives an upgrade allowance from the utility, and then is responsible for the remaining cost of the update. Our installation prices for DC fast chargers are based on two sources. Information from the Rocky 6 Each Level 2 charging installation now costs an additional $36.99 due to changes made in the Southern California Edison service area[4].

Installation costs per charger decrease when additional chargers are placed per location, similar to Level 2 charging. A charger with three times the power does not result in three times the cost since expenses do not increase proportionately with power. As a result, installation costs mostly depend on the quantity of chargers per site. The importance of power and multi-charger locations in influencing per-charger installation costs is shown in Table 4. For instance, installation expenses at a location with one 50-kW charger are around $45,000. The cost of installation rises by around $65,000 when the power is increased by 7 times to 350 kW due to greater material costs and the possibility that switchgear and distribution lines may need to be replaced. While we indicate an increase of almost $20,000, this is very variable and, depending on the charging site, some 350 kW sites need very costly changes while other sites just need small upgrades.

Based on the aforementioned per-charger cost examples and trends in the number of chargers per site, we may forecast general future charging improvements. Smaller markets may use recent information on the number of chargers per site from U.S. urban regions with higher electric car adoption. Markets are first classified and binned by the state of the development of the electric vehicle market by metropolitan area at the end of each year from 2014 to 2018, in order to ascertain the link between chargers per site and electric vehicle market development. Electric cars per million people, which range from 6,000 in areas with low electric adoption to 40,000 in places with strong uptake, are used to define the market development bucket. After that, the linked charger sites and their respective site densities were examined by metropolitan region. To correspond with the characteristics examined above, these sites are divided into four groups: 1, 2, 3, and 5 or more chargers per site. Sites with six outlets or more are uncommon in places with few electric cars per million people, but they may nevertheless make up a significant fraction of the charging stations in a metropolitan region [5].

DISCUSSION

An increase in the number of chargers per location in regions with more electric car use. The relative growth of the electric car market is shown on the horizontal axis as automobiles per million inhabitants in bins. On the basis of the charger data for all the metropolitan areas in each bin, the vertical axis displays the proportion of chargers per site size category. For instance, at the lowest market development level examined 6,000 electric vehicles per million people—about 30% of charging outlets are at locations with two chargers, 30% are at locations with three to five chargers, 30% are at locations with six or more chargers, and the final 10% are at locations with just one charger. The majority of metro regions fall into the lower categories, while the 40,000 electric cars per million category is represented. Retrieved from Alternative Fuel Data Center (Electric, hybrid, and other alternative fuel stations) The pattern implies that as the market for electric vehicles expands, so do the number of outlets per site and the cost per outlet. The greatest market penetration category will be determined by total sales in San Jose by the end of 2018, where there are 40,000 electric cars per million people and 60% of all outlets are found at locations with six or more chargers. The equations are applied to the infrastructure buildout cost analysis that appears in the cost scenario section that follows, and the lines indicate the natural log fit of these points. DC fast chargers do not exhibit the same obvious trend for chargers per site vs electric car penetration as Level 2 chargers do. Yet, the total size of the site for new installations is expanding annually. We extend the trend from 2014-2018 into the future in order to represent a general rise in the number of charges per site. There were 11%, 20%, 17%, and 52% of chargers at sites with one, two, three to five, or six chargers, respectively, in 2018. For 2025, such percentages are 5%, 13%, 15%, and 67%. These proportions are Among the 100 most populated U.S. metropolitan areas, costs are projected for home, public, and workplace charging for over 2.6 million new electric car sales between 2019 and 2025. This results in a 2.3 million vehicle stock increase and a total stock of 3.2 million electric cars in the top 100 metropolitan areas in 2025, according to a model of the whole vehicle fleet that takes vehicle retirement into account. This amounts to 88% of the projected 3.6 million electric cars expected to be in use in the US by 2025. The cost possibilities provided below are calculated based on the annual sales of electric vehicles and the total cost of all metropolitan regions combined.

HOME CHARGING

The ecology of charging includes home charging, which is significant. Below is an analysis of the cost to support new electric car sales in the top 100 most populated metropolitan regions from 2019 to 2025. To offer a breakdown of electric cars by home charging category and housing type, we use electric vehicle charging dynamics and sales across metropolitan regions and the areas' housing stock as in our prior analysis11. Table 6 lists our overall projections for the number of electric car sales in the United States from 2019 to 2025 for each kind of home charging scenario and for all dwelling types. There are three different house styles, two kinds of cars (BEV and PHEV), and seven different categories for home charging[6].

Drivers that mostly depend on workplace and public charging are shown in the first row. The three types of Level 1 customers are those who install a new, upgraded 120-volt home outlet for their electric car, those who have an existing outlet with no improvements required, and those who install a Level 1 charger upgrade specifically. Comparable to Level 1 categories, Level 2 home charging covers those with existing 240-volt dryer-type outlets as well as improvements for new outlets and new dedicated chargers. The findings of a survey conducted by the California Air Resources Board were used to calculate the ratios for identifying the outlets and upgrades by charge level[7], [8].

Although the findings are shown below for all 100 regions together, the total charging infrastructure costs, the key underlying cost factors, and the costs per electric car are all calculated based on the individual demands in each of the 100 areas[9], [10]. The total expenses for workplace, public Level 2, and DC fast charging from 2019 to 2025, broken down into hardware, labour, materials, permits, and taxes. The total expenses for that charger type are shown on the vertical axis and are around $190 million, $360 million, and $390 million for workplace, public Level 2, and DC fast chargers, respectively. As shown, hardware costs make up the majority of each case's expenditures, accounting for 43%, 40%, and 68% of the overall expenses for each of the three charging methods, respectively. In terms of cost component breakdown, workplace chargers and public Level 2 chargers are comparable, although DC fast charging hardware is more costly, particularly for the highest power stations driving a relatively high hardware cost, as stated on a percharger basis. Hardware expenditures total roughly $490 million, with labour costs coming in at $230 million, materials at $190 million, taxes at $12 million, and permits at $9 million, in that order. In addition to how average charging prices for extra charging required in each year drop on a per-electric-vehicle-sold basis, annual charging infrastructure expenses rise over time with larger electric car sales volumes. Three things are to blame for this deterioration. First, fewer chargers are required for each electric car due to increased charger use, measured in hours of daily active charging per charger. Second, with increasing market penetration, installation costs decrease as the number of chargers per site rises.

CONCLUSION

In this research, we assess the capital expenditures, including hardware and installation, for a case in which there are 2.6 million new electric car sales in the top 100 U.S. metro regions from 2019 to 2025. Our main conclusions are as follows: the cost of home charging for these electric cars is $1.3 billion, while the cost of new workplace, public Level 2, and DC fast charging is $940 million. A thorough charging ecosystem's many important components are not included in the home and public charging expenses examined here. This research does not take into account the infrastructure required for fast-charging corridors connecting cities, which was the initial focus of certain efforts by the car industry. The 100 metropolitan regions examined here account for 88% of all newly sold electric cars and 75% of the whole U.S. auto market; however, this research does not include smaller markets. The project management and land-related expenses, which may vary greatly and depend on location, are also not included in this study. Lastly, these cost projections do not take into account the possible expanded electrification of ride-hailing services. Nonetheless, it is crucial to offer capital cost estimates in order to determine the amount of infrastructure investment required in critical markets.

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