AN ARCHIVE OF SWITCHGEAR AND RELAYING

Sunil Dubey, Dr. Prabhu T

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CHAPTER 1

REVIEW ON FUNDAMENTALS OF SWITCHGEAR ANALYSIS

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ABSTRACT:

Switching and safety devices in a variety of forms have been developed. As a result, the term "switchgear" can be used to refer to a wide range of electrical equipment that is involved in switching, protecting, and controlling various electrical devices. The Industrial and Commercial Power Systems Committee is working on a proposed publication on preferred practice in system protection and coordination. It offers concepts for how protective equipment can be used on buses and switchgear for industrial and commercial power systems. We have to protect our devices or equipment in power system network that the reason of using switching.

KEYWORDS:

Electrical, Equipment, Network, Power Systems, Switching.

INTRODUCTION

In the beginning of the 20th century, it was almost certain that a switchgear lineup would consist of an enclosed metal structure with oil circuit breakers and electrically operated switching components. Automatic equipment can now safely regulate a wide range of currents and input voltages thanks to the effective replacement of oil-filled equipment by air-blast, vacuum, or SF6 equipment.

The term "switchgear" refers to any combination of switching devices and the associated control, measuring, protective, and regulating equipment. The term refers to groups of these devices and equipment, as well as the enclosures, supporting structures, interconnections, accessories, and enclosures that go along with them and are intended for use in transmission and distribution networks. The various types of air, oil, vacuum, and SF6 switchgear, in addition to the arc interruption theory. Before electricity was invented, switchgear was in use. The initial designs were extremely straightforward, with each component directly attached to the wall. After that, wood frames were used to mount them[1]. For the sake of fire safety, slate or marble were used in place of wood. This led to additional modifications because the measuring and switching instruments could be connected to the front while the wire was on the back. A tumbler switch with an ordinary fuse was the simplest type of switchgear and was used to operate and secure lights and other appliances in homes, workplaces, and other locations. Higher-rated circuits can be controlled and secured with the help of a switch and a fuse with a high rupturing capacity (H.R.C.). Moreover, such switchgear is unprofitable on a high-voltage grid. In an electric power system, electrical disconnect switches, fuses, and circuit breakers are used to operate, secure, and differentiate electrical devices. Switch gear is made up of these components. Equipment is de-energized by switchgear in order to clear faults downstream and perform maintenance tasks on it. This kind of equipment is directly related to how efficient the power supply is. With oil-filled switchgear, arc energy can be safely stored and managed.

You must keep an eye on the mechanical and electrical parameters that have an effect on the health of the device in order to comprehend the state of the high voltage switch throughout its entire life cycle. As a result, an innovative ARM-based high voltage switch gear detecting unit is presented in this paper. To assess the device's health, it can measure the temperature of the contactor, the storage motor current wave, and the closing-opening mechanical wave. It can be alert and offer guidance when something goes wrong. The experiment demonstrated its suitability for online temperature and mechanical properties of a circuit breaker detection. The equipment that is used to switch, control, and protect electrical circuits and equipment is known as switchgear. Switches, circuit breakers, switch fuse units, off-load isolators, HRC fuses, contactors, miniature circuit breakers, ELCBs, GFCIs, and other switching devices are all included in the broad category of "switchgear"[2].

The arrangement of these switching devices includes with the equipment that controls, measures, protects, and regulates them. Electrical energy generation, transmission, distribution, and conversion all rely on the switchgear devices and assemblies. In our homes, we are all familiar with low voltage switches and re-wireable fuses. Fuse protection against overcurrent and short-circuit is provided by switches, which are used to open and close electric circuits. As a result, a switching and protecting device are necessary for each and every electrical device. As a result, the primary focus is on the explanation of a variety of switching phenomena under a variety of real-world circuit conditions before applying these fundamental concepts to the various designs of switchgear currently on the market.

LITERATURE REVIEW

According to the Ibrahim et al. [3] as talked about to its advantages of high reliability and performance, compact dimensions, and outstanding environmental compatibility, gas insulated switchgear (GIS) plays a crucial role in the transmission of electrical energy at high voltages. Due to its high dielectric strength and excellent ability to quench arcs, it uses sulphur hexafluoride gas as an insulant and coolant. When in use, gas-insulated switchgear faces the challenge of insulation decomposition and eventual failure as a result of partial discharge caused by defects. Since this failure is catastrophic and will result in a complete power outage that affects all human activities, gas insulated switchgear condition monitoring and diagnostics are required for preventive maintenance. In order to carry out preventative maintenance and avert its failure, this paper examines diagnostic techniques and methods for Gas insulated switchgear insulation degradation caused by partial discharge.

Biasse et al.[4] conducted that in public and industrial applications, MV switchgear are crucial components of the overall electrical distribution networks. Condition monitoring is used in electrical switchgear predictive maintenance for a long time. More data can now be collected and trends can be analyzed thanks to recent advancements in condition monitoring technology. This paper provides a comprehensive overview of the various condition monitoring technologies that are currently available for electrical switchgear. These technologies include partial discharge monitoring, vacuum monitoring, thermal monitoring, pollution and climate monitoring, and vacuum monitoring.

According to A. U. Dowell, et al.[5] they talk about that do not adequately reflect the current service and type test requirements or practices but there is an examination of the current specifications for switchgear has revealed that, in some ways This is mostly due to the inevitable and time-consuming process of developing specifications. This paper aims to highlight and discuss some of these issues. The first section of the paper discusses the significance of single-phase conditions for testing and application, as well as a few issues with unit and synthetic testing and possible solutions to them. The need for greater care in maintaining the mechanical integrity of circuit breakers, evaluating their thermal capabilities, and adapting to shifting environmental conditions is brought to the forefront.

S.H Telander conducted et al. [6] conducted that in motor feeder applications where motor terminal surge protection is not typically utilized, the use of vacuum circuit breakers may necessitate the installation of overvoltage surge protection within the switchgear in order to adequately safeguard the motors. Surge limiters that are made to be installed inside the switchgear that is connected to the load side of the vacuum circuit breaker can meet this need. The authors discuss the need for surge limiters and go over the fundamental phenomena that lead to surges in vacuum switchgear. They also provide information and performance data for the application of these surge limiters as well as a description of their design.

C. Kimblin, [7] gives the statement about Contactors, motor starters, tap-changers, distribution equipment, and metal clad switchgear all make extensive use of vacuum interrupters. A brief history of the development process, descriptions of the internal components of a vacuum interrupter, and a discussion of the variety of applications for these devices round out the current paper's examination of this developing technology. A discussion of the arcing and interruption phenomena that take place in vacuum interrupters during an alternating current wave is included alongside a description of the fundamental physical properties of cathode and anode spots. An explanation of arc initiation, the high current arc mode, current zero phenomena, dielectric recovery, and voltage withstand are all included in this. Included are the effects of electrode configuration and material. The paper concludes with a brief description of dc applications for vacuum interrupters, including the use of transverse magnetic fields to commutate current from vacuum arcs to parallel circuits and the use of axial magnetic fields in conjunction with a current counter pulse in to make circuits. The extensive references were chosen to provide the reader with a more comprehensive understanding of vacuum switching technology.

Henning Text,[8] gives statement about due to its excellent insulation and current interruption capabilities, SF6-gas is currently utilized extensively in switchgear for both medium and high voltages. However, given its high potential to cause global warming, there is political pressure to replace it whenever possible, necessitating the development of novel, cost-effective, and compact switch gear. Reviewing and further developing promising technologies prior to SF6's arrival is an obvious response. In a process known as ablation, one of these was the use of insulation materials that released gases. From the 1930s to the present, a variety of commercial breaker designs have utilized ablation in the interruption process. This paper examines these designs. The main designs and advancements are described, as well as some crucial parameters like the steady-state ablation-dominated arc, arc quenching, and dielectric recovery when ablation material is present. The ratings of the aforementioned products as well as more recent experiments indicate that simple ablation-assisted breakers have a design limit of approximately 20 kV, but the reasons for this apparent limit have not been thoroughly investigated or explained. For the development ofSF6-freeMV switchgear, reviving ablation breaker knowledge and combining it with new information and tools could be beneficial.

According to S. Yanabu et al.[9] circuit breakers were at the forefront of advancements in high voltage transmission and distribution equipment in Japan during the 20th century. And as a result, 1100 kV SF6 gas insulated switchgear (GIS) for ac transmission systems as well as 500 kV dc GIS for dc transmission systems are now available. Vacuum circuit breakers (VCBs) are also being actively developed, and 168 kV two break and 100 kA VCBs are already on the market.

According to the C. Xu et al. [10] the cryogenic switchgear that will be used in multi-terminal superconducting power systems in the future is introduced in this study for protection and control purposes. Cryogenic switchgear implementation is anticipated to increase system dependability and reduce overall volume and weight, although such switchgear is not currently available. Typical circuit breakers are used as a starting point for the design of cryogenic switchgear before a quick overview of contemporary switchgear technology is provided. Then, promising cryogenic interruption media are found and their physical and dielectric characteristics are examined. Finally, we suggest a number of cryogenic circuit breaker designs for prospective applications in the aircraft, marine, and land sectors. Investigated is the cryogenic switchgear's actuator mechanism.

According to D. Grattan et al. [11] designed electrical circuit breakers are tripped in the process industries for a variety of reasons, including to prevent and reduce hazards. The use of tripping electrical breakers for process safety is the topic of this paper. A lot of the time, a risk assessment study will find that a safety instrumented function (SIF) must include the shutdown of a large electric motor. Medium-voltage switchgear breakers are frequently used in the process industries to control and safeguard large Hp motors. The unique final element subsystems of safety instrumented functions, such as electric motors with medium-voltage switchgear for tripping, necessitate specialized knowledge for proper implementation. The design considerations for incorporating medium-voltage switchgear used to shut down an electric motor into a safety instrumented function will be discussed in this paper. First, we'll go over the typical low- and medium-voltage electrical components that are used to control and protect electric motors. Following that, a review of medium-voltage switchgear breakers' generic sourced failure data will be presented. The taxonomy used to classify various breaker types and the relevant failure modes and effects used to quantify performance will be the primary focus. In the context of achieving a particular integrity level, specific SIF design details for tripping medium-voltage switchgear breakers will then be examined. Hardware fault tolerance requirements, voting, available diagnostics, energize versus de-energize to trip shutdown circuits, certified versus proven-in-use equipment, and alternative shutdown methods are all factors to take into account. This paper will also look at the electrical equipment that can be used by multiple potential protection layers to trip the same breaker. It will also figure out how much credit can be given for failure with a common cause. Finally, medium-voltage switchgear inspection, testing, and preventive maintenance (ITPM) will be discussed as a way to keep electrical equipment in "as good as new" condition.

According to H Fugazza et al.[12] have given the statement about a wide range of technical requirements must be met by emergency power supply systems. They must meet stringent reliability requirements and be clearly organized. Complex power supply installations with integrated switchgear and distribution equipment are described following a review of emergency supply systems. Installations that are both function-oriented and cost-effective can be built thanks to the MNS system. A communications center serves as an illustration of the compact design of the power supply's standard and unique modules. An automated star/stop control system for diesel engines that was recently developed and designed to simplify control is described.

DISCUSSION

The term "electrical switchgear" refers to a centralized collection of circuit breakers, fuses, and switches also known as "circuit protection devices" that serve the purposes of safeguarding, controlling, and isolating electrical equipment. Metal structures hold the circuit protection devices in place. A switchgear line-up or assembly is a collection of one or more of these pieces. Switchgear is commonly found in medium- to large-sized commercial or industrial facilities, as well as in electric utility transmission and distribution systems. In North America, IEEE sets standards for electrical switchgear, while IEC sets standards for Europe and other regions.

An Electric Power System's primary function is to generate and distribute electrical energy to end users. The power system ought to be designed and managed in such a way that it can deliver this energy to the points of use in a way that is both economical and reliable. Because the power system's capital investment for generation, transmission, and distribution is so high, it is necessary to take the necessary measures to ensure that the equipment not only operates as close as possible to peak efficiency but is also protected from accidents.

Types of Switchgear:

There are three different types of switchgear:

1) **LV(Low Voltage)**
2) **MV (Medium Voltage)**
3) **HV (High Voltage)**

A. LV switchgear

A power grid that operates at less than 1 kV is referred to as low voltage switchgear, and the secondary side of the power distribution transformer also has low-voltage switchgear. A substation is this arrangement of transformers and switchgear. Most of the time, low-voltage switchgear is used to feed LV-MCCs, low-voltage switchboards, and other feeding and branching systems. It supplies electricity to critical energy and process applications like heavy industry, construction, mines and steel, petrochemical, pulp and paper, water, and healthcare. Switches, LV circuit breakers, HRC fuses, earth leakage (EL), disrupting circuit breakers, offloading electrical insulators, MCBs, and MCCBs are the most frequently used pieces of equipment.

B. MV switchgear

MV switchgear is a type of switchgear that can handle voltages between 3 and 36 kV. It comes in a variety of designs, including outdoor models with metal enclosures, indoor models with metal enclosures, and outdoor models without metal enclosures. In this kind of switchgear, oil, vacuum, and SF can all be used as disturbance mediums. In the event of a grid failure, this type of power network is primarily responsible for interrupting current flow. Numerous applications make use of this, which is capable of ON/OFF service, capacitive current switching, inductive current switching, and short circuit current interference. Examples of applications include arc furnaces, medium-voltage electrical transmission lines, vacuum, SF6gas-insulated, air magnetic, gas-insulated, and electrical power generating stations.

C. HV switchgear

A power system that deals with voltages greater than 36 kV is known as high voltage switchgear. The arcing that occurs during switching operation is also extremely high due to the high voltage.

As a result, high-voltage switchgear construction necessitates extra caution. Since the high voltage circuit breaker (CB) is the most crucial component of HV switch gear, it must have particular characteristics to function safely and reliably. Faulty tripping and switching operations in high-voltage circuits are extremely unlikely caused by friction in the dielectric contact within the circuit breaker, which may result in the destruction of the entire system or workplace. In the worst case, the light or sparks will initially be detected by the light sensor, which will activate an alarm to notify the controller of the malfunction and prevent any damage to the system.

The state of operation of a power system in any abnormal condition is known as FAULT. However, the insulation may break down due to either the effect of temperature and age or a physical accident. Short circuits and open circuits are the two most common types of faults. Short circuit faults are more common than open circuit faults, and they frequently become short circuits as a result of subsequent events. The power source obtained the normal path of the electric current to the load runs through insulation in generators, transformers, and transmission lines. The current may, nevertheless, follow an abnormal path that is generally referred to as a Short Circuit or Fault.

There are two different types of Faults:

1) **Short circuit fault current**
2) **Open circuit fault- voltage**

Both the faults are later divided into further types as shown below:

Short circuit fault current: Short circuit fault further divided into three types, as they follows given below.

- **i.** 1- Phase faults
- **ii.** 3- Phase faults
- **iii.** Single phase to earth faults

Open circuit fault- voltage: Open circuit fault further divided into three types as they follows given below.

- **i.** 1- Phase open Circuit
- **ii.** 2- Phase open circuit
- **iii.** 3- Phase open circuit

Although some open circuits pose some potential hazards to personnel, short circuits are of far greater concern in terms of the severity of the consequences of a fault.

Consequences of existence of faults:

- **i.** Equipment damage as a result of abnormally high, unbalanced currents and low voltages caused by short circuits
- **ii.** Equipment faces explosion having insulating oil, especially during short circuits. It results harmful effect and fire and to equipment and also personnel.
- **iii.** Single generators operating at a lower voltage in a power station or a group of generators operating at a lower voltage may cause loss of synchronism, resulting in islanding. This could cause a fire as well as hazardous conditions for personnel and equipment.

iv. The potential for synchronous motors in large industrial buildings to trip and fall out of step.

Classification of Organization Switchgear committee:

Let's understand the classification of organization switchgear committee with the help of given below Figure 1.

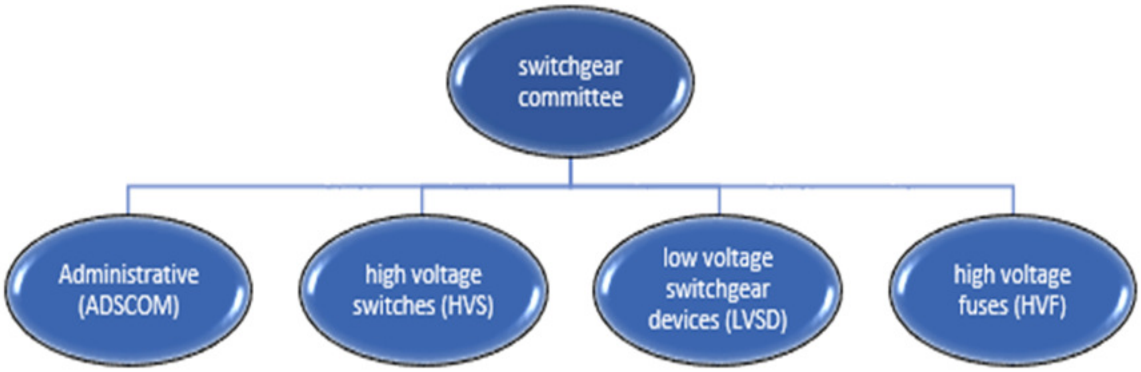

Figure 1: Illustrate the Organization of Switchgear committee.

Some basic terminologies used for the requirements of protection system:

i. **Reliability:** The correct operation of the protection system is termed as reliability. Security and dependability are the two fundamental components of the reliability feature. In the event of a fault, the dependability feature demands that the designed system operate correctly. In a similar vein, the capacity of the designed system to prevent incorrect operation during faults can be defined as the security feature. Before the protection system can be put into operation, a comprehensive statistical method-based reliability study must be conducted.
This feature of any protection system is affected by a number of factors, some of which are listed below.
   1) The design philosophy, the supply and availability of spare parts and stocks.
   2) The repairing schedule,
   3) The quality of the employed components
   4) The electrical and mechanical stress that the protected portion of the system is exposed to are all factors.

ii. **Speed:** The shortest amount of time it takes to fix a problem to prevent equipment damage. The protection system's speed is mostly made up of two important time intervals.

   a) Time for the Relay: It is defined as the period of time between the moment the fault occurs and the moment the relay contacts open.

   b) The Time Breaker: It is defined as the period of time between when the relay contacts are closed and when the medium experiences its final arc extinction and the fault is removed.

iii. **Selectivity:** By disconnecting only the minimum portion of the network required to isolate the fault, this feature aims to maintain supply system continuity. Discrimination is another name for selective tripping. Because of this, the entire system is divided into several protective zones to ensure that the network is accurately isolated in the least amount possible. Time-graded systems and unit systems are two applications of this feature in a relaying scheme.

iv. **Sensitivity:** The smallest value of the actuating quantity at which a relay operates to detect any abnormal condition is referred to as its sensitivity. The ratio of the short circuit fault current (Is) to the relay operating current (Io) in the case of an overcurrent relay can be expressed mathematically. The relay shouldn't be too sensitive or slow to respond if the value of Io is too small or too big.

v. **Stability:** Stability within a set of defined operating scenarios and procedures is a quality of any protection system. For instance, differential protection's biased differential scheme is more stable against switching transients than differential protection's more straightforward Merz Price scheme.

vi. **Adequacy:** A system that is protected 100% of the time is not financially viable. As a result, the criticality and importance of the protected zone affect the cost of the designed protection system. Because all of a good protection system's features are maximized in this area, the protection system for more critical parts is typically more expensive. However, a straightforward and inexpensive thermally operated relay can safeguard a small motor. As a result, the cost of the protection system ought to be sufficient.

Even though switchgear provides protection for a variety of electrical devices, it is necessary to constantly monitor the devices themselves to prevent any malfunctions. Arc faults, increased pressure, and increased heat are the most typical issues that Switchgears encounter.

i. Temperature Rise

a. The temperature has grown to be a major concern because the switchgear contains extremely high-voltage equipment. With repeated visits to the setup, it is impossible to continuously monitor the switchgear temperature conditions because problems can get worse if they are not fixed immediately.

ii. Vacuum / Over pressure

a. During the suction of air, a small amount of pressure remains within the switchgear containers or escapes, causing significant performance degradation. Due to the buildup of pressure in the undesirable system breach, this could have an effect on future processes or cause an explosion.

iii. Arc Flash/ Arcing

a. During the opening of current-carrying contacts in a circuit breaker, the medium between the opening contacts becomes heavily ionized. This makes it possible for the interrupting current to travel along a low resistive path even after the contacts are physically isolated. Because an arc fault in the switchgear results in a prolonged power outage, the destruction of equipment, and a risk to workers' safety, we are compelled to take preventative measures well in advance of any unwelcome incidents. A more proactive and comprehensive arc-flash prevention system can be made possible through continuous equipment monitoring and early detection of potential failures.

Types of Protection

i. **Primary protection**
ii. **Back-up Protection**

i. **Primary protection:** The strategy which protect the primary makes sure that any faults inside the boundaries of the circuit element that the zone is supposed to protect are quickly and carefully cleared. Each portion of an electrical installation typically has primary protection. The principal defence, however, might fall short. The main reasons why the Primary Protection system failed are listed below.

a) Voltage or Current provide to the relay
b) Tripping voltage store D.C
c) Circuit Breaker
d) Tripping circuit
e) Protective relays

ii. **Back-up Protection:** The protection that backs up the primary one in the event that the primary one fails is known as back-up protection. By definition, the primary protection system is faster than the backup protection system. Back-up protection is essentially the second line of defense after the primary protection system, and its design must be coordinated with that of the primary protection.

Zones of Protection system

There are several protection zones in an electric power system. In addition to two circuit breakers, each protection zone contains one or more power system parts as shown in below Figure 2.

i. The boundaries of a particular zone comes under when a fault occurs, the zone's protection system isolates all of the equipment in that zone from the rest of the system by tripping the Circuit Breakers.

ii. The zone component and the remainder of the power system are separated by the circuit breakers. As a result, the boundaries of the protection zones can be better defined by the location of the circuit breaker.

iii. The overlapping of various neighboring zones of protection ensures that no part of the power system is left unprotected. However, if the fault occurs in the overlapped area, a series of different circuit breakers will trip, requiring only minimal effort to disconnect the defective component.

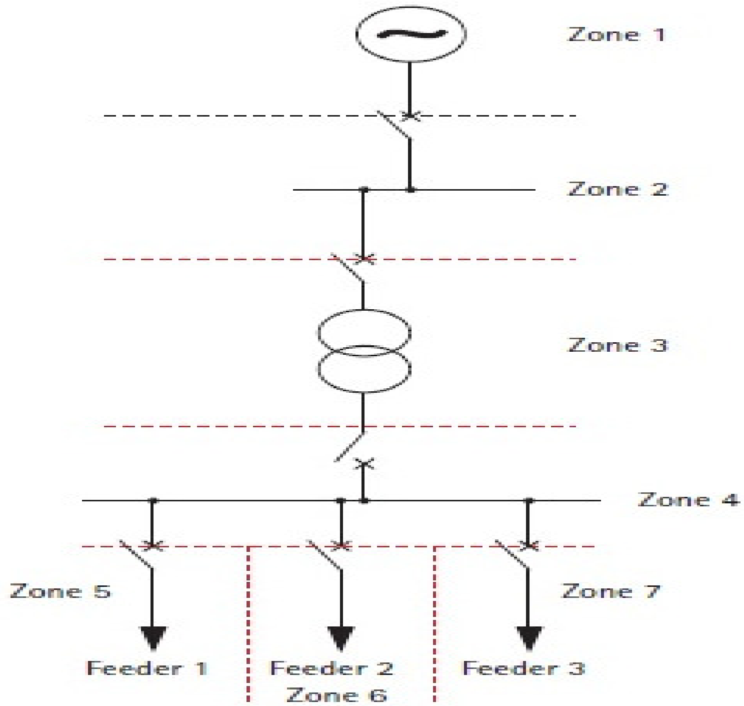

Figure 2: Illustrate the Zones of Protection system.

CONCLUSION

The main goal of this review is to provide a brief overview of the fundamental of switchgear and the difficulties encountered in one. Electrical switchgear is a key component of electrical control systems used to transfer and selectively segregate electrical loads all over the world. Particularly, the unexpected temperature increase in a specific spot might be a sign of corrosion or another kind of flaw.

This further necessitates control of the network pressure within the switchgear to prevent excessive pressure, which could result in serious dangers. As a result, this needs to be maintained using reasonably priced, advanced technologies that allow us to continuously monitor the system health of the switchgear and its components through online monitoring systems. Furthermore, from a commercial perspective, any electrical power supply needs a weighing, controlling, and regulating scheme.

Switchgear and power system safety are two terms used to describe the complete system. In today's power networks, from generation to transmission to delivery, switchgear safety is essential. Like a switch, the switchgear must be able to carry, make, and split regular load currents as well as handle simple control grid faults and also circuit breaker is a part of this.

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CHAPTER 2

CONCEPT OF CIRCUIT BREAKER

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ABSTRACT:

More than 60% of all accidents in the power transformation and distribution system were unplanned blackouts brought on by faults in high voltage circuit breaker systems. A method for understanding the concept of circuit breakers is presented in this paper based on the electrical characteristics of circuit breakers. Circuit breaker prevent our components and electrical equipment. The contacts of circuit breakers that switch on and off can be compared to a capacitance that changes over time. The term "automatic means of power removal from a defective device" is frequently used to describe the general feature of a circuit breaker or fuse.

KEYWORDS:

Circuit breaker, Distribution, Electrical, Transformation.

INTRODUCTION

The electrical circuit breaker is a crucial piece of equipment to safeguard the electrical system from harm. These gadgets are made to cut off the electricity when there is an overload or a short. When working under unusual conditions, the breakers have both automatic and manual controls. A switching device, an electrical circuit breaker is used to control and protect the electrical power system. It can be operated manually or automatically. When designing a circuit breaker, it is especially important to ensure the safe interruption of an arc that is generated when the breaker is in use because modern power systems deal with high currents. The modern power system works with a huge power network and a lot of electrical equipment that goes with it. This equipment and the power network are subjected to a high stress of fault current during a short circuit fault or any other electrical fault, which may cause permanent damage to the networks and equipment. The fault current needs to be removed from the system as soon as possible in order to save these pieces of equipment and the power networks. Once the problem is fixed, the system needs to get back to normal as soon as possible to ensure that the receiving ends receive high-quality, dependable power [1].

In addition, a variety of switching operations must be carried out in order to ensure that the power system is properly controlled. Therefore, in order to promptly disconnect and reconnect various parts of the power system network for control and protection, specialized switching devices must be able to operate safely under high current carrying conditions. When a lot of current is interrupted, there will be a lot of arcing between switching contacts. Because of this, it is important to be careful when putting these arcs out of the circuit breaker safely. During a current-carrying condition, the special device known as the circuit breaker performs all necessary switching operations. You must keep an eye on the mechanical and electrical parameters that have an effect on the health of the device in order to comprehend the state of the high voltage switch throughout its entire life cycle. The electrical power system can be controlled and protected by an electrical circuit breaker, which can be operated manually or automatically [2]. Special care should be taken to ensure that modern power systems can safely interrupt the arc caused by the circuit breaker's shutdown because they operate under high currents.

A circuit breaker, in contrast to a fuse, which only works once and must be replaced, can be reset manually or automatically to resume normal operation. These come in a wide range of sizes, from small appliances that safeguard low-current circuits to individual household appliances. They are also manufactured in large switchgear sizes. The high-voltage circuits that supply the entire city are intended to be protected by these. [3]

There are following parts of a circuit breaker, they are shows in the given Figure 1.

1. Frame or external casing
2. Operating mechanism
3. Electrical contacts
4. Arc extinguisher
5. Trip unit

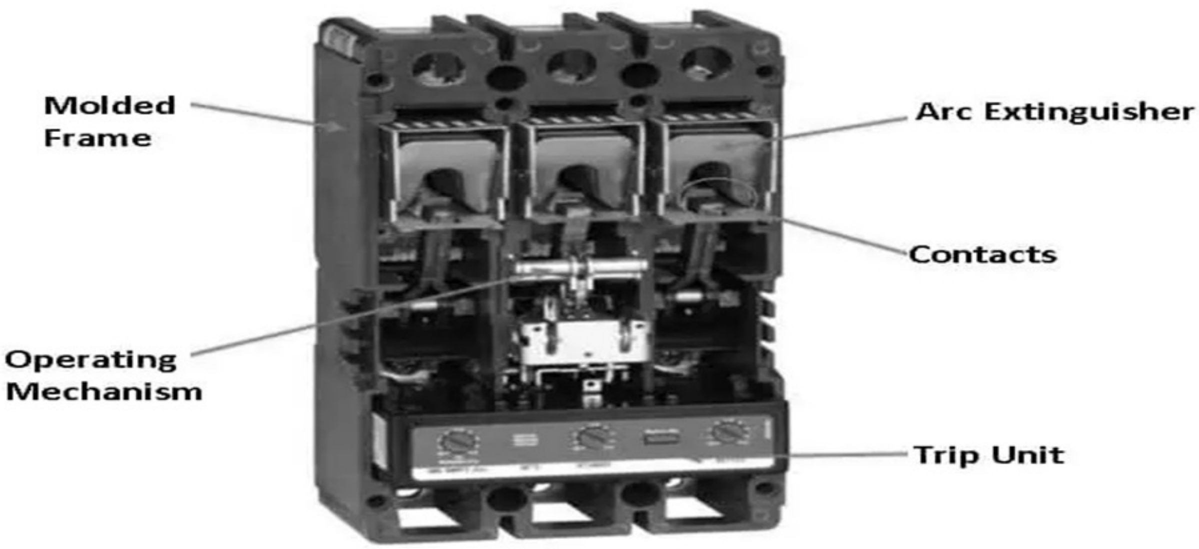

Figure 1: Illustrate the Parts of circuit breaker [circuit globe].

LITERATURE REVIEW

According to the Roston Rodrigues et al.[4] study on the emerging power distribution technologies and architectures, such as dc microgrids, necessitate enhanced interruption performance characteristics, despite the fact that conventional electromechanical circuit breakers have a track record of being efficient and dependable devices for circuit protection. Solid-state circuit breaker research and development has increased as a result of the need for faster switching operation and the most recent advancements in cutting-edge power semiconductor technologies. The various solid-state circuit breaker technologies that have been reported in the literature over the past few years are discussed in depth in this article. First, we classify solid-state circuit breakers according to key characteristics and subsystems, such as power semiconductor devices, main circuit topologies, voltage clamping techniques, gate drivers, fault detection techniques, and power semiconductor device commutation techniques. Second, we provide a comparison of several solid-state breaker technologies based on key metrics and discuss the various difficulties associated with the design of solid-state circuit breakers from the perspective of general applications. Last but not least, we offer a useful framework and reference for the design of solid-state circuit breakers for a wide range of upcoming power distribution applications.

According to Amir Heidary, et al.[5] conducted that the power system is concerned about preventing voltage drops from damaging delicate loads. For sensitive loads, a fast fault current limiter and circuit breaker can be used to quickly recover voltage. A compound current limiter and circuit breaker (CLCB) that can fast break to adjust voltage sags at protected buses and limit fault current is proposed in this paper. Additionally, it can open the broken line by acting as a circuit breaker. A resonant transformer and a series capacitor bank make up the proposed CLCB, which is based on a series L-C resonance. In addition, the CLCB consists of two anti-parallel power electronic switches, an IGBT and a diode connected in series with bus couplers. The proposed structure was simulated in MATLAB for the purpose of analyzing CLCB performance. Additionally, an experimental prototype was built, put through its paces, and the outcomes of the experiment were reported. The CLCB's capacity to serve as both a fault current limiter and a circuit breaker is confirmed by comparisons, which demonstrate that the experimental results were in reasonable agreement with the simulation results.

According to Oliver Cwikowski, et al.[6] tested by using HVDC circuit breakers, high voltage direct current (HVDC) grids can be shielded from dc faults. Recent advancements in the technology of dc circuit breakers may make it possible to clear faults in the dc grid without causing a permanent loss of power to the connected ac grids. The protection's requirements have not yet been fully defined; especially when it comes to controls for half-bridge modular multilevel converters (MMCs). This paper looks into how to recover from a pole-to-pole fault by integrating dc circuit breakers with half-bridge MMC converters. The converter's response to a fault is thoroughly examined. The MMC fault currents can be predicted thanks to this analysis, which focuses on important phases in the converter's response to a dc fault. After that, PSCAD simulations confirm this analysis, and the power flow recovery is demonstrated. The need for arm current controllers is emphasized, power flow recovery enhancements are made, and the converter controls are investigated.

C. N. Muhammed Ajmal, et al.[7] talk about the growing interest in the development of LVDC systems has resulted from the rising demand for the production and application of renewable energy resources. In order to effectively integrate various forms of renewable energy, the DC grid offers more flexibility. However, the primary obstacle to the expansion of dc distribution systems is still the absence of a dependable protection mechanism. The use of a standard mechanical circuit breaker (MCB) is less reliable in dc systems because there is no natural zero crossing for arc extinction. Due to the on-state voltage drop of the semiconductor devices, utilizing a solid-state circuit breaker (SSCB) results in rapid fault interruption but reduces the system's overall efficiency. Although a hybrid circuit breaker (HCB) that combines MCB and SSCB delivers superior static and dynamic performance, the primary obstacle remains demagnetizing the transmission line inductance following a fault interruption and the formation of an arc between the MCB contacts. This paper proposes a hybrid circuit breaker (HCB) that addresses the aforementioned issues while also being suitable for quick fault interruption in low voltage dc (LVDC) systems. To speed up current commutation during a fault, the proposed topology uses a semiconductor switch and an actively switched capacitor branch in parallel with the main mechanical breaker. At zero voltage, the mechanical breaker that forms the main branch is turned off. The formation of an arc across the breaker's moving contacts is prevented as a result of this.

According to Ataollah Mokhberdoran et al.[8] gives the statement about The central idea of a hybrid HVDC circuit breaker for meshed HVDC grid application is combined with the features of an interline dual H-bridge current flow controller in this paper to create a novel device. At a DC bus with at least two transmission lines that are adjacent, the proposed device can take the place of two dc circuit breakers. The embedded current flow controller can control the current in one of the adjacent lines in addition to the current interruption action. The proposed current flow controlling hybrid dc circuit breaker behaves in a manner that is analogous to that of the standard hybrid dc circuit breaker and interline dual H-bridge current flow controller at the system level. This work provides an overview and analysis of the proposed device's operating principles. The proposed device's functionality is validated through simulation, and the component ratings are compared to the existing solution.

According to Goh Hui Hwang et al.[9] talked about the generation, transmission, distribution, and substation all make up the power system. In order to safeguard the system in the event of a fault, each component of the power system needs appropriate protection devices. The circuit breaker has been chosen as one of the protection devices in a number of applications in this paper. This paper examines the oil circuit breaker (OCB), air circuit breaker (ACB), sulphur hexafluoride (SF6) circuit breaker, vacuum circuit breaker, and hybrid and solid-state DC breaker types of circuit breakers. Typically, the fault causes disruption or damage to the systems or circuits. To implement the protection system in the system or circuit, it is necessary to identify the kind of faults and their causes. The substation is necessary to regulate the high voltage that is transmitted from the generating station in order to supply the consumer with the appropriate voltage. A substation must also have a protection system.

Chuanyue Li et al.[10] gives statements about the which is due to its low conduction losses and quick interruption speed, the idea of a hybrid dc circuit breaker to protect HVDC grids from dc faults is widely accepted. A large number of hybrid dc circuit breakers must be installed in order to construct a DC grid that is well-built. High capital costs will result from this. To cut down on the overall cost of circuit breakers in a dc grid, an interlink dc circuit breaker based on the idea of sharing a main breaker branch between two breakers is proposed. The interlink hybrid dc circuit breaker can achieve the same dc fault interruption capability as existing hybrid dc circuit breakers with fewer components. In order to make the interlink hybrid dc circuit breakers able to interrupt in either a single direction or both directions depending on the situation, novel main breaker branch structures are created and their parameters are determined. The size of metal-oxidevaristors (MOVs) in a unidirectional interlink hybrid dc circuit breaker is reduced by 50%. The number of IGBTs and MOVs in a bidirectional interlink hybrid HVDC circuit breaker is reduced by 25%. In PSCAD/EMTDC, a three-terminal HVDC grid is used to verify and compare the hybrid dc circuit breaker to the interlink hybrid dc breakers.

According to Michal Szulborski et al.[11] An essential and potent numerical technique that has the ability to explicitly optimize the electrical device design process is the finite element analysis (FEA). In order to facilitate the engineering and modeling of low voltage modular circuit breakers in electrical apparatus, the use of the finite element method (FEM) as ANSYS is proposed in this paper. Transient thermal simulations of the current path were taking place on the purchased detailed model of a miniature circuit breaker (MCB). The laboratory's experimental data were compared to the acquired data. The experimental results clearly showed that the simulation method was used. When tested under the specific conditions, the modeled element's various regions displayed similar physical properties and toughness errors, faithfully replicating the experimental conditions. Additionally, the model stage could be used to determine the physical phenomena that are necessary for electrical engineering. The thermal behavior of the current path under current flow can be studied with these kinds of 3D models.

Chunyang Gu et al.[12] both AC and DC power systems rely heavily on circuit breakers (CBs), which can be as large as megawatts. Solid-state circuit breakers (SSCBs) and hybrid circuit breakers (HCBs) with semiconductor power devices are examined in this paper. This paper discusses a few novel SSCB and HCB concepts, such as the advantages and disadvantages of wide-band-gap (WBG) devices in the basic SSCB/HCB configuration through simulation and 360 V/150 A experimental verifications. At normal operation, novel SSCB/HCB configurations that combine high efficiency with ultra-fast switching are proposed. Various sorts of force gadgets are introduced in these circuit breakers to accomplish satisfactory execution. The difficulties posed by semiconductor power devices in SSCB/HCB with distinct voltage/power levels and performance requirements are clarified, as are potential trends for the future.

Omid Homaee, et al.[13] during the closing operation of a CB prestrike occurs when the moving contact approaches the fixed contact. Prestirke modeling in SF6 circuit breakers is the primary focus of this paper. In order to accurately model the prestrikes in SF6 circuit breakers, a multi-physics approach is developed. In order to take into account the effects that the plasma and the circuit have on each other, a model that allows for simultaneous solutions to the MHD equations and the governing equations of the plasma feeding circuit is developed in this research. The physical equations that govern the circuit breakers are the Navier-Stoke equation, the turbulent flow equation, the heat transfer in fluids equation, and the Maxwell equation. The external electric circuit is governed by the equations of the voltage and current laws of Kirchhoff. The electromagnetic properties of conducting fluids that are supplied by electrical circuits can be studied using the Electric-Circuit-Constrained Magnetohydrodynamic (ECC-MHD) model that is developed in this paper. This multi-physics problem is solved by taking into account the temperature dependence of SF6 gas properties and the motion of a moving contact. The circuit breaker's multi-physics equations are solved using the Finite Element Method (FEM). Lastly, for numerical studies, a 72 kV single pressure puffer type SF6 circuit breaker is utilized. Numerical studies are carried out for various values of resistance and inductance in the arc current path in order to investigate the mutual effects of the feeding circuit parameters and the generated plasma in the circuit breaker.

According to Anshuman Shukla and Georgios D. Demetriades,[14] power semiconductors can be used in circuit-breaker (CB) technology to help achieve significant performance enhancements and possibly new capabilities. New power electronics trends for CB applications are discussed in this paper. The appropriate hybrid mechanical-static CB topologies are also reviewed and summarized. For ac and dc applications, various conventional and derived topologies are described. This technology's development is discussed in terms of current and potential trends. The development of hybrid CBs for various applications will benefit from this study's useful framework and reference point.

DISCUSSION

The issue of aging assets has raised the importance of maintaining power system equipment, particularly transmission and medium voltage distribution circuit breakers. The proposed circuit breaker monitor system will facilitate online monitoring of all available signals in the breaker control circuit, enhancing CB condition monitoring. This system ought to have data that can be used to continuously assess the condition, find issues, and, in some cases, predict failures and operating issues before they become critical. Planning equipment maintenance can be made easier with knowledge of the condition of the circuit breaker. The circuit breaker's availability and dependability would rise as a result of this, and downtime would be reduced.

Data from multiple circuit breakers located across substations can facilitate the implementation of substation and system-wide monitoring and control applications in contrast to the monitoring data from a single circuit breaker, which can only provide information about the operation and status of the individual breaker. It is critical that additional applications can be implemented without modifying existing data acquisition units by utilizing data from multiple circuit breaker monitors. There are three possible levels of analysis applications based on the availability of the data. First, a single breaker operation and condition analysis that can be carried out using only one circuit breaker monitoring device's current and historical data.

Second, time-correlated data from multiple circuit breakers from a single substation or two substations adjacent are used in the analysis of a switching sequence involving multiple breakers. Finally, data from a number of system-wide circuit breakers is being used by system-wide applications.

Why we need of circuit breaker?

Our electrical system is susceptible to a wide range of abnormal situations that could harm the circuit and its constituent parts. These circumstances are referred as faults. Additionally, fault is divided into the following categories i.e. Overload, Short-circuit and Earthing.

We have to keep our system and electrical equipment safe, and protect from harmful damages and alongside with the faults that why we have necessity to put the circuit breaker in our system.

Types of Circuit breaker (CB):

Different types of circuit breakers exist based on various factors. The circuit breaker can be grouped into the following categories based on their arc quenching media:

1. **Oil CB**
2. **Air CB**
3. **SF6 CB**
4. **Vacuum CB**

The circuit breaker can be categorized on the basis of their services as:

1. **Outdoor CB**
2. **Indoor CB**

Circuit breaker can be categorized according to the operating mechanism as follows:

1. **Spring operated CB**
2. **Pneumatic CB**
3. **Hydraulic CB**

On the basis of voltage level of installation types of the circuit breaker can be classified as follows:

1. **High voltage (HV)**
2. **Medium voltage (MV)**
3. **Low voltage (LV)**

An extensive power network and a large number of electrical devices connected to it make up the modern electrical system. When there is a disruption in the flow ofelectricity, like a short circuit, the power and the equipment both face high current, which damages the network as well as the equipment. The fault current within the system needs to be cleared as soon as possible in order to safeguard the components of the equipment and the power networks. In orderto supply power to the receiving ends, the system must function normally as soon as the fault is fixed. The power system must be controlled through a variety of switching operations in addition to being properly controlled.

The power system should be disconnected and reconnected promptly to guarantee control and protection. Additionally, switching devices must be installed tosafeguard equipment during extensive current supply. When the large current is interrupted, it can cause asignificant arcing between switching contacts extreme caution must be exercised to safely quench these arcs within the breaker. To put it simply, a circuit breaker is referred as an electrical device that protects electrical equipmentand the power supply frompotential damage by performing the switching function.

Large-rated or fault power must be carried by the circuit breaker. During the operation of the circuit breaker, there is always dangerously high arcing between moving contacts and fixed contacts due tothis large power.

As previously stated, the arc in a circuit breaker can besafely quenched if the dielectric strength between the circuit breaker's current-carrying contacts rapidly increases ateach alternating current zero crossing. There are anumber of ways to increase the dielectricstrength of the media between contacts. Some examples include compressing theionized arcing media to speed up thedeionization process, cooling the arcing media to increase the resistanceof the arcing path, or replacing the ionized arcing media with newgases. Therefore, the circuit breaker's operation should involve some arc quenching processes.

OIL CIRCUIT BREAKER (OCB)

Oil was employed as the arc quenching medium and oil circuit breakers were also used on high voltages.

Working principle of OCB:

Under the influence of oil, an arc is created between the contacts of the oil circuit breaker. The surrounding oil is vaporized by the arc's heat and separated into a significant volume of gaseous hydrogen at high pressure. The volume of the hydrogen gas is approximately one thousand times that of the oil that has been decomposed. As a result, the oil is pushed away from the arc, and a growing hydrogen gas bubble covers the arc and the contacts near it, as shown in Figure 2.

Two processes mostly help the arc extinction.

1. First, by cooling the arc, the high heat conductivity of the hydrogen gas aids in the de-ionization of the medium between the contacts.
2. The oil is forced into the gap between contacts by the gas's creation of turbulence, which also removes the arcing byproducts from the path of the arc.

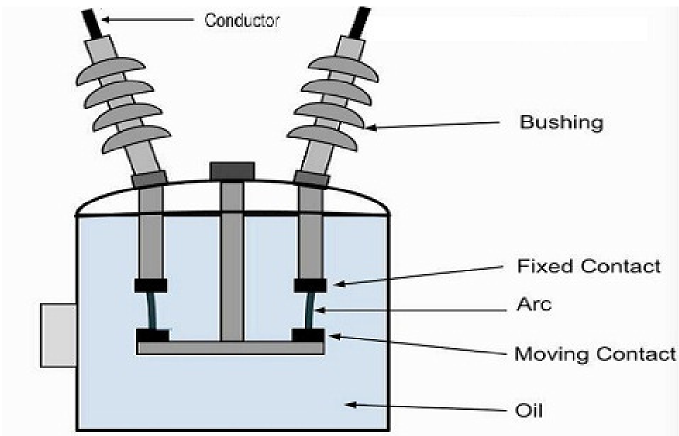

Figure 2: Illustrate Construction of Oil CB [elprocus].

Advantages of OCB:

i. It decomposes the oil into gases with excellent cooling properties by absorbing the arc energy.
ii. It allows for a smaller clearance between earthed components and live conductors because it is an insulator.
iii. The cooling surface close to the arc is shown by the oil that surrounds it.

Disadvantages of OCB:

i. There is a possibility of fire because it is flammable.
ii. It may combine with air to form a volatile mixture.
iii. The oil retains the arcing products such as carbon and loses quality with each operation. Because of this, the oil needs to be changed and checked periodically.

AIR CB

An electrical switching mechanism known as an air circuit breaker (ACB) is used to protect electrical circuits against overcurrent, undervoltage, and short circuits. Given the atmospheric pressure, these devices typically operate in low voltage applications and employ the air as an arc extinguishing medium. The steel frame of an ACB has pieces put within, and it has a great capacity.

The Air Circuit Breaker's Working Principle differs significantly from that of any other type of circuit breaker. By creating a situation in which the contact gap will withstand the system recovery voltage, every type of circuit breaker aims to prevent the reestablishment of an arc after current zero. The same thing happens, but in a different way, with the air circuit breaker. It produces an arc voltage higher than the supply voltage when interrupting arc. The minimum voltage required to maintain an arc is known as arc voltage.

There are primarily three ways this circuit breaker raises the arc voltage:

1. By cooling the arc plasma, it may increase the arc voltage. As the temperature of the arc plasma decreases, the particle's mobility decreases, requiring a greater voltage gradient to maintain the arc.

2. By lengthening the arc path, it may increase the arc voltage. In order to maintain the same arc current, more voltage must be applied across the arc path as the length of the arc path increases the path's resistance. This indicates an increase in arc voltage.

3. The voltage of the arc also rises when the arc is divided into several series arcs.

There is no need for an arc control device when using the air circuit breaker at voltage level 1 KV. ABCs with the appropriate arc control device are a good choice primarily for heavy fault current at low voltages (low voltage levels above 1 KV). There are typically two pairs of contacts on these breakers. Copper is used to make the main pair of contacts, which carry the current at normal load. Carbon forms the arcing contact of the additional pair. The arcing contacts remain in contact with one another even as the main contacts open first when the circuit breaker is opened. During the opening of main contacts, the arcing contact will no longer exist because the current will travel in a parallel, low-resistance path through it. When the arcing contacts are finally separated, the arcing only begins. An arc runner is installed on each of the arc contacts. This enables the arc discharge to move upward due to both thermal and electromagnetic effects, as can be seen in the Figure 3.

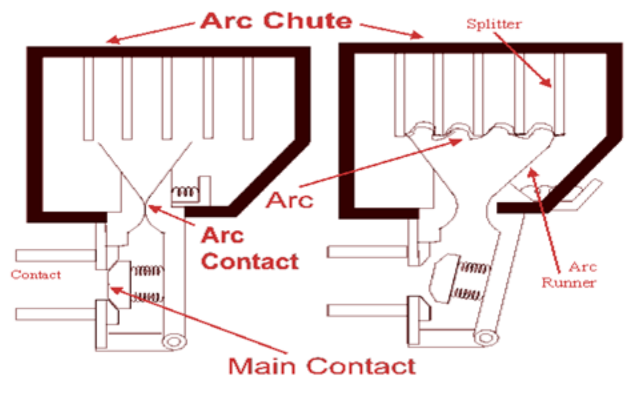

Figure 3: Illustrate Construction of Air CB [imimg].

Types of ACB

Usually there are two types of ACB, as they classified below as follow:

1. Plain air circuit breaker

2. Air blast Circuit Breaker

Air Blast Circuit Breaker:

These air circuit breakers were utilized for system voltages of 245 KV, 420 KV, and even higher, particularly in situations in which breaker operation had to be accelerated.

Compared to oil circuit breakers, air blast breakers offer the following distinct advantages:

1. There is no risk of oil posing a fire hazard.
2. During operation of an air blast circuit breaker, the breaker's breaking speed is significantly higher.
3. When the air blast circuit breaker is operating, arc quenching happens much faster.
4. For both low and high interruption values, the arc lasts the same amount of time.
5. As the arc's duration decreases, the amount of heat transferred to current-carrying contacts decreases, extending their service life.
6. The speed of the circuit breaker's operation determines how well the system can remain stable.
7. It is much less likely to need maintenance than an oil circuit breaker.

Air blast circuit breakers also have a few drawbacks.

1. An air compressor with a sufficient amount of capacity is necessary for frequent operations.
2. The compressor, associated air pipes, and automatic control equipment all require routine maintenance.
3. There is always a chance of high rate of rise in restriking voltage and current chopping due to high speed current interruptions.
4. Additionally, there is a possibility of pressure leakage from air pipe junctions.

SF6 CIRCUIT BREAKER

An SF6 circuit breaker is one in which the current-carrying contacts operate in sulphur hexafluoride, or SF6 gas. The property of insulating SF6 is excellent. The electro-negativity of SF6 is high. This indicates that it has a high affinity for taking in free electrons. A negative ion is formed whenever a free electron collides with the SF6 gas molecule and is absorbed by that gas molecule.

Working principle of SF6:

The first-generation SF6 CB's operation was straightforward and somewhat analogous to that of an air blast circuit breaker. A high-pressure reservoir was used to store compressed SF6 gas in this location. This highly compressed gas is released through the arc in the SF6 circuit breaker, collected in a relatively low-pressure reservoir, and then pumped back into the high-pressure reservoir for further use. The SF6 circuit breaker's operation is slightly different today. The SF6 CB's innovative puffer-type design makes it much simpler to operate.

The arc energy is used to create pressure in the arcing chamber for arc quenching in buffer-type designs. At this point, the breaker is filled to its rated pressure with SF6 gas. There are two fixed contacts with a particular contact gap installed. These are connected to fixed contacts by a sliding cylinder. Along the contacts, the cylinder can axially slide up and down. The SF6 circuit breaker has one stationary piston inside the cylinder that is fixed to other stationary parts in such a way that it cannot move while the cylinder is moving. When the cylinder slides, the internal volume changes because the piston is fixed and the cylinder is movable or sliding.

Compressed SF6gas is produced inside the cylinder as a result of the cylinder moving downward against the fixed piston position during the opening of the breaker. During the closed position, a number of the cylinder's side vents were blocked by the upper fixed contact body. These vent openings cross the upper fixed contact and become unblocked as the cylinder moves further down. As a result, the compressed SF6 gas contained within the cylinder will flow rapidly toward the arc through the axial holes of the two fixed contacts. During this SF6 gas flow, the arc is stifled.

The sliding cylinder moves upwards when the circuit breaker is closed. Because the position of the piston remains fixed, the volume of the cylinder increases, resulting in a lower pressure inside the cylinder than in the surrounding area. Because of this difference in pressure, SF6 gas from the surrounding area will attempt to enter the cylinder. During this flow, the higher-pressure gas will enter the cylinder through the vent and through the axial hole of both fixed contacts; The arc will be cooled by the gas.

Also primarily utilized in medium voltage applications are SF6 circuit breakers. Due of its high efficiency at quenching arcs, SF6 gas is used in this breaker for this purpose. Despite being extremely effective in quenching arcs, SF6 breakers are still not widely used because they pose a risk to both humans and the environment, as shown in the Figure 4.

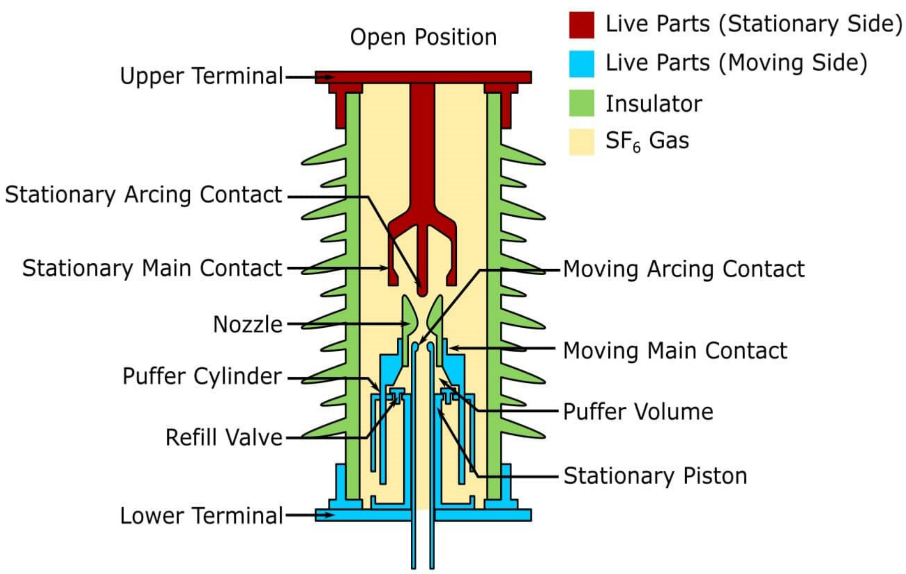

Figure 4: Illustrate Construction of SF6 CB [saVRee].

As a result, SF6 gas acquires a very high dielectric strength for charged particles that are heavier and less mobile. The gas not only has a high dielectric strength, but it also has the unique property of rapidly recombining when the spark source is removed. Additionally, the gas has excellent heat transfer properties. SF6 gas can effectively convect heat because of its low gaseous viscosity due to less molecular mobility. Therefore, SF6 gas is approximately 100 times more efficient than air as an arc quenching medium due to its high dielectric strength and high cooling effect. This gas SF6 circuit breaker is used in every type of medium- and high-voltage electrical power system because of its unique characteristics. These breakers can be purchased for voltages ranging from 33KV to 800KV and beyond.

Disadvantages of SF6 CB:

Since SF6 is known to be a greenhouse gas, safety regulations are being implemented in many nations to stop its escape into the environment. A significant mechanical energy is required for the puffer-type SF6 CB, which is about five times more than for an oil circuit breaker.

VACUUM CIRCUIT BREAKER (VCB)

The vacuum of 10^-5 to 10^-7 torr is used as an arc quenching medium in a vacuum circuit breaker (1 torr equals 1 mm of Hg). In essence, a vacuum is a pressure below atmospheric pressure at which there is no gas. In the power system, they are used for switching and protection. In the 1970s, vacuum circuit breakers took the place of oil breakers, followed by SF6 breakers in the 1980s.

The insulating strength of these breakers is the highest of any medium. At the first current zero, the vacuum circuit breaker interrupts the flow of current. This indicates that it interrupts the current half-cycle. For medium voltage applications, vacuum circuit breakers, or VCBs, are employed. In a vacuum-filled bottle, the contacts are operated upon and the arc is quenched, as shown in the given below Figure 5.

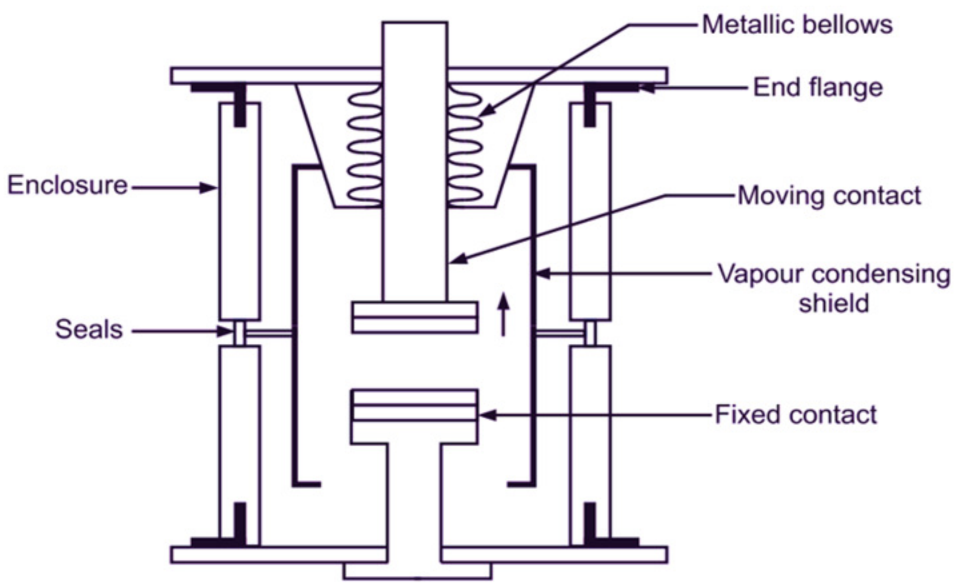

Figure 5: Illustrate the Construction of vacuum CB [electrical workbook]

Advantages of VCB:

1. No fire risks or hazards when we used VCB.
2. Smaller in size due to others breakers.
3. Require less upkeep and have a longer lifespan.
4. These are extremely dependable. This indicates that they stand a very good chance of successfully completing the arc extinction process each and every time.

5. Arc energy is lower than that of other types of circuit breakers, making it ideal for quiet or silent operation.
6. Additionally, they can withstand lightning strikes.
7. Quick operation: The current is interrupted after the first half cycle.

Disadvantages of VCB:

1. They are not suitable for higher voltage levels like the SF6 circuit breaker because their voltage range is limited.
2. Some units must be connected in series, which adds complexity and costs if they are used at voltages higher than 36 kV.
3. Extra caution should be taken to prevent leaks.

Applications of VCB:

1. Both indoor and outdoor uses exist for these circuit breakers.
2. Because they require less care and have a longer lifespan, they are excellent for isolated places like mountainous or rural areas.
3. Reactor switching, capacitor bank switching, and transformer switching all use vacuum circuit breakers.

LOW VOLTAGE CB

When the voltage up to 1KV are LV, then low voltage CB comes under the opeartion or Low Voltage Circuit Breakers which are as follows:

1. Molded Case Circuit Breaker (MCCB)
2. Miniature Circuit Breaker (MCB)
3. Motor Protection Circuit Breaker (MPCB)
4. Residual Current Circuit Breaker (RCCB)

MEDIUM VOLTAGE CB

When Voltage level varies from 1KV-69KV is considered under medium voltage CB.

HIGH VOLTAGE CB

When Voltage level varies from 69KV-230KV is considered under high voltage CB.

The state of operation of a power system in any abnormal condition is known as fault. However, the insulation may break down due to either the effect of temperature and age or a physical accident. Short circuits and open circuits are the two most common types of faults. Short circuit faults are more common than open circuit faults, and they frequently become short circuits as a result of subsequent events. The power source obtained the normal path of the electric current to the load runs through insulation in generators, transformers, and transmission lines. The current may, nevertheless, follow an abnormal path that is generally referred to as a Short Circuit or Fault.

CONCLUSION

Electricity, sound, and vibration signals should correspond to the curve in this article when the circuit breaker is operating normally. A mechanical problem with the circuit breaker may arise in the event that any signal does not match the previously mentioned curve. A method for fusion of multiple signals is proposed in this paper. A variety of evidence points to a circuit breaker mechanical characteristic test method that is both efficient and precise, allowing for significant improvements in fault recognition accuracy. When a critical current or voltage rating is exceeded, a circuit breaker is a switch that automatically interrupts the circuit. AC are much simpler to interrupt than DC. When the current drops to zero, current interruption typically necessitates first replacing a portion of the metallic circuit with an arc, followed by its deionization to prevent the arc from reestablishing itself.

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CHAPTER 3

AN ANALYTICAL REVIEW ON THEORY OF ARC INTERRUPTION

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ABSTRACT:

By utilizing the voltage drop at the electrode plasma interface to force current to zero, low-voltage circuit breakers provide crucial protection for residential and commercial power installations. As the contacts open, the arc is pushed toward a stack of steel plates, where the magnetic force and unbalanced pressure break the arc into sub-arcs, increasing the number of voltage drops. The interactions between the arc and solid counterparts which brought about by the high fault current that can be generated. The metallic components of low voltage breakers are carried by molds made of synthetic resin. Ceramic parts are used for higher temperatures. Because of their greater arc resistance, melanine or a specific kind of alkyd resin is utilized when the arc is likely to come into contact with molded parts its caused arc interruption.

KEYWORDS:

Arc Resistance, Circuit breaker, Interaction, Voltage Drop.

INTRODUCTION

Present-day circuit breakers use pure SF6 gas very effectively to interrupt currents up to 63 kA and 80 kA, but it is a costly gas and condenses at temperatures below – 20°C at the normal operating pressure of 6 bar. As a result, a number of gas mixtures have been investigated with the intention of making effective use of them in switchgear. One such mixture is SF6/N2, which has a dielectric strength that is 80% higher than that of pure SF6, but its interrupting performance is not as good as that of pure SF6 gas. The short circuit rating of an SF6/N2 circuit breaker is typically lower than that of an SF6 insulated circuit breaker, which is 50 kA. In recent years, the number of interrupters per phase has decreased from six to one for 550 kV circuit breakers. As a result, the dielectric performance has taken on greater significance. Due to the extremely high temperatures generated during interruption in applications in circuit breakers, SF6 gas breaks down into its various components, some of which are harmful. Since the insulating material must be resistant to SF6 decomposition products over time, the majority of manufacturers use alumina-filled cast resin insulators.[1]

Before the protective system opens the contacts of the circuit breaker in the event of a short circuit, a significant current flows through them. The contact area rapidly shrinks when the contacts begin to separate, and a large fault current increases the current density and, as a result, the temperature. The heat generated in the medium between contacts, usually air or oil is sufficient to vaporize and ionize the oil or ionize the air.[2] An arc is created between the contacts because the ionized air or vapor acts as a conductor. There are the following points which describe it properly.

i. The minimal potential difference that exists between the contacts is just enough to keep the arc going.

ii. As long as the arc continues, the circuit's current will not be interrupted because it provides a path with low resistance.
iii. The arc resistance determines how much current flows between the contacts during the arcing phase. The current that flows between the contacts is smaller the higher the arc resistance.

The following factors affect the arc resistance:

1. **Degree of ionization:** As the number of ionized particles between the contacts decreases, so does the arc resistance.

2. **Arc Length:** the distance between contacts causes the arc resistance to increase.

3. **Area of arc's Cross-section:** increases the arc resistance as with the decreasing area of the X section of the arc.

LITERATURE REVIEW

According to the Wenji Liu et al.[3]has given the statement above the Arc interruption is a significant and unavoidable issue among the factors that influence welding defects. During narrow gap pulsed gas metal arc welding (P-GMAW), the arc interruption phenomenon always occurs at the same location along the torch trajectory. As a result, some specific conditions must be met when the welding torch swings. The voltage signals vary significantly and the arc takes on a distinct shape prior to interruption. The gap's narrowness was found to play a significant role in the internal causes of the distinctive arc shape. The arc rises along with the rising vapor plume as the metal vapor is easily ionized, expanding beyond the wire's end and forming an approximate parabolic shape. The generation and collection of metal vapor will benefit from the effect of narrow grooves on the droplets and weld beads, particularly when the torch deviates from the groove center. The arc interruption of this kind can be predicted and eliminated, thereby improving the welding quality of narrow gap, as the arc will always be extended prior to interruption and the voltage will fluctuate.

T. Ueyama et al.[4]studied on the how to avoid arc interruption in tandem pulsed gas metal arc welding, it is crucial to avoid negative effects brought on by electromagnetic interaction between adjacent arcs. In tandem pulsed gas metal arc welding, arc interference can be reduced with a pulse timing control. Delaying the pulse end timing of the trailing arc by 0–5ms in comparison to that of the leading arc is one effective method. In addition, pulse peak modulation for the trailing wire and pulse frequency modulation for the leading wire, with pulse timing synchronized with the leading pulse, ensure arc length control. As a result, the leading and trailing arcs remain constant without interruption, and a stable control of the arc length is established that is little affected by changes in wire feedrate and extension length.

According to Xue Wing Hua et al.[5]studied on the Signal acquisition systems and high-speed camera synchronous acquisition systems were developed to sample the welding electric waveform and arc characteristics of triple-wire GMAW in order to uncover the mechanism of interference and arc interruption. Based on electromagnetic theory, the factors that affect arc deflection were looked at. It was found that the frequency of arc interruptions decreases as the welding current increases and decreases, as well as the distance between the wires. Based on theoretical analysis, the experimental results demonstrate that triple-wire GMAW does not result in arc interruption by selecting the appropriate combination of inter-wire distance and welding current. Additionally, the electromagnetic force that exists between arcs causes arc interruption and lifts arc plasma upward.

Yuki Inada et al.[6]talked on the using highly sensitive Shack-Hartmann laser wavefront sensors, two-dimensional electron density imaging was carried out at current zero over free burning SF6 arcs and SF6 gas-blast arcs to experimentally characterize electron density distributions for the success or failure of arc interruption in the thermal reignition phase. Free burning SF6 arcs with axially asymmetric electron density profiles were interrupted with a success rate of 88%, as demonstrated by the experimental results under an interruption probability of 50%. On the other hand, the current interruption of SF6 gas-blast arcs was successfully interrupted at 100% success rate under locally reduced electron densities.

According to Patrick C. Stoller et al.[7]stated that in gas circuit breakers, CO_2 could be used as an alternative to SF6, which has a high potential to cause global warming. In this paper, experiments in representative test devices and computational fluid dynamic (CFD) simulations are used to investigate CO_2's performance. There are some comparisons with air and SF 6. CO_2 has a thermal interruption performance that is superior to that of air but lower than that of SF6. For CO_2 and SF6, the measured dielectric recovery following arcing is compared, if the breakdown voltage of CO_2 is calculated using a streamer model this measurement and agreement are satisfactory. For SF6, CO_2, and air, the adiabatic coefficient and speed of sound, two crucial parameters that affect pressure buildup and gas flow, are compared. Both CO_2 and SF6 pressure buildup CFD simulations and measurements agree well, illustrating the qualitative differences between the two.

Author J.P. Dallas,[8] has given the statement about testing procedure for aircraft circuit interrupting equipment that makes use of magnetic arc suppression is dictated by arc immobility and arc reversal phenomena. These phenomena also have an impact on the design and limit the use of the equipment. When applied to magnetic arc interruption equipment intended for use at altitude, it turns out that physics laws that are routinely applied by earth-bound electrical designers need to be reexamined. For more than half a century, it had been assumed that, like any other conductor that could move in a magnetic field, an electric arc would move in the direction that Ampere's Law dictated. In all practical terms, this assumption holds true for circuit breaking equipment operating at sea level. However, an electric arc in a magnetic field may falter, stop, and eventually change direction as the altitude increases. According to W. Rieder [9] discussed about the presentation of arc/electrode and arc-column issues, the four established media for arc interruption are addressed paper examines the methods, effects, and implications of arc interruption in a vacuum and in gas at atmospheric or higher pressures, as well as current interruption in general.

Tengyu Huo et al.[10] give the Complex arc motion control as well as arc back-commutation present challenges for conventional air dc circuit breakers. An arc squeeze method, which stretches the arc in the insulating slit to raise the arc voltage, is proposed in this paper to simplify arc motion control, solve arc back-commutation, and reduce breaking time. The current crosses zero when the arc voltage acts as a counter voltage to the system voltage, completing the current interruption. A test apparatus was created and designed for the experimental study. During the breaking process, the arc voltage increased as a result of various structural parameters such as the insulating plate's penetration depth, slit cross section circumference, and area and external parameters such as the operating speed of the insulating plate and peak circuit current. When the fault current's maximum value is between 12 and 22 kA, the interruption time is only about 5 milliseconds.

According to Ruodong Huang et al.[11] they studied on the due to its perfect arc extinguishing performance and insulation strength, SF6 is frequently used in high voltage electrical equipment as an arc extinguishing gas. However, SF6, a type of gas with a significant greenhouse effect, will be phased out over time. As a result, the study of C_4F_7N, a new environmental gas that can replace SF6 and is being analyzed for its ability to interrupt an arc, has become a hot topic in recent years. A complicated process of multiple physical coupling, current interruption. Additionally, understanding the gas arc law is crucial for increasing a circuit breaker's capacity to interrupt current. The arcing process of SF_6 and C_4F_7N/CO_2 is simulated in this paper, and the temperature and pressure distribution of the C_4F_7N gas mixture and SF_6 are compared and contrasted. Through the interruption experiment of a 35 kV circuit breaker, the related physical phenomena in the interruption process can be explained. C_4F_7N/CO_2's specific arc interruption performance is examined to determine whether or not it can replace SF_6. The final result demonstrates that the gas mixture of 5%C_4F_7N, 6%O_2, and 89%CO_2 can successfully interrupt a short circuit at 25 kA under both interruptions.

Asif Islam et al.[12]discussed on the results of a series of experiments on dc current interruption in air in an axial magnetic field provided by rare earth magnets mounted in the test electrodes are presented in this paper. The following was the range of the experiment: Arc voltage of 80-100 V, arc length of 5-10 mm, arc current of 80-800 A, and applied field of 35-2400 G were used in these experiments to measure the free-burning arc diameter. It was discovered that air-arc's ability to interrupt is significantly enhanced by a strong magnetic field. In the experiments, the 220 A and 330 A free-burning air-arcs' successful switching times in 2.4 kG were less than half of those for air-burning free-burning arcs. The outcome was more encouraging for current arcs of higher magnitude. An 800 A free-burning arc lasted about 48 milliseconds before being interrupted by a 315 G field within 8 milliseconds. The lack of data on arc-root diameter and current density of free-burning 80-800 A arcs in air has been filled by the findings. The theories on free-burning arcs that are currently out there will be enhanced as a result of this information.

According to John F. Perkins and Leslie S. Frost,[13] both gives the statement on ten nozzle configurations with upstream and downstream pressures of 4 atm, experimental measurements of dielectric recovery were carried out following 400 sec square current pulses of 350 A and 1000 A. and one atm. respectively. The data have been looked at to see how nozzle geometrical parameters affect recovery, or the ability to interrupt current. Recovery is insensitive to divergence angles (ø) between 9° and 15°, according to the analysis, but the ability to interrupt an arc is severely diminished by a cylindrical nozzle. A nozzle with a ratio of Ac/At equal to 2 minimizes tR at high VR because the nozzle expansion matches the arc's expansion, whereas for low recovery voltages VR, recovery time tR decreases as the ratio of outlet area Ac to throat area at increases. Upstream arc length Lu should be about half the effective nozzle throat diameter for optimal performance. Ultimate dielectric strength rises significantly with an increase in Lu, however, if l is greater than optimum, upstream energy accumulation tends to occur, delaying recovery. When VR is applied, the voltage stress per unit length on the column is reduced and the arc channel recovers more quickly when the downstream arc length is either very long or very short.

According to Yan Hong Fu and RP Paul Smeets [14] give the statement about an experimental investigation of the voltage escalation processes and vacuum arc interruption behavior at a small gap length(1 mm) for three contact materials (Cu, CuCr, and CuTeSe) is presented in this contribution. There have been two experiments conducted: a current injection in a 10-kV ac circuit and a circuit with a low voltage. The dielectric breakdown voltage and high-frequency current interruption ability are presented as experimental findings. There are three types of breakdowns: the voltage of restart, the voltage of breakdown, and the voltage of cold breakdown. The ability to interrupt has been found to have a direct correlation with the reignition voltage.

According to Yong Jung Kim and Hyo Sung Kim [15] both gives the statement about low-voltage direct current (LVDC) distribution system has gradually emerged recently as DC power generation and DC loads like EVs and renewable energy rise. When compared to AC distribution systems, the DC system has a number of advantages, including system stability, transmission efficiency, and connection to renewable power generation. Safety is one of the crucial technical issues for commercializing a DC distribution system. In contrast to the AC system, the DC system does not have a current zero point, making it simple to generate a breaking arc and a high-temperature plasma when the circuit is cut off. The arc might start fires that could hurt people or damage buildings. A study of the characteristics of the DC breaking arc is required to safeguard facilities and customers from damage resulting from the arc in the DC system. An arc extinction distance at which the DC breaking arc is completely extinguished is an important characteristic of the DC breaking arc fault. In the DC Breaking Arc, there are two main behaviors; According to Kirchhoff's voltage rule, one type of behavior is active, in which the arc voltage is inversely related to the arc current for a given gap distance. The other type of behavior is passive, in which the arc voltage is inversely proportional to the arc current. A DC breaking arc model is proposed and a method for estimating the arc extinction distance is proposed in this paper by combining the two arc characteristics. The method is confirmed by the experiment's outcomes under various power and load conditions.

According to Mukesh Nagpal et al.[16] studied that because they aid in maintaining synchronism and stability in sparse transmission networks, single-phase trip and high-speed reclose (SPTR) schemes applied to extra-high-voltage (EHV) lines offer significant advantages over three-phase schemes. However, a secondary arc may persist and delay the air insulation's recovery. High-speed reclosing will attempt to reenergize the still-failed line in this instance, putting more stress on the system than the SPTR scheme would otherwise. This paper validates an enhanced hybrid scheme that incorporates secondary arc extinction detection logic to prevent high-speed reclosing onto faults and to permit single-phase reclose when it would be successful by using staged fault and fault disturbance data recorded from several 500 kV lines. BC Hydro is currently implementing the new logic on a number of 500 kV lines to enhance the reliability of the transmission system.

According to Patricia Mestas and M. Cristina Tavares[17] talked about the majority of faults in transmission lines are transient and line-to-ground. In this way, high-speed auto reclosing improves system stability; however, the arc must be certain to have been snuffed out. A second singlephase reactor is frequently connected between neutral and ground on shunt compensated transmission lines. This paper examines various aspects of the neutral reactor optimization and its effects on the reduction of secondary arc extinction time during three-phase reclosing. It finds that this reactor is important for reducing secondary arc current amplitude and contributing to coupling reduction. In addition, the outcome of using a switching technique to lower overvoltage during three-phase reclosing is shown.

DISCUSSION

Fundamentals of Arc Extinction:

It is necessary to examine the factors that maintain the arc between the contacts prior to discussing arc extinction methods. They are:

1. There could be a difference between the contacts.
2. Ionized particles that move through the contacts one at a time.

The Potential difference between the contacts is sufficient to maintain the arc when there is only a small distance between them. The arc can be destroyed by separating the contacts so far apart that the Potential difference is no longer sufficient to maintain the arc. However, in a high-voltage system where a distance of many meters may be required, this approach is impractical. The arc is typically maintained by the ionized particles located between the contacts. The arc extinction will be made easier if the arc path is made into a demon. Either physically removing the ionized particles from the space between the contacts or cooling the arc can accomplish this.

Method of Arc Interruption or Extinction:

According to the interruption process, it classified into two ways that interruption is carried out:

1. High resistance technique Method
2. Low resistance technique Method or zero current interruption method.

High Resistance interruption Method:

The high interruption method allows us to repeatedly raise the electrical resistance to such an extreme level that it reduces the current to zero and reduces the likelihood of arc restruck. In order to avoid creating harmful induced voltages in the system, proper measures must be taken to ensure that the rate at which the resistance is increased or decreased is not abnormal. The lengthening or cooling of the arc, among other things, can raise the arc resistance. In this instance, the arc is controlled so that its effective resistance increases over time. As a result, the current is reduced to a point where the heat it produces is insufficient to keep the arc alive, and either the current is cut off or the arc is destroyed. The rate at which the system's resistance or current decreases is not abnormal enough to result in harmful induced voltages.

Limitations of high resistance method:

It is just because of arc discharge has a due to resistive nature, the majority of the energy is received by the circuit breaker itself, so mechanical strength and other considerations should be taken when making circuit breakers. As a result, this approach is utilized in DC, low, and medium AC power circuit breakers.

The arc's resistance can be increased by:

i. **The arc's lengthening:** The length of the arc directly correlates with its resistance. The distance between contacts can be increased to increase the arc's length.

ii. **Cooling the arc:** The deionization of the medium between the contacts is aided by cooling. The arc resistance goes up as a result. A gas blast that runs along the arc can cool things down well.

iii. **Reducing the arc's X-section:** The voltage required to maintain the arc rises if the area of the X-section decreases. To put it another way, the arc path experiences an increase in resistance. Having fewer contacts or allowing the arc to pass through a narrow opening can both reduce the arc's cross-section.

iv. **Splitting the arc:** Splitting the arc into a number of smaller ones in series can increase its resistance. These arcs all experience a cooling and lengthening effect. Conducting plates can be inserted between the contacts to split the arc.

Low resistance technique Method or zero interruption method:

The low resistance method can only be used in an AC circuit, where the natural zero of the current makes it possible. At the natural zero of the ac wave, the arc is extinguished, and the rapid growth of the contact space's dielectric strength prevents it from restricting again. This technique is used exclusively for arc extinction in AC circuits. This approach prevents arc re-striking despite increased voltage between the contacts by maintaining low arc resistance until current is zero, at which point the arc automatically extinguishes.

This technique for arc extinction is used by all contemporary high power ac circuit breakers.

i. In an AC system, the current decreases to zero at the end of each half-cycle. The arc is briefly extinguished at each current zero.
ii. Now that there are ions and electrons in the medium between the contacts, it has a low dielectric strength and can be easily broken down by the rising contact voltage, or restriking voltage.
iii. The arc will continue for another half cycle in the event of such a breakdown.
iv. The arc will fail to restrike and the current will be interrupted if, immediately after the zero current, the dielectric strength of the medium between the contacts builds up faster than the voltage across the contacts.

However, the solution to the fundamental issue in AC arc interruption is to quickly deionize the medium between contacts as soon as the current drops to zero, preventing the space between contacts from being broken down by growing contact voltage or restriking voltage.

The medium can be de-ionized in the following ways:

1. Extinction of the gap: The distance between contacts is inversely proportional to the medium's dielectric strength. Therefore, the medium's dielectric strength can be increased by rapidly opening the contacts.

2. High tension: The density of the particles that make up the discharge also rises when the pressure near the arc is raised. Particle density increases the rate of de-ionization, which in turn increases the medium's dielectric strength between contacts.

3. Cooling: If ionized particles are allowed to cool, they naturally combine more quickly. As a result, cooling the arc can increase the medium's dielectric strength between the contacts.

4. Effect of blast: The medium's dielectric strength can be significantly increased by replacing the ionized particles between the contacts with UN-ionized particles. This can be accomplished by either forcing oil into the contact space or by directing a gas blast along the discharge.

The phenomenon of zero current arc extinction can be explained in two ways:

1. **Theory of recovery rate**
2. **Theory of energy balance.**

Before getting into the specifics of these theories, we should be familiar with the following important terms:

I. **Recovery Voltage:** It is the voltage that appears across the breaker contact following the complete elimination of transient oscillations and the arc's final extinction at all poles.

II. **Restriking Voltage:** It is the brief voltage that develops between contacts when the current is zero or almost zero. During the arcing phase. The rapid energy transfer between the magnetic and electric fields associated with the plant and transmission lines of the system causes a high-frequency transient voltage to develop across the connections at zero current. Restriking voltage is the name given to this transient voltage.

III. **Active Recovery Voltage:** The instantaneous recovery voltage at the instant of arc extinction is referred as active recovery voltage.

IV. **Arc voltage:** The voltage that appears across the contact during the arcing period, when the flow of current is maintained in the form of an arc, is one way to define it. Except for the point at which the voltage rapidly rises to a peak and the current reaches zero, it assumes a low value.

V. **Arc quenching:** The act of cooling, stretching, or spreading the arc within the spark gap to stop the previously ionized path from starting over when voltage is applied again. AC power arcs, RF spark gaps, and high voltage DC switching are the most common applications. In order to quench a high voltage arc, the arc current must first pass through zero for some time. Which can be accomplished both during brief current zeros and with the usual AC current zeros.

By separating the system's current-carrying contacts, the circuit breaker automatically shuts off the system in the event of a fault. The process results in the formation of an arc between the contacts, which the circuit breaker must put out. An enormous amount of heat energy is produced by the arc, which is a type of electric discharge. The equipment that needs to be protected may be damaged if the arc is not quenched immediately. However, the arc extinction process is extremely complicated, and the circuit breaker needs to be able to put the arc out without damaging the equipment. Now let’s discuss both the theorem in an elaborative way.

Recovery Rate Theory or Slepian’s Theory

This theory has another name that is Slepian’s theory. The rate at which the dielectric strength is restored is compared to the rate at which the restriking voltage across the contacts increases. The space breaks down and the arc continues if the rate of rising of the re-striking voltage is faster than the dielectric strength, because the arc is a column of ionized gases. Therefore, the ions and electrons must be removed from the gap as soon as the current reaches zero in order to end the arc. It can be removed by recombining neutral molecules with ions and electrons, or it can be removed by using an insulating medium in the gap. When ions are removed from the gap at a rate that is faster than the rate at which they are ionized, the arc is interrupted.

According to this theory, the arc will be extinguished if the rate at which the ions and electrons combine to form or are replaced by neutral molecules, also known as the rate at which the gap recovers its dielectric strength faster than the rate at which voltage stress rises, if not the arc may be briefly halted, but it will eventually resume. The re-striking voltage and dielectric strength buildup are assumed to be independent quantities in this theory. The observed value and the calculated dielectric strength do not match, so this assumption is not entirely accurate.

Ionized gases form a column in the arc. After the current reaches a natural zero, the electrons and ions in the gap must be removed immediately to end the arc. Either by recombining them into neutral molecules or by sweeping them away by inserting an insulating medium either gas or liquid into the gap, ions and electrons can be removed. The rate at which the restriking voltage across the gap rises is compared to the rate at which the arc is interrupted if ions are removed from the gap. The arc is put out if the dielectric strength rises faster than the restriking voltage. Ionization continues and the gap breaks down, resulting in an arc for another half cycle if the restriking voltage rises faster than the dielectric strength.

The arc will be put out if the dielectric strength increases in line with curve 1 while the restriking voltage increases in curve 2, due to the fact that the dielectric strength increases more quickly than the striking voltage. The arc restarts if the dielectric strength increases as in curve 3. The breakdown of the gap happens because the ionization persists and the restriking voltage rises faster than the dielectric strength. Dielectric strength and restriking voltage can be shown with the help of graph shown below in the Figure 1.

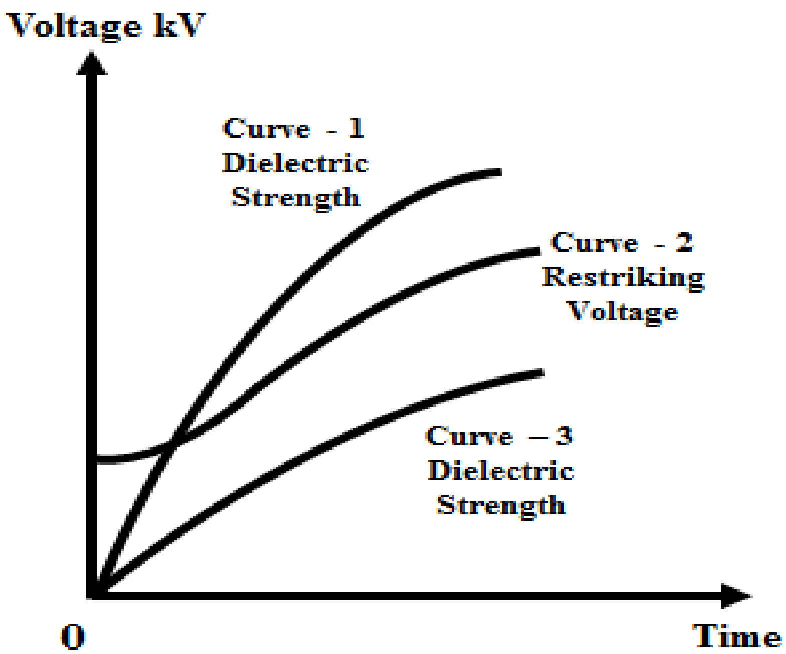

Figure 1: Illustrate the Graph build-up of Dielectric strength and restriking voltage.

Disadvantages of Slepian's Theory:

i. The restriking voltage and the rate of rising dielectric strength are assumed to be comparable in this theory, but this is incorrect because they are not.

ii. The arc extinction's energy relation is not taken into account in this theory.
iii. Since the idea of arcing phase is not covered in this theory, it is incomplete.
iv. Due to the fact that the values of dielectric strength calculated and observed do not match, it is unacceptable to assume that the increase in dielectric strength and restriking voltage are independent quantities.

Energy Balance Theory:

Cassie's theory is another name for Energy balance theory, it is sometimes known for this name.

The theory is based on the following assumptions:

1. A cylindrical column with a constant temperature at its cross section makes up the arc. Energy is dispersed evenly across this column.
2. The temperature won't change at all.
3. The cross-section of the arc adjusts itself to accommodate the arc current.
4. The arc column's cross-sectional area and power dissipation are proportional to one another.

The arc will restrike when the rate of heat removal between the contacts is lower than the rate at which heat is generated, according to this theory, which explains how the arc is extinguished or restricted. The arc will be extinguished when the rate of heat generation between the contacts is lower than the rate of heat removal. The separation of contacts is necessary for the production of heat. The restriking voltage will be zero at the instant of zero, and consequently the power. Ions are present in the space between the contacts at the following instant. As a result, the gap will have a finite resistance after zero.

Power is zero because Restriking voltage is zero, and there is some ionized gas in the space between the contacts immediately after current zero. As a result, it has a finite post-zero moment. The gap is completely de-ionized and has an infinitely high resistance when the arc is finally put out of power.

As depicted in the figure, the power first increases, reaches a maximum, and then decreases until it eventually reaches zero. Energy is produced in the space between the contacts as a result of an increase in the Restriking voltage and the associated current. The heat is the manifestation of the energy.

By cooling the gap and delivering a blast of air or oil at high velocity and pressure, the circuit breaker is intended to eliminate the heat that is generated as quickly as possible. The arc is extinguished if the rate of heat removal is faster than the rate of heat generation. The space breaks down once more, resulting in an arc for another half cycle if the rate of heat generation is greater than the rate of heat dissipation.

The associated current and power of the restriking voltage will have a finite value as long as it exists. Since there are no ions in the gap at the moment of final arc extinction, its resistance will be infinite and its power will be zero. Therefore, the power rises to a maximum value at an instant between the instants of current zero and final arc extinction. Energy balance provides the relation between power and time and it is shown by plotting the graph between power and time, as you see in the given Figure 2.

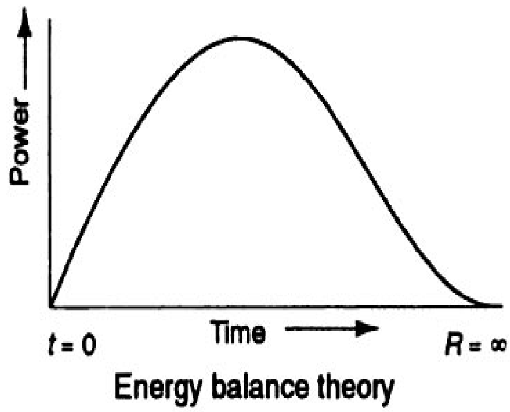

Figure 2: Illustrate Variation in power with respect to time [Electrical Exam].

According to this theory, the arc will be extinguished if the rate of heat dissipation between the contacts is greater than the rate at which heat is generated; otherwise, it will restrike. Depending on how far apart the breaker contacts are, different amounts of heat are produced at different times. When the contacts are about to open, the re-striking voltage is initially zero, so there is no heat produced. Again, the resistance between the contacts is infinite when they are fully open, so there is no heat produced.

The production of heat reaches its maximum level between these two limits. Now, the arc is extinguished if the heat that was generated could be removed by cooling, lengthening, and splitting the arc at a rate higher than the rate of generation. Heat energy appears in the gap because the electricity stays there for a limited amount of time. Therefore, the circuit breaker must use appropriate techniques to evacuate the heat produced.

CONCLUSION

After investigating the arc extinction now we conclude that the arc interruption is necessarily used only when we have to examine the factors that maintain the arc between the contacts prior. Later we discussed about what is actually arc extinction and how it useful. In this series, we understand about the theories of arc interruption and how arc resistances can be achieved by improving the following parameters. Later we discussed about the comparison between both the theories and find some limitations in recovery theory which can be further improved in energy balance theory, and now we have to discuss further about the recovery, restriking in details explanation.

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CHAPTER 4

CURRENT CHOPPING AND RATE OF RISE OF RESTRIKING VOLTAGE (RRRV)

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ABSTRACT:

One approach that has been proposed in the literature for measuring the chopping current and calculate the value of rate of rise of recovery voltages in order to analysis the state of the circuit is presented in this chapter. Furthermore, as thermal conductivity diminishes, the lowest stable arc current does as well. These outcomes directly relate to the current amount of cutting. These demonstrate that if the chopping current is decreased, the transient recovery voltage peak will also be decreased. The outcomes lead to the continuation of its application in real life.

KEYWORDS:

Chopping Current, Conductivity, Recovery Voltage, Thermal.

INTRODUCTION

The term "current chopping" first appeared in our vocabulary with the commercialization of vacuum switching in the 1950s. Before the main contacts parted, the arc would go through several zero crossings before finally going out. The dielectric strength across the now open gap had to be strong to prevent a restrike and, as a result, the continuation of the current for another half cycle. These earlier switching means in oil or air have a relatively slow dielectric recovery rate. With the introduction of vacuum as a dielectric medium with a much faster dielectric recovery rate than air or oil dielectrics and completely distinct characteristics Due to the small movements and low mass required to achieve arc isolation up to limited high voltages, high velocity movements can be easily obtained upon opening the main contacts of a vacuum interrupter whether it is a contactor or a circuit breaker. As a result, the arc will end after half a cycle and at the first current zero. The arc in a vacuum interrupter will typically go out before the current reaches zero because of the dielectric's rapid recovery rate. This will cause the instantaneous current to drop to zero and cause downstream equipment to experience an induced voltage or voltage transient.[1]

The current level is controlled to remain below the maximum level in the chopping mode. This entails turning on and off the voltage across the phase in such a way that the current stays between a predetermined upper and lower hysteresis current level. The current hysteresis level and the control turn-on and turn-off angles determine the motor's actual torque production in chopping mode. There are two current hysteresis control schemes that can be utilized in the cutting mode of operation. Soft and hard chopping are the two types. One switching device remains on throughout the entire conductivity period for soft-chopping control, while the other is switched on and off to maintain the desired current level. The phase winding experiences a zero-voltage freewheeling loop that will reduce the current when only one switching device is on, whereas when both switches are on, the phase winding receives the full positive supply.[2]

The abbreviation for it is R.R.R.V., and its unit is kV/m sec. It is the rate at which the restraint voltage rises. The fault short-circuits the capacitance C prior to the interruption of current, and the system's inductance L limits the short circuit current that can pass through the breaker. The short circuit current will lag the voltage by 90 degrees, where i is the short circuit current and ea is the arc voltage. When the contacts are opened and the arc finally goes out at some current zero, the generator voltage e is suddenly applied to the inductance and capacitance in series. This occurs under the short circuit condition. A transient with the frequency fn= 1/ [2π(LC)1/2] occurs across the capacitor and, consequently, across the contacts of the circuit breaker as a result of this L-C combination creating an oscillatory circuit. Restriking voltage is this transient voltage's instantaneous peak value, which may be twice the peak phase neutral voltage, or 2Em [3]. The decision regarding whether the arc will re-strike is made by R.R.R.V. The arc will re-strike if R.R.R.V is greater than the rate of rise in dielectric strength between the contacts. If R.R.R.V is lower than the rate of increase in dielectric strength between the breaker's contacts, the arc will not restrike. R.R.R.V's value is determined by: Natural oscillation frequency and recovery voltage.

LITERATURE REVIEW

According to the A. N. Shpiganovich et al.[4] stated about here are a lot of low-oil circuit breakers in use right now. They are regarded as outdated and inferior to vacuum and gas-insulated circuit breakers, which are more recent switches. The current chopping that is connected with the arc-extinction mechanism in a dense environment is one of the causes of the significant over voltages that can result when low-oil circuit breakers are activated. Small inductive currents, such as the no-load current of transformers and electric motors, typically result in current chopping. Various approaches, including adaptive ones (the "black box" method), are utilized when investigating arc processes in circuit breakers. For the purpose of investigating the phenomena of current chopping and over voltages caused by a low-oil circuit breaker, the Mayr equation-based arc model is looked at in this paper. The structure, appearance, and description of such a model are presented after an examination of its components. The MATLAB software package was used to build the model. Taking into account the arc-extinction mechanism, the scenario of the RLC-circuit disconnecting from a source of a low-resistance EMF was considered. An electric motor that was connected by a cable line was simulated by this circuit. Additionally, a comparison of the calculated and experimental data is presented in this article.

Atsushi Yamamoto et al.[5]studied on the chopping current of various metal-carbide contact materials was tested to determine how carbides affect current chopping characteristics. The vapor pressure of the metals and the carbide's work function were found to be related to the chopping current at metal-carbide contacts. When the contacts' melting point was lower than the heat treatment temperature, it was also discovered that heat treatment reduced the chopping current.

According to Dexiang Tian et al.[6] A current chopping control-based analytical calculation method for PWM duty cycle is proposed in this paper. The issue of large current ripple in switched reluctance motor drives under current chopping control is the focus of this approach. The primary cause of the large current ripple was investigated by combining the actual control procedure with the control principle. Analytical approaches to PWM duty cycle were proposed for the small inductor region and the inductor rise region, respectively, in accordance with the switched reluctance motor's electromagnetic relationship. The proposed method ensured that the inductor rise region's winding current remained virtually constant after monotonically increasing to the reference current in the small inductance region. An experimental approach to determining the inductance value in the small inductor region and the inductor slope in the rise region was also proposed at the same time. A polynomial-fitted curve was applied to the relationship between the winding current and the inductance slope in the inductor rise region based on the measurements. The bend is utilized to the web based computing of PWM obligation cycle. Finally, the experimental results demonstrate that the proposed method effectively reduces current ripple and enhances motor control performance in comparison to the conventional current chopping control method.

According to the author Pen Peter Paul Smeets [7]the phenomenon of "current chopping" of vacuum arcs is linked to rapid, microscopic processes on the cathode surface by the semi-empirical model presented in this work. First, two experiment-derived dc arc lifetime parameters were used to calculate the approximate chopping current for a resistive circuit as a function of power-current amplitude. Second, it is demonstrated that an accumulation of distinctive arc instabilities, each of which can be described as a randomly occurring transient arc resistance, results in spontaneous arc extinction. Qualitatively, it is demonstrated that the arc current, arc length, and circuit parameters influence the "severity" of these instabilities. Thirdly, it appears that an absence of ions in the vicinity of the anode is reflected in the presence of instabilities. A failure to initiate a new cathodic emission site "in time" may be the cause of this deficit, which may be caused by a discontinuity in the ionized mass flow into the plasma. The spot's dynamics can be linked to the nature of the current-chopping phenomenon, which was previously explained by a minimum cathode spot operation current, by following these three steps.

According to the Edgar Dullni et al. [8] has given the statement in a laboratory circuit with a three-phase 20 kV cable system and a 900 kVA dry-type distribution transformer, the distribution of chopping currents from a vacuum circuit breaker with CuCr25 contact material was measured. Between the circuit breaker and the upstream feeding transformer, the cable was several hundreds of meters long. A 10A rms 50-Hz current was provided by an inductive load connected to the distribution transformer. The arcing time, which varied between 2 and 8 milliseconds, had no significant effect on the mean chopping current level, which was between 3.2 and 3.5 A under these conditions. The chopping current level increased to 5.6 to 7.7A depending on the arcing time after a surge capacitor of 130 nF was added between the transformer terminals and ground. This greatly reduces the overvoltage that occurs during switching. This must be explained by looking at how the arc interacts with the electric circuit, particularly with the cables on both sides of the breaker. In a three-phase circuit, traveling waves and all return current paths must be taken into account if the cables are long. Momentary amplification or damping of excited network oscillations can occur when random arc instabilities coincide with excited network oscillations. An additional capacitor that has been installed serves as a source for maintaining a momentary reduction in current following an arc instability. It also makes it possible to excite a subsequent arc instability, which results in an increase in the chopping current and longer arcing times. Since there is no interaction on the load side due to the low capacitance, the arcing time has no effect.

According to the authors Mo Li and David A. Horsley,[9] by reducing the Lorentz force bias current, we demonstrate a technique for reducing offset in micromachined Lorentz force magnetic sensors. The magnetic sensor's sensitivity changes sign when the polarity of this current is changed, but the offset stays the same. The proposed method also significantly reduces the magnetic sensor's long-term drift by obtaining a residual offset of 31 T from the initial offset of 25 mT. Allan deviation measurements demonstrate a 120-fold reduction in long-term drift, and a 9-hour measurement demonstrates a reduction in the maximum drift error from 500 T to 1 T. The thermal-mechanical noise limits the white noise to 400 nT/rt-Hz at 0.9 mArms bias chopping current.

According to Wei Xu et al.[10] Powder metallurgy was used to make CNTs/Cu composites and Gra. /Cu composites. In a vacuum, the two kinds of Cu matrix composites' chopping current and cathode spot movements were investigated. CNTs/Cu's vacuum arc is found to be more stable and dispersive, and its chopping current is lower than that of Gra. /Cu, according to the findings. Cathode spot craters on CNTs/Cu range in size from 0.1 to 5 micrometers, whereas those on Gra./Cu range from 10 to 100 micrometers. The cathode spot walks randomly on the surface of Cu matrix composites and initiates selectively on Cu phases are common features. It is concluded that CNTs can effectively increase stability and reduce the chopping current of Cu matrix composites, and that CNTs/Cu has a higher arc erosion resistance than Gra. /Cu.

According to the Rene P.P. Smeets et al.[11] stated about short peaks in arc voltage (500 ns) occur in vacuum arcs with low current, abundantly present at heights up to ten times the usual arc voltage. Ion starvation near the anode is thought to be the cause of the instabilities. In a real-world ac circuit, a number of parameters of these instabilities, which occur in vacuum interrupters with CuCr or AgWC contact materials, have been statistically analyzed. There is a striking difference in height (134 V for CuCr versus 54 V for AgWC) and median rate of rise (2.8 kV/s for CuCr versus 0.63 kV/ps for AgWC). Recovery and current chopping level are two important switching characteristics that are made plausible by these parameters. In addition, qualitative explanations are provided for the parameters' relationship to momentary arc current and contact distance. It is concluded that a high-frequency arc current oscillation of increasing amplitude causes current chopping. In a self-enhancing manner, a series of instabilities periodically excite this oscillation at the current minima. The well-known connection between chopping level and circuit parameters is clarified through an examination of the interaction between arc and circuit.

According to the authors J. Panek and K.G. Fehrle,[12] studied about a series of reignitions and clearings can occur when three-phase load currents are switched with low power factors, as is the case in arc furnace installations. The switching transients may involve one, two, or three phases, depending on the switch's performance and system parameters. It is explained how virtual current chopping can cause line-to-line over voltages. Digital computer studies handle more complex situations, while simplified conditions are used to explain the phenomena.

According to A. Ullah et al. [13]studied on a novel type of breaker called a High-Temperature Superconductor (HTS) Breaker is intended to safeguard power engineering applications based on HTS. When compared to a standard breaker, it has the advantage of having a lower voltage prestriking effect for equipment like HTS transformers. Saw-tooth Transient Recovery Voltage (TRV) is characterized by a high RRRV in a breaker application. This study shows that the proposed breaker arc model has a good chance of protecting HTS equipment thanks to the improved values of RRRV. By optimizing the parameters of the arc and design model, the obtained values demonstrate that the HTS breaker arc model can achieve a reduction in the RRRV of up to

70%. This study uses the comprehensive arc model for the HTS breaker to evaluate the interrupting efficiency and its impact on the current interruption study.

DISCUSSION

The blast effect and rapid deionization of the contact space may interrupt highly inductive current before its natural zero when interrupting transformer no-load current. "Current chopping" refers to an interruption of current prior to its natural zero. Air-blast circuit breakers, which apply the same deionizing force to all currents within their short-circuit capacity, are particularly susceptible to this phenomenon. Even though the instantaneous value of the interrupted current may be lower than the breaker's normal current rating, it poses a significant risk of system damage from over voltages. It is the interruption of current prior to the natural zero of the current. Air-blast circuit breakers are particularly susceptible to current chopping because they maintain the same extinguishing power regardless of the magnitude of the current to be interrupted.

The powerful de-ionizing effect of air-blast causes the current to fall abruptly to zero well before the natural current zero is reached when these breakers are used to break low currents, such as the magnetizing current of a transformer. This is known as current chopping, and it causes a high voltage transient to occur across the circuit breaker's contacts.

Let's say that L is the system's inductance, C is its capacitance, and i is the instantaneous value of the arc current. V is the instantaneous value of the capacitor voltage. Let's say that the arc current is i when it is reduced to zero, as shown by point a in Figure 1.

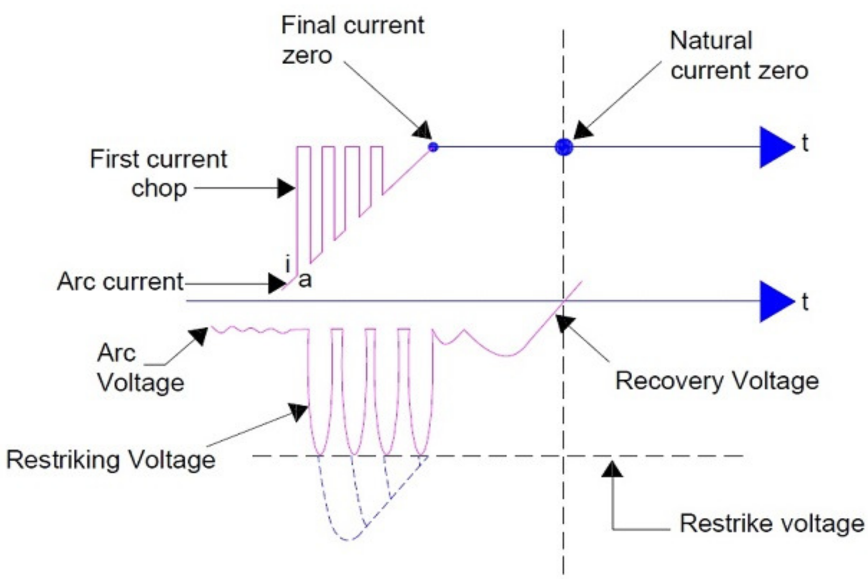


Figure 1: Illustrates the characteristics of current chopping

The system stores $1/2(Li^2)$ of electromagnetic energy prior to interruption. The value of i drops to zero when the current is interrupted. However, due to the system's capacitance, the electromagnetic energy that is stored in the system $1/2(Li^2)$ is converted into electrostatic energy $1/2(CV^2)$.

On the basis of energy conservation's principle, as they follows:

$1/2Li^2 = 1/2CV^2$

$V = i\sqrt{L/C}$ volts

"Prospective Voltage or Arc Voltage" is the name given to this theoretical value of V. The gap breaks down and "the arc restrikes" if this voltage is very high in comparison to the gap resisting voltage. Because of the high quenching force once more, the current is cut off, and consequently, restriking takes place. This process continues until the current is finally reduced without restriction, which occurs close to current zero. The breaker restrains because the potential voltage V is very high in comparison to the dielectric strength gained by the gap. Chop occurs once more because the de-ionizing force is still operating, but this time the arc current is smaller than in the previous instance.

This causes a lower potential voltage to be applied to re-ignite the arc. In fact, there may be multiple chops before a low enough current is interrupted, resulting in insufficient induced voltage to re-strike across the breaker gap. As a result, the final current interruption occurs. Shunting the breaker's contacts with a resistor so that reignition is unlikely prevents excessive voltage surges caused by current chopping.

Characteristics of Rate of Rise of Restriking Voltage:

The following crucial characteristics of Rate of Rise of Restriking Voltage have a significant impact on the operation of the circuit breaker: Amplitude factor and rate of rise of restriking voltage (RRRV).

Amplitude Factor: The ratio of the transient voltage's peak to the system frequency voltage's peak is the amplitude factor. The standard for evaluating the amplitude factor is outlined in BS 116.

Rate of Rise of Restriking Voltage (RRRV): The slope of the steepest tangent to the restriking voltage curve is the RRRV. Volts per microsecond are the unit of measurement. The RRRV can be calculated by dividing the duration of the first half wave by the maximum amplitude of the oscillation for a restriking voltage with only one frequency transient component. Characteristics of Rate of Rise of Restriking Voltage can be correlated with higher natural frequency values. Because the average RRRV is significantly higher in the first scenario, it is evident that, all other things being equal, the duty of a circuit breaker is significantly greater when utilized in a network with a high natural frequency than when utilized in a network with a low natural frequency. The voltage across the circuit breaker's contacts rises slowly in the latter scenario, allowing the dielectric strength to build up for a longer period of time.

Restriking voltage is the transient voltage that appears across the circuit breaker's contacts at the current zero period during arcing.

The re-striking voltage is expressed as:

$$v_c = E_{max}\,(1 - \cos \omega t) \qquad (14.2)$$

The re-striking voltage's maximum value occurs at $t = \pi / \omega n = \pi \sqrt{LC}$

The re-striking voltage's maximum value = 2 Vm = 2 × peak value of the system voltage

$$RRRV = \frac{dv_c}{dt}$$

$$\frac{dv_c}{dt} = E_m \omega \sin \omega t \qquad (14.3$$

The Maximum value of RRRV arises when:

$$\omega t = \frac{\pi}{2}$$

$$t = \frac{\pi}{2\omega}$$

$$t = \sqrt{LC}\,\frac{\pi}{2} \qquad (14.4)$$

The RRRV is directly proportional to the natural frequency:

RRRV $\propto \omega \propto 1 / \sqrt{LC}$

Where L is the inductance of the system C is the capacitance of the system

So, RRRV is reliant on upon both the inductance and capacitance of the system. Now, the maximum value of RRRV occurs when $\omega t = \pi/2$ i.e. when $t = \pi/2\omega$

∴The maximum value of RRRV = Em x ω = Em / √ L C

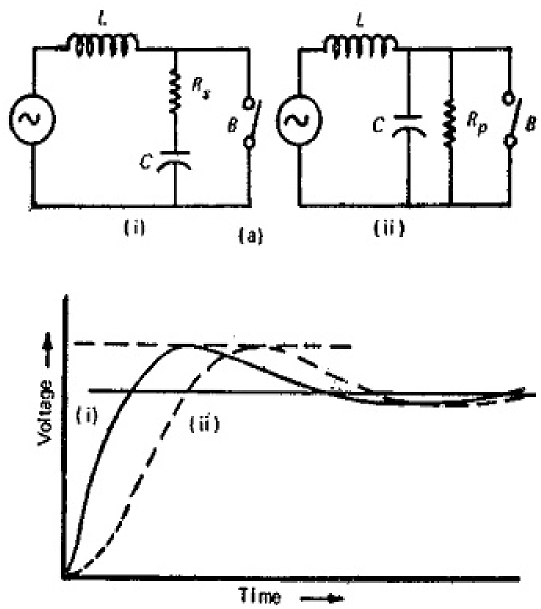
RRRV max = Em / √ L C

RRRV is measured in kV / µ-sec

The Restriking Voltage's Characteristics are affected by:

The configuration of the network, its natural frequency, and the relative positions of the resistances either in parallel or series with the main capacitance of the circuit determine the initial rate of rise and peak value of the restriking voltage stressing the contact gap after current zero. The true nature of attenuation is complicated due to the fact that losses depend on numerous factors, such as conductor resistance, iron loss, dielectric loss, corona, and so on. It is quite logical to assume that the presence of resistance damps the characteristics of the rate of rise of restriking voltage. Different ways affect how these factors change with frequency and voltage, as shown in the Figure 2.

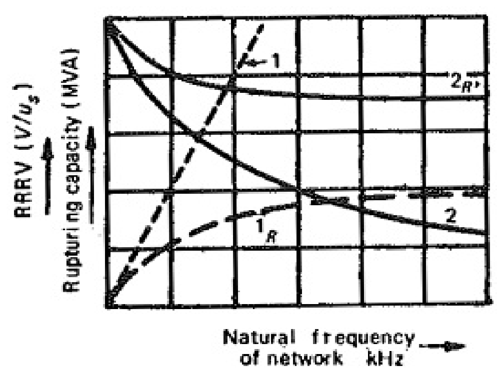
Each component of a network with generators, transformers, reactors, transmission lines, and other components exerts its own damping. They typically have insufficient attenuation to be relied upon for improved breaker performance. When a high RRRV is anticipated, shunt-resistant circuit breakers are utilized. The value of resistance Rp required to achieve critical damping is 1/2 L/C in order to guarantee that the voltage across the breaker does not overshoot and instead exhibits the oscillatory doubling effect associated with an undamped circuit.



(b)

Figure 2: Illustrate (a) Resistances either in parallel or series with the main capacitance of the circuit and (b) curve of restriking voltage

As a function of natural frequency, the relationship between RRRV and the rupturing capacity of an air-blast circuit breaker with and without shunt resistors is depicted in below Figure 3. Since the RRRV is directly proportional to the natural frequency of the circuit in the absence of shunt resistance, the breaker's rupturing capacity decreases rapidly with increasing frequencies. The rupturing capacity does not decrease to that extent when a breaker has shunt resistance because the RRRV cannot exceed a certain value set by the resistor. The advantage in rupturing capacity that is gained is greater for natural frequencies with higher values.



RRRV and rupturing capacity of an *ABCB* expressed as a function of natural frequency. 1—RRRV without resistor; 1_R—RRRV with shunt resistor; 2—rupturing capacity without resistor; 2_R—rupturing capacity with resistor.

Figure 3: Illustrate RRRV and rupturing capacity curve

CONCLUSION

In conclusion, it is possible to draw the conclusion that the physical mechanism underlying the current instability and transient recovery voltage induced by decreasing cathode thermal conductivity is clearly demonstrated by the findings of this study. In this we clearly see the characteristics of current chopping and RRRV, and see the curves of both and values changing from point to point. Calculate the maximum value of RRRV.

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CHAPTER 5

RATINGS AND SPECIFICATIONS OF CIRCUIT BREAKERS

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ABSTRACT:

The asymmetrical short-circuit interrupting current rating for high-voltage circuit breakers is discussed in this chapter. The decaying dc component of the asymmetrical fault current has an impact on the breaker and relay operating time have an impact on the breaker rating for the asymmetrical fault current. In this chapter we covered the ratings and specifications of CB and how the ratings affect the transmission and generation of power. A number of ultra-high-speed protection principles that can operate in a few milliseconds are briefly discussed in the chapter and illustrated with field cases. The chapter includes the losses which are happened due to the caused by fast tripping and suggests that customary margins applied to the selection of breakers may be sufficient to alleviate the impact of high speed of relays without replacement of CB.

KEYWORDS:

Circuit Breakers, Current ratings, High-voltage, Relay, Short- Circuit.

INTRODUCTION

Instrument transformers, protective relays, circuit breakers (CBs), and control power circuits are the four main components of any protection system. Instrument transformers for current and voltage provide protective relays with input signals. Short-circuit protection is just one of many protection functions offered by protective relays. Breakers interrupt the fault current to isolate the affected zone from the rest of the power system when protective relays trip them. Over the course of numerous standards, requirements and specifications for power circuit breakers and circuit switchers have been established. The ANSI/IEEE standards C37.04, C37.06, and C37.09, as well as their IEC counterpart, IEC 62271-100, make up the majority of these standards.[1]

Device for Limiting Overcurrent Protection is a device that, when it interrupts currents within its current-limiting range, significantly reduces the magnitude of the current flowing in the faulted circuit compared to that which could be achieved in the same circuit if the device were replaced by a solid conductor with a similar impedance. The current limit range is the current-limiting range for an individual overcurrent protective device starts at the lowest value of the rms symmetrical current at which the device becomes current-limiting and continues all the way up to the device's maximum interrupting capacity. It is essential to take into consideration both the short-circuit current ratings and the short-time current ratings when selecting the appropriate low voltage power circuit breaker for a given application. Choosing between the various circuit breaker designs will be easier for you if you are familiar with these performance characteristics.[2]

The electrical ratings of a circuit breaker are taken into consideration when selecting one for each application. Proper selection of the circuit breaker is crucial to the safe and correct operation of the electrical system. Consider the following two significant ratings: the short-time current rating and the short-circuit current rating, also known as the maximum interrupting rating. We'll talk about these ratings for circuit breakers and how they can affect the system's protection and selective coordination in this post. The maximum short circuit current that a circuit breaker can safely interrupt at a particular maximum voltage is known as the short-circuit current rating. The current magnitude alone specifies this short-circuit current rating, which is typically expressed in rms symmetrical amperes. The interrupting capacity of a circuit breaker that has instantaneous phase trip elements is the maximum rating of the device without any deliberate delay. The interrupting capacity is the device's maximum rating for the rated time interval if the circuit breaker does not include instantaneous phase trip elements or if instantaneous phase trip elements can be disabled by the user. When the available short-circuit fault current on the supply side terminals does not exceed its maximum interrupting rating, an engineer can safely install a circuit breaker in a power system.[3]

Definition of short-time current ratings A circuit breaker's short-time current rating is its capacity to withstand the effects of the rated short-time current level for a predetermined amount of time. It demonstrates that the breaker can remain closed for a period of time when the fault current is high. The engineer uses the short-time current rating to determine whether the circuit breaker can protect itself and work with other circuit breakers to select which ones will trip.

LITERATURE REVIEW

According to the authors Amandeep and Gagandeep Kaur [4] talked about the order to ensure that a power system operates in a manner that is both economical and stable, fault studies are an important part of the analysis. The most common types of problems with the power system are symmetrical and unsymmetrical problems. For the purpose of determining the circuit breaker's short circuit rating, the paper describes the short circuit analysis for a three phase symmetrical fault. As interrupting devices, circuit breakers cut off the operating and short circuit currents. For three-phase short circuit studies and load flow studies to determine pre fault conditions, MATLAB-based programs were developed. Short circuit studies on the IEEE 14 bus system are the subject of this paper. These studies provide us with the maximum fault current and fault MVA rating, both of which are helpful in setting the relay.

Both the authors Bogdan Kasztenny and Joe Rostron [5] studied on the essay describes the high-voltage circuit breakers' asymmetrical short-circuit interrupting current rating. The paper explains how the asymmetrical fault current's decaying dc component impacts the breaker and how the X/R ratio and relay running time effect the rating of the asymmetrical current breaker. The paper quickly describes many ultra-high-speed protection methods that can work in just a few milliseconds and uses real-world examples to explain them. In the following section, the article describes how to derate a breaker for a relay running period that is less than the industry standard reference value of 0.5 cycles. The study quantifies the "rating loss" caused by rapid tripping and contends that using the usual margins when choosing breakers may be adequate to lessen the impact of ultra-high-speed relays without the need of additional measures.

According to Ademola Abdulkareem et al. [6] talked on the security of the power system that provides and generates electrical energy for end users is significantly influenced by fault studies. In order to ascertain the test system's voltage and fault current magnitudes, this study focuses on the analysis and simulation of the "3 kV" fault phenomenon. The Nigerian 28-bus, 330 kV Transmission System serves as the test system. Using a program that is based on MATLAB, the 28-bus system is simulated, and the maximum current magnitude that is obtained is used to select the appropriate rating for the circuit breaker for each line in the 330 kV power system. As a result, this study provides recommendations for the level of protection that should be applied to Nigeria's 330 kV power lines in order to enhance system security. The information gleaned from this study also assists in the setting of a relay. When Jebba GS is faulty, the highest value of the abnormally high current that flows through the powerline to the point of fault was recorded at 6.4376 kA (36.796 pu), according to the study.

Authors O. Naef et al. [7]worked on the recovery voltage ratings for power circuit breakers have been determined by selecting representative unmodified transient recovery voltages (TRVs) from power systems. To describe the TRV withstand requirements for power circuit breakers, mathematical expressions have been derived that combine fundamental system parameters like load current, line impedance, voltage regulation, and transformer reactance with the breaker's rated voltage and circuit interrupting capabilities. The TRV withstand requirements of power breakers are described using two points in a volt-time plane, and the proposed rating values for these points are listed numerically. Additionally, the TRV ratings for fault currents that are lower than the rated currents and for faults in kilometric short lines are developed. The developed expressions can be used to calculate the TRV of actual power systems because they describe system recovery voltages.

According to E. Calixte et al. [8]using series-connected resistive and inductive fault current limiters (FCLs) at various fault locations allowed for a reduction in the rating that is required for circuit breakers. A necessary additional capacitance and a coil stray capacitance were taken into account in the inductive FCL model's capacitance Cp. In order to use a circuit breaker with a lower rating, the resistive and inductive FCLs with Cp = 100 nF that were added to the power system proved to lessen the severity of the interrupting duty. The inductive FCL with Cp = 10 nF, on the other hand, was found to reduce the fault current while simultaneously increasing the rate of rise of the recovery voltage. The limiting impedance necessary for a circuit breaker to provide a satisfactory interruption is discussed based on the variation in the breaking condition.

Both the authors Avni Alidemaj and Qendrim Nika [9] studied on the occurrences of a current interruption caused by faults in the high voltage circuit breaker are described and analyzed in this paper. That takes place when a generator is connected to the network without meeting the synchronization requirements. In addition, the significant aspects that must be taken into account when specifying SF6 circuit breakers for high voltage generators are described and analyzed in this paper. During these interruptions, a significant issue arises as a result of the fault current's high direct current component. Using programs like EMTP-ATP, PSS-E, and MATLAB, simulations were carried out on a power network model that was completed with the data of the network in order to investigate this issue and offer potential solutions. Simulated modes of operation are crucial for assessing the strain placed on generator-area circuit breakers. Due to the high value of the direct current component in the fault current, which prevents the current from passing through zero within a short time, it is possible to draw the conclusion that circuit breakers with rapid reactions in interrupting the fault current in an energy system are not always a favorable solution.

According to IEEE Switchgear and Energy Society [10] worked on AC high-voltage circuit breakers with ratings greater than 1000 volts are covered by these specifications for both indoor and outdoor applications. Specifications for ac high-voltage circuit breakers can only be compiled with the help of this document, which is only provided as a guide. The language's imperative mode is an example of how specifications are written.

According to Jiaren Zhuang et al. [11] talked about the specified power frequency recovery voltage (PFRV) of the circuit breaker and the synthetic test standard are used to calculate the decaying time constant of the power frequency recovery voltage (PFRV) in the synthetic test. The PFRV's severity is evaluated. The correct PFRV reactor setting procedure and an analysis expression for the decaying time constant are provided.

According to J.P. Bowles et al. [12]studied on the metallic return transfer breaker and the functions of a DC circuit breaker in an HVDC system employing simple diode rectifiers are discussed. It is demonstrated that a straightforward diode rectifier can effectively and efficiently replace the controlled rectifier.

DISCUSSION

The characteristic values that define the working conditions for which a circuit breaker is designed and constructed are referred to as its ratings. Circuit breakers must be able to withstand electrodynamic forces and carry the full load current continuously without experiencing excessive temperature rise. Additionally, the circuit breaker should be able to safely interrupt fault currents. Various national and international standards specify the standard ratings for various classes of circuit breakers.

The ratings and specifications of a circuit breaker typically determine its performance. This means that you can avoid electrical issues by knowing the standard ratings of circuit breaker. The nameplate of the device itself indicates the rating of the circuit breaker. The voltage rating, frequency rating, current rating, and other information may be displayed on this nameplate. If you're wondering what they are, the following is a brief explanation for each.

The rating of a circuit breaker is as follows:

1. Rated voltage
2. Rated current
3. Rated frequency
4. Rated breaking capacities, symmetrical and asymmetrical braking
5. Breaking current
6. Rated making capacities
7. Rated short time current or rated maximum duration of short circuit.
8. Rated operating duty

Rated Voltage:

The voltage at any point in the power system is not constant under normal operating conditions. As a result, the manufacturer guarantees that the circuit breaker will operate flawlessly at rated maximum voltage, which typically exceeds rated nominal voltage. The maximum operating voltage of a circuit breaker is its rated maximum voltage, which is the highest rated voltage above the nominal system voltage for which it was designed. In most power systems, the voltage rated by the circuit breaker is higher than the voltage rated by the bus and load. Low Voltage Breakers and High Voltage Breakers, which share the following characteristics, are typically the two voltage-related types of circuit breakers.

i. While the high voltage level is higher than that of the low voltage breakers, low voltage breakers can be utilized for 1kV AC and 1.2kV DC.

ii. In a high voltage system, high voltage circuit breakers are utilized for both indoor and outdoor controls, whereas low voltage circuit breakers are utilized for indoor applications.

iii. Because there are fewer phase-to-phase and phase-to-ground clearances, low voltage breakers are more complicated and require more frequent operation than high voltage breakers. For both kinds of voltage levels breakers, the testing methods differ.

Rated Current:

The designated maximum amount of current in rated amperes that a circuit breaker is supposed to be capable of carrying continuously without going over the maximum amount of detectable temperature rise is known as the rated current. When the circuit breaker is tested to verify rated continuous current, the temperature rise of each component cannot climb over the limit specified for that component as shown in Figure 1.

	Limit of temperature rise °C	
	Oil CB	*Oilless CB*
(a) Contact in air when clean and bright	30	35
(b) Contacts in oil	30	
(c) Oil	30	
(d) Potential coils, class *O* insulation	35	35
(e) Series coils, class *O* insulation	50	50
(f) Series and potential coils class A insulation	50	50
(g) Series and potential coils, bare or class B insulation	70	70
(h) All other parts	70	70

Figure 1: Illustrate the rising limit of Temperature for different types of a CB.

These temperature rise limits for circuit breakers installed in enclosures are based on the temperature inside the enclosure. If the breakers have copper-to-copper contacts, the temperature should not exceed 40°C, while if the breakers have silver or other contacts, it should not exceed 55°C.

Consider the possibility of contacts in air rising in temperature as a result of oxidation of the contact surfaces with care. The breaker can keep its rating as long as enough maintenance is done to keep the temperature rise within the limits that are specified.

Rated Frequency:

The frequency at which the circuit breaker is intended to function is known as its rated frequency. 50 Hz is the standard frequency. Special consideration ought to be given to applications at various frequencies.

Rated Breaking Capacities, Symmetrical and Asymmetrical Breaking:

The current-carrying parts of a circuit breaker would experience thermal and mechanical stresses when a short circuit passes through them.

There may be a possibility of permanent damage to both the insulation and the conducting parts of the circuit breaker if the contact area and cross-section of the circuit breaker's conducting parts are not large enough. The rising temperature is directly proportional to the square of the short circuit current, contact resistance, and short circuit current duration, according to Joule's law of heating. Until the short circuit is cleared by opening the circuit breaker, the short circuit current continues to flow through it.

The electrical circuit breaker's breaking capacity is determined by the operating time because the thermal stress in the device is inversely proportional to the duration of the short circuit. At 160 degree C, aluminum becomes brittle and loses its mechanical strength; this temperature can be used as a limit on how hot breaker contacts can get during a short circuit. Both symmetrical and asymmetrical rated breaking capacities represent the shape of the short-circuit current that the DC component of the current which decreases over time, causes the tins value of the current to change over time, as shown in the given Figure 2.

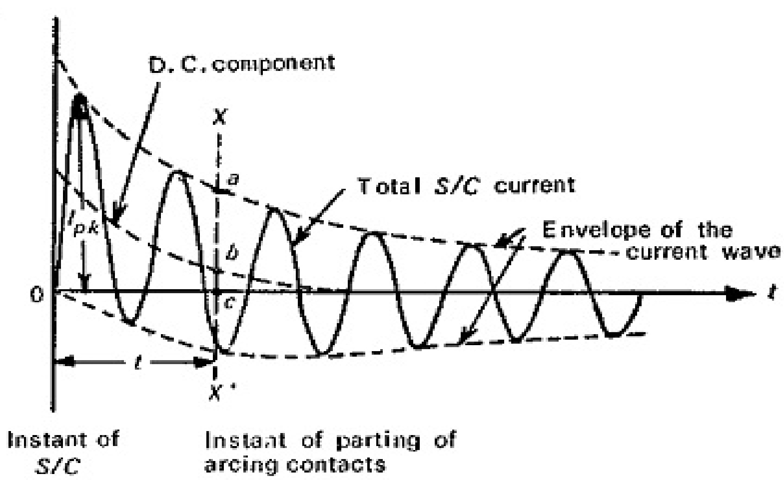

Figure 2: Illustrate Short – circuit current wave.

The short circuit current begins to decrease from a high initial value to a sustained value shortly after the fault occurs. Additionally, the relaying time causes the circuit breaker to open its arcing contacts only after the short circuit has begun. As a result, the actual short-circuit current interrupted by the circuit breaker is less than the initial value.

Breaking capacity (MVA) = Rated symmetrical breaking current (kA) × Rated service voltage (kV) × √3

Breaking Current:

The current that is present in a particular pole of a circuit breaker at the exact moment of contact-separation is known as the breaking current.

Two values are used to express it.

(a) Symmetrical Breaking Current:
The r.m.s value of the AC component of the current at the moment of contact separation at any instant in the pole.

$$I_{sym} = \frac{ab}{\sqrt{2}}$$

(b) The Asymmetrical Breaking Current:
It is the r.m.s value of the total current of both the AC and DC components of the current at the moment of contact separation at any instant in the pole.

$$I_{asym} = \sqrt{\left[\left(\frac{ab}{\sqrt{2}}\right)^2 + (bc)^2\right]}$$

The curve between current and time known as the curve of the breaking capacity is shown below in the given Figure 3.

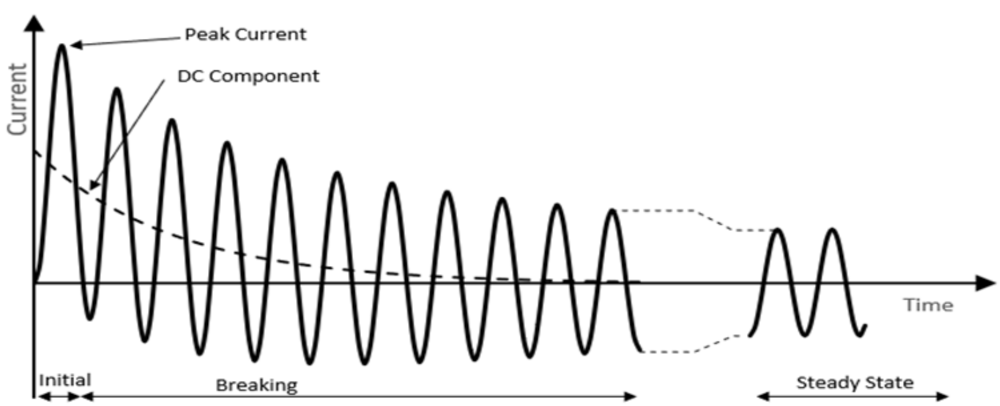

Figure 3: Illustrate waveform of breaking capacity.

There are now two breaking capacities that correspond to these two values of breaking currents. Typically, the breaking capacity in MVA is equal to approximately three times the rated voltage in KV divided by the rated breaking current in KA. However, the following definitions now apply to the breaking capacities:

The value of the symmetrical breaking current that the circuit breaker is capable of breaking at a specified recovery voltage and a specified reference restriking voltage under prescribed conditions is known as the symmetrical breaking capacity. On the other hand, the asymmetrical breaking capacity is the value of the asymmetrical breaking current that the circuit breaker is capable of breaking at a specified recovery voltage and a stated reference restriking voltage.

Rated Making Capacity:

The ability of breakers to close their contacts in the face of short-circuit currents is indicated by this value of generating currents.

Making Current: The r.m.s value of the total current including both AC and DC components which is determined from the envelope of the current wave at the time of its first major peak, is the making current of a circuit breaker when it is closed on a short circuit. The making current can also be measured at the first significant peak of the current wave if it is expressed as an instantaneous value of current. The term "planned peak making current" refers to this amount.

A circuit breaker's making capacity is the amount of current it can produce at a given voltage under specified usage and behavior conditions. A circuit breaker rating's rated making capacities are those that are equivalent to the rated voltage. Each rated making capacity is of the value given by, as there is no indication to the contrary on the name plate.

$$\text{Rated making capacity} = 1.8 \times \sqrt{2} \times \text{symmetrical breaking capacity}$$
$$= 2.55 \times \text{symmetrical breaking capacity}$$

The sub transient period of the current begins to flow as soon as the circuit breaker makes the circuit on the existing short circuit. As a result, the sub-transient period's electrodynamic forces must be withstand by the circuit breaker. A circuit breaker's breaking action typically takes place during the transient period. As a result, the transient period's electrodynamic forces must be withstand by the circuit breaker. As a result, a circuit breaker's making capacity exceeds its breaking capacity.

Rated Short Time Current:

In a closed position, a circuit breaker should be able to carry high currents safely and without causing excessive stress it is referred as Short time rating. A circuit breaker's short time current is the rms value of current it can carry in a fully closed position without causing damage for the specified short time interval under the specified conditions. It is typically expressed in terms of KA for either a one-second rating or a four-second rating, which are referred to as ratings. Low-voltage breakers typically have direct acting series overload trips, so there are no comparable short time ratings for them.

The fault clearing time is longer in this instance. As a result, a circuit breaker must carry the short circuit for a certain amount of time following a fault. All time delays should not add up to more than 3 seconds; As a result, a circuit breaker ought to be able to handle the maximum amount of bad current for at least this short time.

In a circuit breaker, the short circuit current can have two major effects.

i. The insulation and conducting parts of CB may experience significant thermal stress as a result of the high electric current.
ii. The circuit breaker's various current-carrying components are subjected to significant mechanical stresses as a result of the high short circuit current.

These stresses are designed to withstand a circuit breaker. However, no circuit breaker is required to carry a short circuit current that is greater than current for a predetermined amount of time. A circuit breaker's rated short time current must be at least equal to its rated short circuit breaking current.

Rated operating duty cycles of CB:

A Circuit Breaker Rating's operating duty consists of a predetermined number of unit operations performed at predetermined intervals.

There are two choices for rated operating duty for breakers that are not intended for auto-reclosure, as recommended by the IEC.

$$\text{(a)} \quad O - t - CO - t' - CO$$
$$\text{(b)} \quad O - t'' - CO$$

Where

O = The operation of opening

C = The operation of closing

CO = closing followed by opening

t, t′, t″ = time intervals, t′ and t″ are expressed in minutes, t″ in seconds

Auto-reclosing circuit breakers perform the following functions:

$$O - 0 - CO$$

0 is the time of dead of the CB expressed in cycles.

Lte's us assume that the rated duty circle of a CB is:

$$0 - 0.3\ sec - CO - 3\ min - \ CO$$

This indicates that a circuit breaker's opening action is followed by a closing action after 0.3 seconds, and the breaker then opens again without any deliberate delay. After this opening operation, the CB closes once more after three minutes and trips immediately without any deliberate delay.

CONCLUSION

After examining the ratings and specifications of CB now we conclude that the rating is useful and aids in the correct operation and maintenance of protective devices. The circuit breaker's price can be reduced because it can be shielded from damage with knowledge of ratings. It is necessarily used only when we have to examine the factors that maintain the arc between the contacts prior. In order to safeguard vital machines, devices, and other components from damage brought on by the fault current and save lives, circuit breakers play a significant and crucial role in protecting the power system. Circuit breakers are categorized according to their operation, voltage level, packaging, and other factors. Circuit breakers are used according to their types because different CB have different applications.

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CHAPTER 6

RELAY SAFETY IMPROVEMENTS FOR THE SMART GRID

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ABSTRACT:

One of the most challenging areas of electrical engineering is power transmission and distribution since it necessitates not only a thorough comprehension of the many power system components and how they execute, but also a comprehensive awareness of abnormal situations and potential failures in each component. Other aspects that require those working in the sector to regularly extend and refresh their expertise include the quick altering and development of relays' technologies as well as their underlying principles. We also make an effort to anticipate the prospects and trends for the future in this field. In this we explain how relay can improve the power system.

KEYWORDS:

Power System, Relay Protection, Smart Grid, Faulty System.

INTRODUCTION

In the year 1809, a scientist by the name of Samuel Thomas von Sommerring developed a component known as a relay as part of his electrochemical telegraph. However, a later American scientist by the name of Joseph Henry asserted that he invented the relay in 1835 with the intention of improving on the version of the telegraph that had been developed in 1831. The relay, a straightforward device, was included in the original 1840 telegraph patent. This device's mechanism is described as a digital amplifier in which the telegraph signal was repeated, resulting in the desired propagation of signals. Since 1860, it has been utilized in electromagnetic operations. A power system's safe operation depends on relay protection. Relay protection's functions have been developed alongside enhancements to electrical power systems and implementation strategies developed with related scientific and technological fields.

A number of important technical issues must be resolved in order for a relay to fulfill the requirements of the development of the smart grid and carry out the task of protection with high reliability. The principles, criteria, and algorithms for distinguishing between internal and external flaws are just one example of these issues. Multiple protection relays need to be set up and their technical coordination coordinated in order to remove the defective component with the least amount of disruption to the surrounding area. Protection devices based on various hardware platforms, various techniques, and on-site operational management of these devices are adopted in order to satisfy the aforementioned requirements. Each stage plays a crucial role in ensuring that the relay works properly [1].

Based on the lumped parameter model and the use of differences between power frequency voltage and current in normal operation and fault states, numerous protection principles have been developed for over a century. The theoretical foundation for fault identification also includes the development of vector and symmetrical component analysis techniques. Numerous filtering techniques have been developed in order to eliminate the non-power frequency components of the fault transient period and have emerged as an essential component of the protection algorithms. Many power system fault conditions can be correctly and selectively removed very quickly thanks to the maturation of these theories and algorithms over time. However, it takes at least 20 milliseconds to collect complete information over a power frequency period (50Hz). An approximation technique is used to reduce the operational zone of the protection while still guaranteeing selectivity in order to remove a fault more quickly. This technique uses information from 12 or 14 of the period to represent the entire period [2].

It depends on how well the relay protection works to use this kind of transmitting capacity while keeping the transient stability limits in mind. As a result, the development of ultra-fast protection with a response time of less than 5ms has significant practical significance. The most recent protection hardware is capable of recording and calculating precise fault transients thanks to the application of optical sensors and the development of high-speed DSP embedded system techniques. A powerful tool for analyzing and calculating fault transient data is the mathematical Wavelet transform, which is used to examine the characteristics of non-periodic sudden changes in a signal. Information about the fault's location and type can be found in the fault transient components. Based on detecting and processing the high frequency components of such fault transients, ultrahigh speed protection relays can be developed using the aforementioned device and algorithms to identify the fault type and location [3].

The community for power quality requirements is becoming more stringent, and smart grid technology continues to apply and gradually mature. Power technology is developing rapidly. However, there are grid insecurity factors and the power supply capacity cannot meet the community's electricity requirements in the power distribution system. As a critical technology, relay protection technology as a smart grid should be of concern for its development and application. Relay protection and security requirements for the electric power system become more stringent. This discusses the significant significance of relay protection in the context of a smart grid, provides a brief analysis of the smart grid system, and then examines the technology of relay protection in a smart grid context in light of the fundamental characteristics of a smart grid.

LITERATURE REVIEW

Both the authors Abdelkader Abdelmoumene and Hamid Bentarzi [4]studied and then concluded that power system protection is one of the most complex areas of electrical engineering. It requires not only a thorough understanding of the various power system components and how they behave, but also a thorough understanding of the abnormal conditions and failures that can occur in any power system component. In addition, those working in the field are compelled to continuously expand and update their knowledge due to the rapid change and development of relays' principles and technologies. We provide insight into the development of protective relays from the beginning of electricity to the present day in this paper. We also try to anticipate this area's future prospects and trends.

According to Baohui Zhang et al.[5] Strategies for relay protection that meet the needs of a robust smart grid are discussed in this collection of papers. Ultra-high-speed transient-based fault discrimination, novel coordination principles for main and back-up protection to accommodate the power network's diversity, and optimal coordination between relay protection and auto-reclosure to improve the power network's robustness are among these methods. Protection early warning and tripping functions based on wide area information have also undergone new development.

According to Qing Chen et al.[6]concluded that in this paper, fault tracking for relay protection devices is described. When relay protection devices fail, anomalies and warning information are gathered using data mining technology using fault tracking, and the fault tracking algorithm is used to determine what went wrong. Let's take the protection of microcomputers as an example: First, empirical field data can be used to collect common failure symptoms and prior probability of failure causes. The idea of an event set is then presented; As a result, the set of failure's causes and symptoms can be created. The reasoning chain and the associated Bayesian network model are constructed based on the causal relationship between the failure's causes and symptoms. The probability of failure causes can then be calculated using backward reasoning to continue the tracking analysis of relay protection device failure causes. This method is highly applicable and represents a straightforward and dependable strategy for the prompt identification and elimination of power system failure due to the fact that the modeling data are all derived from statistics.

Authors Youjun Li et al.[7] Relay protection devices are essential for the secure operation of the power grid; however, the auto-nomization degree of their key components is low, necessitating their urgent reconstruction. The difficulty in selecting the primary control chip and the memory chip's low reliability and consistency are the primary obstacles to the auto-nomization of relay protection devices. Following the fundamental requirements of relay protection device reliability, selectivity, sensitivity, and speed, the platform frame of a Loongson processor-based relay protection device is described in detail, including the main control chip selection standard, the overall platform structure, dual-core operation mode, data exchange between cores, memory error detection and correction, and other aspects. The platform for autonomously controllable relay protection device's design principle and key technology are presented from both a hardware and software perspective. Numerous substations have tested the relay protection device based on the designed platform scheme, and it works well.

According to A. P. Kulikov et al.[8] Due to the unique characteristics of microgrid regimes with distributed power generation sources, new relay protection algorithms are required. It is possible to use novel relay protection algorithms that are implemented in a centralized, decentralized, or mixed variant, as well as the freedom to freely select different devices on each level and in each protection zone, thanks to the strategy that is proposed in this article.

According to Mikhail Andreev et al.[9]studied about the integration of renewable energy sources through distributed generation is the current development trend for electric power systems. It was discovered that a change in the EPS operating modes is one of the main factors preventing this process from happening. This change has a big effect on how relay protection and automation work and how they are set. Experiments have demonstrated that the integration of wind power generation into EPS results in a decrease in sensitivity and a violation of relay protection selectivity in the distribution network. The capacity and location of the connection between the wind power generation facilities are significant factors. The article also looks at how these power systems' relay protection is currently implemented. Since existing approaches either limit the integration of new installations, are difficult to implement, or are not flexible enough, it is theoretically proven that new methods and means must be developed for comprehensive relay protection and automation setup.

According to Yunliang He et al.[10] Power systems existing communication channels lack reliability and make it difficult to locate faults. Based on the relay protection's communication performance requirements, this paper discusses the viability of using 5G communications in relay protection in terms of message format, bandwidth demand, transmission delay, communication architecture, security, and data synchronization. It suggests that distribution power systems can fully benefit from pilot protection based on 5G communication, but that medium and high voltage power systems should optimize the network structure and forward protocol. Finally, protection strategies are provided for the error code, frame loss, communication interruption, abnormal transmission delay, abnormal time service, and other abnormalities. In the field of power system relay protection, these offer an engineering example of how 5G communication technology can be applied.

According to Mohammad Helal Uddin Ahmed et al. [11]worked on the architecture and communication models of smart grids have been the subject of numerous studies in recent years. However, the architecture and communication model for a smart grid are still a mystery. Due to the absence of energy generation, distribution, and consumption management systems that are both effective and cost-effective, today's electric power distribution is extremely complex and poorly adapted. In order to accomplish these objectives, a wireless smart grid communication system may be of significant assistance. Customers and distributors are combined into a single domain in our smart grid communication architecture, which is the subject of this paper. A local wireless mesh network (LWMN) is formed by all home area networks, neighborhood area networks, and local electrical equipment in the proposed architecture. A source, router, or relay can all be performed by any meter or device. Through other nodes, the data generated by any node (device or meter) reaches the data collector. This data is sent by the data collector through an access point in a WAN. Finally, the data are transferred to the smart grid's control center or service provider. For the LWMN, we propose a model of wireless cooperative communication. In order to boost the network's performance, we only put a small number of smart relays into operation. Relay selection overhead can also be cut down with the help of a novel mechanism. End-to-end packet delivery latency, throughput, and energy efficiency are all enhanced by our cooperative smart grid communication model over Wang et al. and Niyato and others models.

According to the authors Mehmet Tan Turan and Erdin Gökalp, [12] concluded that the development of smart grids has been prompted by the increasing complexity of conventional power grid management, rising power demand, elevated expectations regarding energy quality and grid reliability, and concerns regarding efficiency and security. Implementing new technologies into existing grids, such as photovoltaic modules and wind turbines, is expected to result in this. The protection concept ought to be taken into consideration by system regulators when such new components are implemented in the system. Before expensive experimental studies, simulation-based analysis should be used to examine protection issues. A smart grid-based distribution system is evaluated through simulation in this study. The best possible operating conditions are obtained through system simulations that take into account various fault scenarios. A generator, a wind turbine, and variable loads serve as consumers in the design of a ring grid. In the MATLAB/Simulink environment, several grid points are chosen as fault locations, and the condition of connecting distributed generation plants to the grid is evaluated. An analysis of the possibility of forming a grid that is highly efficient and reliable in the face of faults is presented in this study.

According to Zeng Ping Wang et al. [13] about the power industry in China is moving in a new direction thanks to the smart grid. Relay protection, the power system's first line of defense, must adapt to the power grid revolution. The smart grid construction's unique issues are first presented. Complex AC/DC power grids across regions, local balance and dispatching of new energy power, electric power demand side response, and other issues are among these issues. UHV transmission, the prevalence of electronic devices, and variations in network topology are among the influential factors that influence relaying. The significance of wide-area protection is emphasized, as are several key research directions for relay protection. Wide area protection's concept, purpose, and system structure are then examined, as are its principles and characteristics.

According to both the authors Hongyun Hu and Shaoping Liu [14] talked about the purpose of this study was to identify issues and enhance the production system by using the relay production line as an example and examining the production process, working hours, logistics, worker movements, and manufacturing line balance. The findings demonstrated that employing industrial engineering techniques resulted in significant improvements in productivity at work. This demonstrated once more that industrial engineering can lead to management innovation, increased productivity, and improved quality in production.

According to J. H. Kim et al. [15] studied on HTS (High Temperature Superconducting) power cable used in a model power system is the subject of this paper's analysis and improvement of protective relay systems. Under a single line-to-ground fault and a three-phase short circuit, the proposed new decision-making algorithm for the over current relay and differential relay are implemented. The findings of the analysis indicate that the impedance variation of the HTS power cable ought to be taken into consideration in the event of a fault, but there is no particular aspect that should be considered by the protection system for the HTS power cable. The induced current ratio-based fault detection scheme is proposed and implemented for the bus-to-bus connection of HTS power cable protection in the differential relay system. The proposed algorithm is followed by the circuit breaker well. The analysis of the simulation's results would yield more useful information for the protection system design and installation of HTS power cables in power systems.

DISCUSSION

A relay is a type of switch that can be turned on or off with an electrical pulse or signal. For instance, if you want to use a microcontroller to turn an LED ON or OFF, you can probably send a signal to, well, turn the LED ON or OFF by connecting the LED directly to the IO pin of the microcontroller and using a current-limiting resistor. Relays are utilized in numerous applications, including home automation, automobiles, DIY projects, test and measurement equipment, automobiles, and industrial applications. Different kinds of relays exist, including solid-state and electromechanical ones. Relays that are electromechanical are frequently used. Before we learn how this relay works, let us see what's inside. Even though there were many different kinds of relays, their operation is the same.

An electromagnet with mechanically movable contact Switching points and a spring are part of every electromechanical relay. An electromagnet is made by winding a copper coil around a metal core. A relay can be used in either an AC or DC circuit. For every zero position of current in an

AC relay, the coil of the relay becomes demagnetized, increasing the likelihood that the circuit will continue to break. In order to avoid the aforementioned issue, AC relays are built with a unique mechanism that provides continuous magnetism. Shaded coil mechanisms and electronic circuit arrangement are two examples of such mechanisms.

How a relay work?

The principle of electromagnetic induction underpins relay operation. A magnetic field is created around the electromagnet when some current is applied to it.

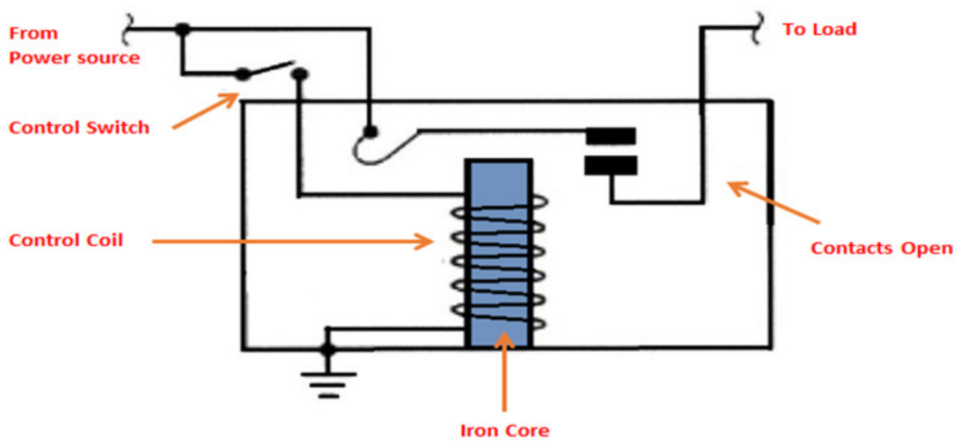

Figure 1: Illustrate the Circuit Diagram of Relay.

The relay operates as shown in the above image. DC current is applied to the load through a switch. Copper coil and iron core function as electromagnets in the relay. When DC current is applied to the coil, it begins to attract the contact. The term for this is "energizing of relay." When the supply is taken away, it returns to its initial position. The term for this is de-energizing the relay, as shown in the above Figure 1. Similar to the relay shown above, there are other types of relays whose contacts are initially closed and then opened when there is supply. Using opto-coupling, the sensing element of solid state relays will sense the input voltage and switch the output.

The armature is activated by the electric current passing through the solenoid, which creates a magnetic field. The movable contacts, which are moving in response, either make or break the contact, depending on the construction. When the relay is de-energized, the movement opens a contact, breaking the connection, and the opposite occurs when the contacts are open. When the current is turned off, a force equal to roughly half that of the relaxed magnetic field causes the armature to return. The majority of the relays are made to work quickly. When the coil is activated, a resistor or diode is placed across it to dissipate the energy from the collapsing magnetic field at the deactivation, or the semiconductor circuit would be damaged. Before transistors were used as relay drivers, diodes were used to dissipate energy. However, when germanium transistors started to fail, diodes were used instead. In contrast, resistors are less effective than diodes at eliminating voltage spikes caused by relays but are more durable than diodes. A similar issue with surge currents occurs around the relay's output contacts when the relay is driving a large reactive load. A snubber circuit, comprised of a resistor and capacitor connected in series with the contacts, is utilized in this instance to absorb the surge. A technique is used to divide the flux into the two out-of-phase parts that are added together if the coil is designed to be energized by alternating current.

As a result, the AC cycle's minimum pull during the armature increases. A small copper shading ring is used to accomplish this, and it is crimped around the part of the core that causes the delay in the out-of-phase component.

Relays use a variety of contact materials, depending on the application. Material that has a low resistance to contact may oxidize in the air or stick instead of opening cleanly. The capacity to withstand the heat of an arc or the repeated operations may necessitate the optimization of the contact material. Signal switching is done with contacts made of silver or silver plating.

Different types of Relays, as they are follows:

1. **Coaxial Relay:** A coaxial relay is used to transmit a relay that assists in switching the antenna from the receiver to the antenna when radio transmitters and receivers share a single antenna.

2. **Force-guided Contact Relay:** Relay contacts are mechanically linked to each other in these. Positive-guided contacts, captive contacts, safety relays, locked contacts, and mechanically linked contacts are all other names for these types of contacts.

3. **Latching Relay:** It is also known as a stay relay or simply as an impulse or latch. Its primary advantage is that one coil only uses power for a brief period of time while the relay is switched.

4. **Machine Tool Relay:** It is standard for transfer machines, machine tools, and sequential control.

5. **Mercury Relay:** Mercury serves as the switching element in this relay.

6. **Mercury-wetted Relay:** The mercury switch makes use of a variant of the reed relay.

7. **Overload-protection Relays:** Overprotection is necessary for electric motors to shield them from overloading and short circuit damage.

8. **Reed Relay:** The solenoid houses a reed switch like this one.

Factor to Consider When Choosing the Right Relay:

1. The coil's energizing voltage and current requirements.

2. The highest voltage we will receive at the output.

3. The amount of armatures.

4. The armature's total number of contacts.

5. Amount of electrical contracts that are neither N/O nor N/C.

CONCLUSION

In this chapter, we examines the characteristics and current research status of intelligent protection by analyzing the relay protection development process. Through an integrated wide-area relay protection scheme and explain the direction of intelligent protection development. A relay network is formed by integrated protection relays that are outfitted with multiple transient protection modules and wide-area relay protection devices. The wide-area relay protection device compares the signals from each substation's integrated protection devices to locate the fault and generates a trip decision to send to the appropriate substation for execution, resulting in wide-area integrated power grid protection.

We can conclude from the preceding discussion that the relay was made to prevent or shield the circuits from faults. In addition, it has human applications. The long-line telegraphs were the first to employ it. Additionally, it is utilized in the logical control of complex switching systems, electro-mechanical computers, and other electromechanical switching systems like Strowger and Crossbar telephone exchanges. Relays are utilized in safety control logics, such as waste handling machinery control panels, because they are more resistant than semiconductors.

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CHAPTER 7

ANALYSIS THE USE OF STATIC RELAYS TO PROTECT THE ELECTRICITY SYSTEM

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ABSTRACT:

The transmission and distribution of electric power to a wide range of locations for a variety of applications is the goal of a power system. The system must be designed to proficiently and reliably deliver energy to the points of use. In large power systems, the demands placed on protective relays are steadily rising. If a power system is not adequately protected, its scheme is flawed. The main focus of this chapter is to analyze the role of the static relay in the power system for the protection of system from faults.

KEYWORDS:

Distribution, Electricity, Power system, Static Relay, Transmission.

INTRODUCTION

The relay is said to be static if there are no moving elements. As the output contacts are still typically attracted armature relays, this is not technically true for a static relay. Static in a protection relay refers to the lack of moving components that give the relay its feature. In the early 1960s, static relays were first introduced. Instead of using coils and magnets to achieve the relay characteristics, their design relies on analogue electrical components. Advances in electronics made it possible to employ linear and digital integrated circuits in subsequent versions for signal processing and the implementation of logic operations instead of discrete components like transistors and diodes along with resistors, capacitors, inductors, etc. [1]

The use of static relays was required to address a variety of design issues. In particular, safeguards to avoid harm to delicate electronic circuits had to be developed because relays typically need a dependable source of DC power.

Due to the ubiquitous occurrence of electrical interference in substation environments in many forms, these conditions are particularly hostile to electronic circuits e.g. switching operations and the effect of faults. If the response is carried out by static units, a relay that combines static and electromagnetic units is also referred to as a static relay. [2]

In static relays, the measurement is carried out without the need of mechanical motion by electrical, magnetic, optical, or other components. However, additional electromechanical relay units could be used as supplementary relays in the output stage. Static relays and electromechanical auxiliary relays work together to create a protective system. Although the typical electromagnetic relays are strong and quite dependable, they must function under various stresses when there is a failure. This causes complicated narrow contact gap setup, specialized bearing and clutch assembly, and numerous measurement issues. These require heavy-duty instrument transformers (CTs and PTs) and are also large in size. [3]

Need for Static Relays:

The responsibility placed upon protective gear increased in severity with the fast expansion of electrical transmission and distribution systems over the past forty years, along with the introduction of considerably larger power plants and interconnected systems. The mechanical complexity of various types of relays tends to increase, making them more expensive, challenging to test, and have increasingly complex tasks. The foundation of "static relaying" is the employment of circuits and components to create a variety of operational characteristics that, historically, electromechanical devices have been used to provide for protection purposes. Because of the rise in short-circuit levels, circuit ratings, and connector complexity, the necessity for quick and dependable preventive schemes was apparent. [4]

In order to maintain the system's dynamic stability as the character and loads get closer to design limitations, shorter operating times are now increasingly crucial. There isn't much room for additional advancements in conventional electromechanical relays now that these prerequisites have been met. Experience has shown that these demands can be easily addressed by static relays, which can perform electrical circuit control tasks similarly to electromagnetic relays without the use of moving parts or other components. Greater sensitivity and good mechanical stability have been made feasible by transistors, which would not have been conceivable with electromechanical relays. The important issue is that switching to static electromechanical relays from their electromechanical counterparts is typically not cost-effective in order to reduce maintenance. It's important to note that overcurrent relays, which are more simpler have not been invented, whereas static relays have been produced commercially first for differential and distance protective schemes. [5] This is due to the fact that the overcurrent characteristics are more of an empirical nature, whilst the distance and differential schemes are more susceptible to mathematical analysis. Static relays have made it feasible to provide a wide range of intricate distance protection features that are not available with traditional electromechanical relays.

LITERATURE REVIEW

Xiaomei Zhang and Guohong Cao [6] Due to the lower cost and greater robustness, mobile social networks have been utilized for data forwarding. In mobile social networks, the pairwise contacts between mobile users underpin the current data forwarding strategies. However, the majority of data is not delivered prior to the expiration date, and these pairwise contacts only offer limited forwarding capabilities. By strategically placing low-cost static relays to increase the number of opportunistic contacts between mobile nodes, we in this paper improve the performance of data forwarding. The location of the static relays in the network to best facilitate data forwarding between nodes is an important question based on this concept. To answer this question, we first look at four real-world datasets of mobile social networks.

We find that only a small number of social links contain data forwarding. Then, to improve the performance of data forwarding along these social links, we propose a heuristic-based solution to the problem of static relay placement, which we formalize as an optimization problem. In light of the possibility that social links change over time, we also propose an effective relay replacement algorithm that, in order to further enhance the performance of data forwarding, swaps out old relays for new ones. The performance of data forwarding in mobile social networks find the evaluation demonstrate that the relay-based solutions that have been proposed have the potential to significantly for enhancing.

Both the Authors Yuanteng Pei and Matt W. Mutka [7] A networking infrastructure is required for mobile surveillance and sensing systems so that data can be transmitted from the field to a base station. We take into account the challenge of effectively using mobile robots to sense not only the area but also to deploy relays to create the networking infrastructure. We initially explain the precedence constrained two travelling salesman problem in order to create an effective solution to the aforementioned issue (PC2TSP). We suggest a near-optimal heuristic to PC2TSP to produce the best single-traveler tours possible while also trimming and balancing the tours. We next address the issue of minimal time two-robot real-time search with online relay deployment by partially modelling via PC2TSP. The solution, which identifies visiting positions, assigns the precedence constraint, and then generates PC2TSP tours, is referred to as Static Relay aided Search (STARS). Remote robotic sensing and control is made possible by STARS solutions. In addition, STARS makes it possible to continuously monitor suspicious areas and reduces costs significantly in comparison to a uniform mobile robot system. Both STARS and our PC2TSP solution can handle more than two travelers. Numerous simulations demonstrate that our PC2TSP solution performs nearly optimally, with an average deviation from optimal of less than 2%.

A Rasaei and A. Emamhosseini [8] Power grids are one of the most efficient parts of the infrastructure on which modern society depends, thus it is now important to have a smarter, more diverse, and more robust electricity infrastructure. For both providers and customers, the stability of an electrical grid is crucial. The power system is unstable as a result of frequency changes. Overproduction, overloading, and other issues will be prevalent and have a permanent negative impact on suppliers and customers. These issues can be effectively solved by balancing the production and consumption of isolated systems and by using frequency relays in power networks. The design and optimization of frequency relays is crucial to ensuring the electrical grid's stability because of their relative importance to dynamic and static relays. The charges for the frequency relays can vary from network to network. Measurement and detection are the two distinct components of the frequency relays. In this paper, we looked into how frequency relays work. Additionally, we simulated and examined the aforementioned problems. Grid charge variations and nominal frequency in disarray and near the ideal state are compared in the simulation. In this simulation, some blocks were used to count the frequency, most notably a block for measuring frequency and another block with protection duties.

A.Shanmugasundaram et al. [9] The creation of a static relay with conic features is described in the study. With the use of a novel type of relay circuitry, the instantaneous comparison of three inputs in a hybrid comparator is now a technique. IC operational amplifiers are used in the output circuit.

Yaxin Huang et al. [10] A crucial factor in the normal operation of users' power consumption systems is the normal communication between the smart meter and concentrator. According to the chain optimization index, the networking method of static and dynamic combination proposed in this paper is first used to select the optimal relay for a smart meter belonging to multiple relay communication ranges in order to solve the communication failure of the smart meter caused by a signal conflict and the collected consecutive information abnormality from the same smart meter. To prevent signal conflicts, the communication with other secondary relays is shut down in the interim. The paper then creates various combinations from the collected data and trains these combinations in the extreme learning machine (ELM) to determine the power consumption information's characteristics and value. Finally, a new communication path could be quickly found by dynamically adjusting the weighted coefficient of the number of relayed smart meters and the chain optimization weighted coefficient if ELM detects the abnormal information in the MATLAB simulation. It prevents consecutive information abnormalities from coming from the same smart meter and increases the communication reliability of smart meters, which has a significant impact on ensuring that users' power consumption systems function normally.

According to P. G. Brown and R. L. Winchester [11] worked on the creation of a new static negative sequence relay for generator protection is discussed in this study. This relay has a wider range of settings and more sensitivity to protect units in unattended stations, like remote-controlled hydro and gas turbine peaking plants, as well as current large generators. An illustration of its use is provided in light of recently proposed ANSI standards.

According to Tomio Chiba et al. [12] For static distance relays, two LSIs are created: a relay and a filter. The reactance relay, the mho relay, the offset mho relay, and the ohm relay can all be used with the relay LSI, which is based on the phase comparison scheme. CMOS switching capacitor technologies are essential for meeting the relay requirements. In this study, circuit compositions and typical test results are detailed. In comparison to a traditional unit, a prototype relay unit outperformed it in terms of compactness, excellent reliability due to its tiny number of parts, great accuracy, and extremely low power dissipation.

According to A. Kuskoand and S. M. Peeran [13] utilized generator sets with a capacity between 50 and 1000 kw, protective-relaying costs represent a sizeable portion of the overall installation cost. There is a strong incentive to create and implement industrial-grade static relays, multifunction relays, and microprocessor-based systems for tiny engine/generator sets. This article describes a fundamental protection system mandated by Southern California Edison Co. in Rosemead, California. The versatility of static relays is highlighted, and their operation is described, particularly for synchronous generator ground fault protection and induction generator single phasing protection. Additionally covered are the use of microprocessor-based relays and the choice of static relays.

According to Su Whan Sung and Jietae Lee [14] In the event of significant static disturbances with magnitudes greater than the relay, none of the preceding relay feedback techniques can produce the requisite cyclic steady state. By inserting a relay in front of a proportional-integral (PI) controller, whose integral element is crucial in rejecting the big static disturbances, the suggested relay feedback approach gets around this restriction. From a practical standpoint, this is quite appealing because the suggested relay test can be used without the requirement to create deviation variables. By modifying the integral gain, the suggested approach may also offer the process' frequency data for a predetermined phase angle.

According to Jiayi Zhang et al. [15] It is necessary to use emerging wireless communication systems like the fifth generation (5G) in order to provide high data rates for high-speed trains (HSTs). HSTs are the focus of an investigation into an asymmetric 5G mobile relay system, in which the mobile relay is deployed at the HST to prevent a high penetration loss of the direct link between the base station (BS) and the users (UE) inside carriages. The relay-UE link uses the millimeter wave frequency, while the BS-relay link uses the sub-6GHz frequency. As a result, the relay-UE link experiences static fluctuating two-ray fading while the BS-relay link experiences fading. Additionally, the channel aging effect is taken into account because of HST's mobility. We begin by investigating the precise statistical characterizations of the system's end-to-end signal-to-noise ratios. Then, for critical performance indicators like the likelihood of a failure, the typical bit error rate, and the typical achievable rate per unit bandwidth, we develop precise closed-form formulas. The findings of the theoretical study and simulations further highlight the important influences of the mobile relay system, channel ageing, and system and channel parameters. Our research indicates that, despite the severe bottleneck brought on by channel ageing, the mobile relay system is a potential network design for HST communications, able to offer HST passenger steady and quick data provisioning.

DISCUSSION

The work of static relay is used to compares or measures electrical quantities to function. It makes use of comparators, level detectors, zero-crossing detectors, etc., which use static electronic circuits for the comparison and output a signal to trip the circuit breaker. A static relay uses no moving components, unlike an electromagnetic relay, which uses an armature. The circuit that trips to detach the breaker contacts, however, can be electromagnetic or electronic. Let's examine the fundamental parts of static relays.

Block Diagram of Static Relay: The static relay's block diagram is shown below along with its key components, as shown in the Figure 1.

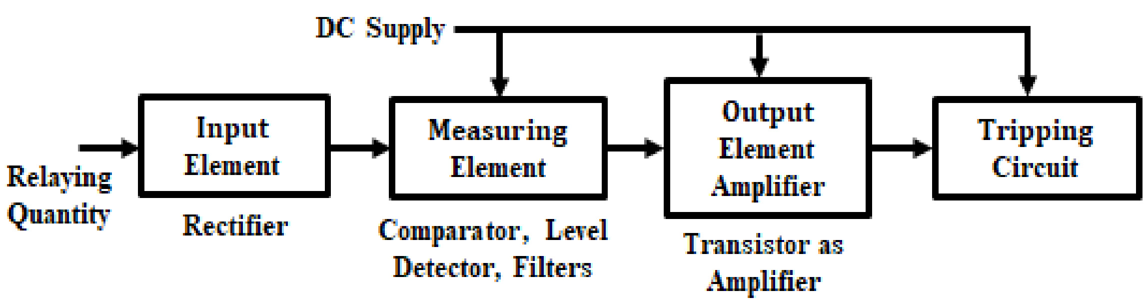

Figure 1: Illustrate the Block Diagram of Static Relay.

A rectifier corrects the relaying quantity which is the output of a CT, PT, or transducer. A measurement device made composed of comparators, level detectors, filters, and logic circuits receives the rectified output. When the dynamic input (i.e., the relaying quantity) reaches the threshold value, the output is activated. The output of the measuring unit is delivered to the output unit device which is often an electromagnetic one, where it is amplified by the amplifier. Only when the relay is operating does the output unit energize the trip coil. A static relay uses static circuits with comparators, level detectors, filters, etc. to carry out the measurement, whereas a traditional electromagnetic relay compares the working torque with the restraining torque or force. There is a significant range in individual relays, voltage and current used for relaying are rectified and measured. The output device is activated when the quantity being measured reaches a certain value, energizing the circuit breaker trip circuit in the process. It is possible to configure static relays to react to electrical inputs. The static relay can be provided with the different sorts of inputs, such as heat, light, magnetic fields, travelling waves, etc., after being appropriately transformed into equivalent analogue or digital signals. A static relay with multiple inputs can accept a number of inputs. The requirements for relay response and the order of events in the response can be determined by the logic circuit in the multiple-input digital static relay.

General Elements of Static Relay:

Input Element: In most cases, the CT and PT connected in the circuit to be protected will provide either current or voltage, or both, as the input to the relay. It cannot, however, be directly connected to the CT and PT in the event of static relays. Therefore, the input amount obtained from the CT and PT is converted into a practical form that can be quantifiable by the measuring device using an electrical circuit, such as a rectifier. The input element circuit also uses some mixing circuits like op-amps and adders, and the input signal occasionally comes from a transducer or a combination of other signals.

Measuring Element: It is the primary component of the entire relay. It consists essentially of a comparator that evaluates the output signal from the input element against a predetermined value. When the circuit it safeguards has a defect, it generates an output signal based on the comparison and applies it to the output element, which drives the tripping circuit.

Output Element: In essence, the output component is an amplifier. Before feeding the trip circuit, the output from the measuring element needs to be amplified. By using an amplifier to drive the trip circuit, the output element amplifies the output signal obtained from the measurement element. It also includes multipliers, which combine the signal with other signals to delay them in addition to amplifiers.

Feed Element: Along with the relay's tripping circuit, the feed element supplies all of the electronics circuits with the necessary dc power.

Advantages of Static Relay:

1. In comparison to their electromechanical cousins, static relays typically consume a lot less electricity. As a result, the workload on the instrument transformers (CTs and PTs) is lessened and their accuracy is increased. Additionally, air-gapped CTs may be used, difficulties associated with CT saturation are resolved, and the cost of CTs and PTs as a whole is decreased.
2. Rapid reaction, long life, stress resistance, fewer maintenance issues, excellent dependability, and a high level of precision.
3. The lack of moving contacts and the resulting issues with arcing, contact bounce, erosion, contact replacement, etc.
4. The lack of mechanical inertia and thermal storage makes it simple to achieve a high reset value and the absence of overshoot.
5. Static relays provide accurate and outstanding qualities. They can be changed within a limited range depending on the necessity for protection.
6. Network monitoring and remote backup can be done with the use of static relays and power line carriers.
7. Static relays may be made to perform the same function repeatedly. The measurement circuitry' lack of moving parts makes this possible.
8. With static relays, there is less chance of unintentional tripping.

9. Earthquake-prone places, ships, automobiles, trains, and other similar structures can all benefit from static relays. High shock and vibration resistance is the reason behind this.
10. The static relays include built-in capabilities for self-monitoring, simple testing, and maintenance. It is simple to repair a defective module.
11. Static relays operate without being affected by gravity, hence they can be mounted in ships, aeroplane, and other structures.
12. Greater sensitivity can be acquired with ease of amplification provision.
13. Using printed (or integrated) circuits prevents wiring mistakes and makes batch production more logical.
14. The fundamental components of semiconductor circuitry enable a higher level of sophistication in the shaping of operating characteristics, allowing for the practical realization of relays with threshold characteristics that are more closely in line with the ultimate necessities.
15. Numerous tasks can be accomplished by a static protection control and monitoring system, including protection, monitoring, data collecting, measurement, memory, indication, data exchange, etc.

Drawbacks of Static Relay:

1. Static relays are more expensive than their corresponding electromechanical counterparts while having a single, basic function. Static relays, however, prove cost-effective for multi-function protection. The plug-in-type static relays on the panel's production technology allow for the mass production of standard relays, and by including the necessary relay units on the panel, the customer's needs may be swiftly addressed. Compared to static relays with discrete components, IC-based relays are less expensive.
2. The functioning of the output device may have an impact on the characteristics of static relays, but not electromagnetic relays, whose operation is based on comparison of operating torques and forces.
3. Their servicing requires highly qualified individuals.
4. The construction of Static relays have flimsy and are readily damaged.
5. Ambient temperature and ageing have an impact on static relays' properties. However, ageing may be reduced by pre-soaking for several hours at a relatively high temperature, while temperature adjustment can be supplied by using thermistor circuits, digital measurement techniques, etc.
6. A lot of tiny parts and their electrical connections are what determine how reliable the system is.
7. In comparison to electromagnetic relays, static relays have a low capacity for short-term overload.
8. An additional DC supply is needed. This flaw, however, is not very significant because auxiliary dc power may be acquired from station batteries and easily modified to meet local requirements.
9. Electrostatic discharges can cause damage to semiconductor components. More sensitive components exist than others. To prevent component failures brought on by electrostatic discharges, safety measures must be taken when producing static relays because even little discharges might harm the components.

10. Voltage transients or spikes can damage static relays so for preventing this issue, special procedures are required such as the use of filter circuits in relays, screening of cables connecting to the relays, etc.

The difference between static and electromagnetic relay is shown below in the given Table 1.

Table 1: Distinguished Between Static and Electromagnetic Relays

Static Relays	Electromagnetic Relays
There are no moving parts in static relays. The parts are all static.	Moving elements in electromagnetic relays can cause issues including contact bounce, arcing, contact erosion, spring restraint, and more.
Due to the lower VA demands of the static circuits, static relays place less strain on protective current transformers and potential transformers.	Due to increased VA, electromagnetic relays place a heavy demand on the CTs and PTs.
Because static relays operate for a very brief period of time, they provide a quicker response.	Response is slower than static relay.
More exact control over relaying properties could be achieved. However, these qualities change with age and temperature.	The shifting core in electromagnetic relays makes the relaying characteristics less exact.
The amplification used in these relays contributes considerably to the sensitivity that is achieved.	Due to a higher VA, less sensitive.
Compact size as a result of tiny ICs.	Due to the inclusion of the armature disc, etc., large in size.
Less maintenance is required for this kind of relay.	The increased need for maintenance is brought on by contact issues, bearing friction, etc.
Dependable static relays.	Due to their low component count and accumulated manufacturing knowledge, electromechanical relays are highly reliable.
The capacity for overload is somewhat lower.	Good overload resistance
Less tough production challenges.	More manufacturing challenges exist.

Applications of Static relay: The following are some uses for static relay.

1. These relays are frequently used in EHV-A.C transmission lines with distance protection systems that are based on very high speeds.

2. These are also utilized in overcurrent and earth fault prevention systems.

3. These are utilized for medium and long transmission protection.

4. It is employed as a feeder guard.

5. It provides the unit with backup security.

6. In interconnected and T-connected lines, these are used.

CONCLUSION

It is evident that power plants and transmission and distribution systems are expanding quickly on a daily basis. As a result, the switchgear equipment is subject to higher duty rates. As a result of the relays' increased complexity in terms of mechanical design, cost, testing, and maintenance, electromagnetic relays now have to execute significantly more challenging tasks. The static relays, however, have surpassed all of the traditional electromagnetic relays that don't have any moving parts because of developments in semiconductor technology. For the purpose of protecting the power system, a static relay, also known as a solid-state relay, uses electronic components such as semiconductor diodes, transistors, thyristors, logic gates, etc, protection is necessary for transmission line, generator and for feeder.

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CHAPTER 8

A REVIEW ON PROTECTION OF FEEDER USING RELAY METHODS

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ABSTRACT:

The power system's feeder protection is a crucial component. A lot of directed overcurrent elements are required since a malfunction with the feeders could leave the entire power distribution system without power. For instance, a relay could be used to maintain a certain type of power system by connecting various sorts of loads to the distribution system via the feeder. A relay needs to be rectified with an alternative power source. This is the reason why over-current relay is used as a sensitive and secure component. A distribution system's forward and reverse faults will cause the relay to trip as well as the fault duration.

KEYWORDS:

Distribution system, Feeder protection, Overcurrent relay, Power system.

INTRODUCTION

Power systems have grown a lot in the last ten years. The modern trend is to locate the power station where energy is available, such as at a dam or a large colliery with a lot of water, to meet this demand. After that, the power travels hundreds of miles to the load centers. The peculiar phenomenon that fault currents are less than or slightly higher than maximum load currents under maximum plant conditions has been caused by the long-distance transmission system that is prevalent in South Africa and many other nations. Pilot wire protection cannot be used because of the length of the transmission lines involved. [1]

Despite being very straightforward, the graded overcurrent prevention design falls short of all the protection requirements of an electrical power system. There are two causes of application problems: First, a complex assignment cannot be graded in an acceptable manner. Second, the protection changes may result in maximum operating times that are excessive and unable to halt failures in the electrical system. These problems centered on the idea of unit protection. According to this theory, individual electrical system components are safeguarded without regard for other electrical system components. The 'Differential Protection' one unit protection idea is well recognized. Finding the difference in currents between the shielded element's entering and outgoing terminals forms the basis of this theory. Other concepts for unit protection may be based on phase comparison, distance tele-protection setups, or directional comparison. [2]

The electrical system's design may support the unit protection concept. For instance, given that the transformer winding connected to the protected feeder is not grounded, a straightforward ground fault protection relay employed at the source end of a transformer-feeder can be regarded as unit protection. Due to the power transformer's inability to transfer zero sequence current to an out-of-zone problem, the protective zone in this scenario is only the feeder and power transformer winding. The most popular kind of protection is feeder protection, or more specifically protection for overhead lines and cables. [3] In order for the electrical grid to continue supplying energy, protection must be in place. In the event of a defect, it must be stopped before it spreads to the network's stable areas. Additionally, the relays must protect everyone's safety and minimize harm to the cables and any associated equipment.

LITERATURE REVIEW

Doug Jones and John J. Kumm [4] nonradial flows of real and reactive power from high penetration distributed generation and, possibly, microgrids could soon make distribution feeder protection more difficult. For faults at distant circuit points, nondirectional overcurrent protection may not provide the necessary security and sensitivity. In order to set overcurrent pickups with sufficient sensitivity for remote faults, directional supervision is required. Traditional methods of setting the directional element carry a reliability risk at various VAR flows that are within the reach of particular kinds of distributed generation. The dangers of an improperly configured directional element and the limitations of nondirectional overcurrent protection will be demonstrated in this paper. These issues can be resolved with a novel approach that makes use of directional overcurrent elements and is secured by a load encroachment function. Over a wide range of operating conditions, this method has been demonstrated to work in renewable plant collector circuit protection applications.

Haitao Song et al. [5] High-penetration distribution generators can be successfully integrated using the DC micro-energy system pattern. Due to its complex fault characteristics and flexible operation modes, it necessitates protection with increased selectivity and sensitivity. Using transient high-frequency currents, a DC feeder protection strategy is proposed in this paper. The amplitudes of the high-frequency currents at all ends are compared to determine the fault direction and fault feeder. In order to locate the fault pole, the DC voltage's amplitude ratio coefficient is used. The communication delay and fault impedance will have no effect on the transient high-frequency components. Before the inverter-interfaced generators and loads fail, the protection scheme quickly detects and clears various feeder faults, ensuring the safe and reliable operation of the non-fault zone. MATLAB/Simulink is used to build the model of a DC micro-energy system, and in-depth simulations show that this method is effective.

According to E. P. Southern et al. [6] In this research, a novel sample synchronisation method for numerical differential feeder protection relays is presented. At each end of the shielded feeder, a Global Positioning System satellite receiver is used for sampling synchronisation. The typical distribution feeder with multiple faults was simulated using the EMTP/ATP power system simulator. The performance of the protection was assessed using the current signals produced at the feeder's two ends. The protection simulator was used to conduct these tests. The outcomes show how current transformer saturation affects the protection's sensitivity and stability. Finally, it is demonstrated how quick, picky, and precise synchronized differential protection is. It has a high operating sensitivity for internal defects while being stable for any external problems.

According to Salauddin Ansari and Om Hari Gupta [7] the expansion of the microgrid protection scheme is complicated by the integration of distribution generation (DG). The microgrid protection schemes are constantly being developed by researchers from all over the world. Using positive sequence (PS) voltage and current components, this paper proposes a differential positive sequence power angle (DPSPA)-based microgrid protection scheme. When the voltage and current signal information at both ends of the feeder are considered, the DPSPA is calculated. If it is higher than the threshold, an internal fault is reported; otherwise, it is an external fault. On a modified IEEE-

13 bus feeder, the proposed protection scheme is tested taking into account the various microgrid operational modes, variations in DG penetration, and variations in fault variables such as fault types and locations. Additionally, a variety of non-faulty events, such as induction motor starting, non-linear loading, load switching, capacitor switching, and section cutoff, were carried out in order to evaluate the suggested scheme's viability and effectiveness. External flaws are also tested, and it is found that the proposed scheme remains stable under these conditions. The results demonstrate that this DPSPA-based proposed plan in a variety of operating conditions can successfully safeguard the microgrid.

Helen Cheung et al. [8] The existing feeder protective devices, which were made for traditional distribution systems with mostly radial configuration, have been significantly affected by the increasing number of connections of various kinds and sizes of distributed generators (DGs) on distribution feeders. Due to the fact that the presence of DGs almost fundamentally alters the existing radial feeder circuit structure and the radial flow of power, the DG connections have presented significant challenges to the operational dependability and security of the existing feeder protections. As a result, the research presented in this paper aims to improve distribution feeder protections' operational dependability and security by focusing on issues with existing feeder protections, particularly those brought on by DGs. The findings of in-depth investigations into DG-imposed protection issues, such as sympathetic tripping, failure of fuse saving practice, mis protection as a result of feeder-network reconfiguration, reduction-of-reach protection, unintentional islanding, and miscoordination, are presented in this paper. The problems with protection brought on by the connections of DGs to power distribution systems are addressed in this paper with straightforward solutions.

According to Li Hsiung Chen et al. [9] In Taiwan, distribution systems are frequently radial type or typically open loop type. A straightforward protection system for distribution feeders often uses overcurrent relays. The coordination between the feeder protection devices is lost when renewable generation (RG) is linked to the distribution feeder, which transforms the feeder from a simple single-source system to a complex multi-source system. Protection failure may result during RG unit operation.

The feeder relay's ability to measure current may be compromised by the fault current that RG units create. In order to link RGs to the feeder, this article suggests using four-way circuit switches with overcurrent relays and segmenting the feeder into several protection zones. Each protective zone has the ability to isolate a particular fault. For distribution feeders with RG, the overcurrent protection algorithm process and design procedure are also suggested. The study's findings offer an invaluable guide for overcurrent protection that enhanced cooperation between protective measures and system dependability.

Alexandre B. Nassif et al. [10] Distributed energy resources (DERs) are becoming more prevalent in distribution systems thanks to growing environmental consciousness, government subsidies, and postponed utility investments. Even if they are advantageous, these DERs present the electricity utility with operational difficulties, from heightened safety hazards to unstable system performance. Due to the increased fault contribution output by DERs, conventional feeder overcurrent protection is one of those that may get desensitized. It might not always be able to completely safeguard the distribution line. The Apparent Effect, which accounts for the decline in fault contribution from the substation, is a new effect that is introduced in this study. Depending on the type of DER technology synchronous, induction, doubly-fed induction generators, or inverter-based DER sit varies in scope. To counteract this tendency and ensure feeder protection dependability, a substantial expenditure may be necessary. This essay provides an analytical description of the problem and offers recommendations for system reconfigurations that may help to lessen it.

According to Alexander Yanushkevich and Jan Svec[11] Future distribution systems are suggested to use medium voltage direct current (MVDC) grids since they offer benefits including lower transmission losses and high controllability. Due to fast fault propagation, high peak currents, the absence of current zero crossing, and other factors, protecting a DC grid presents more of a challenge than it does for AC systems. The power electronic components have up till now been the foundation for suggested hybrid DC circuit breakers, which are also significantly more expensive than AC circuit breakers. The cost of the MVDC grid dramatically rises if DC circuit breakers are used at each individual feeder. In this study, a system for protecting multiple feeders is proposed that makes use of the primary power electronic component of the circuit breaker. The suggested technique permits a protection system cost reduction while keeping the quick fault clearing capabilities offered by hybrid DC circuit breakers. There is a detailed description of the design evaluation of the protection system components. Any hybrid circuit breaker architecture might theoretically be employed with the proposed multi-feeder protection method.

According to Marko Islic et al.[12] The research discusses a novel approach for using an artificial neural network (ANN) to locate a problem in an electric power distribution radial feeder and proposes a novel centralized protection approach based on ANN. The developed algorithm's goal is to identify radial feeder faults and detach faulty laterals from the distribution network. The existing protection techniques cannot leave the entire feeder energized by disconnecting only the defective laterals without even a brief de-energization of the feeder's healthy portion. Additionally, a simulation model is created for use in testing and training the ANN. The simulation model generates current values for problematic and healthy states, which are then used as training and test data for the algorithm. The algorithm's goal is to determine which feeder circuit breakers need to trip. Using MATLAB tools, the simulation model and the ANN are modelled. The outcomes demonstrate that the algorithm's initial trip of circuit breakers is accurate in all states.

Lucas B. Oliveira et al.[13] The primary findings from the deployment and commissioning of the feeder's protection and measuring system, which relies on analogue and digital acquisitions by concentrator merging units, are described in this paper. The AL-60 feeder has the described project installed at the CTEEP-owned Embu-Guacu substation. The operating system's system architecture, protection mechanisms employed, network architecture, data segregation techniques, and outcomes from laboratory and real-world testing are all given. In Brazil, the successful pilot project deployment experience with the Merging Unit operating to trip the system and act on the circuit breaker is novel.

Akshay Kumar and Viranjay M. Srivastava[14] a framework for expanding energy distribution that is implanted with multiple energy distribution sources, such as distributed energy resources, consolidated heat and power, and sustainable power sources is a smart feeder. Low transmission and dissemination costs, as well as high dependability, high effectiveness, and minimal natural impact, are benefits of the smart feeder design. The management of the electrical feeder system is also becoming more and more difficult. The main barrier to effectively monitoring and controlling the electrical distribution system has been identified as the lack of data at the base feeder and the electricity administration network status. With the help of a fast Solid State Relay (SSR), this research effort advances the microcontroller-based smart feeder protection from overcurrent to functional monitoring and control of the Feeder system. The simulation result of this work demonstrates that, with the aid of a microcontroller, the system is capable of controlling and monitoring the feeder protection system from overcurrent. Calculations of the PhotoMOS relay cut-off time and overcurrent parameters have been made in this study. The obtained findings significantly outperform the conventional EMR circuit protection. Compared to the overcurrent values of 0.8, 1.0, and 1.2 mA, the PhotoMOS relay working cut-off time is much slower than the EMR protection system at 1.2, 1.3, and 1.4 ms.

According to Yanxia Zhang and Fengxian Dai[15] the direction of fault currents in distribution networks is altered when distributed generation (DG) is interconnected. As a result, sensitivity would decrease, protective relays would fail, and misoperation would occur. There are two new feeder protection schemes for the distribution network, one of which includes DG. The relays can quickly isolate a fault based on the new setting principle and the operating results of two adjacent relays in the first scheme, in which the zone relay of directional current protection on each line forms a communication unit with the zone relay of next stage protection on the adjacent line. The second one uses wide-area measurement technology and combines the current protection at the first line exit with the direction information detected by directional elements at the line terminations to precisely identify the fault section and guarantee the selectivity and speed of the upper protection.

DISCUSSION

One of the most crucial components in electric power plants and substations are the feeders. The bulk of faults are more likely to occur on feeders or lines, according to statistical data. This is a result of their length and exposure to the atmosphere. For the safety of feeders, there are numerous protective plans available. With a few minor adjustments, the protection strategies used for transformers and alternators can also be used to protect feeders.

Below is a list of the requirements for feeder protection.

1. The system can be damaged by short circuits on the feeders because they produce huge fault currents, a lot of heat, and a risk of fire. As a result, to fix a short circuit in the power system, the circuit breaker closest to the problem needs to be opened; all other circuit breakers should be closed.
2. It is the duty of the closest circuit breaker in that zone to isolate the faulty portion whenever a fault develops in a specific zone. The surrounding circuit breakers should offer backup protection as a second line of defence in the event that the closest circuit breaker malfunctions.
3. The running time of the relay employed should be as short as possible to maintain system stability and prevent needless circuit tripping.

Types of Feeder Protection Relays:

One or more of the following Feeder Protection Relay types may be used in a composite transmission system.

1. **Overcurrent protection:** The two types of overcurrent protection are:
   i. Non-directional time and current graded schemes
   ii. Directional time and current graded scheme

2. **Distance protection:** High speed distance relays are used for distance protection.

3. **Pilot protection:** There are three categories of pilot protection:
   i. Wire pilots protection
   ii. Carrier pilots
   iii. Microwave pilots

The following list of criteria can be used to determine which protection plan to choose:

1. The plan to guarantee complete continuity of both radial and ring main feeder protection relay types is economically justifiable.
2. There are several number of switching stations connected in series between the system's supply point and its farthest end.
3. Pilot wire availability.
4. System Earthing: whether or not the neutral is earthed.

Economic Consideration:

Since there are several ways to accomplish the goal of feeder protection, taking the economy into account is one of the most crucial considerations when developing a relaying system. If an appropriate protection strategy is not chosen for the concerned, the protection scheme is said to be uneconomical and unreliable. We choose overcurrent earth fault protection for earth fault protection, and it must be used in conjunction with phase protection as one of the distance schemes. In some cases, time-graded protection over existing protection will be sufficient and can be chosen. Therefore, careful protection plan selection can result in an economical design.

Availability of Pilot Wires:

Pilot wires are a unit form of protection that are only available for faults that occur in the same zone. This doesn't offer backup security. It provides high-speed protection against all fault kinds and for locating all fault sites. Pilot wire protection for short line systems is based on differential protection. Carrier current protection is utilized for long lines and interconnected connections.

Earthing System:

Surges brought on by lightning harm numerous system components, including feeders and lines in the electrical system. A neutral point of an electrical supply is typically linked to the earth grounded as part of the protective type known as earthing. On equipment enclosures, the grounded conductor's current causes critical voltages. Therefore, by electrical regulation, the grounding wires and neutral conductors are properly installed. It provides a low resistance channel for fault currents.

In large transmission systems or other situations where a time lag is acceptable and instantaneous functioning is not required, time graded overcurrent relays are typically employed for backup protection. They are more significant in distribution feeders and can work in tandem with fuses. Ground faults are also handled by overcurrent relays. When time lag from stability considerations cannot be allowed, distance protection is used. There are many different types of distance protection, each with a specific set of applications. For example, reactance type is preferred for very short lines; impedance relay is suitable for medium-length lines but is likely to operate incorrectly under extremely high reactive power surges; and mho relays are appropriate for phase faults of longer lines. Distance relaying is a quick type of security.

The protection of pilot type is a unit-level protection that would only be activated in the event of a fault happening inside the protected area and would not provide backup protection. This type of protection has the advantage of providing the quickest discriminative clearance of any faults occurring anywhere inside the protected feeder. For short lines where the expense of pilot wires is not prohibitive, pilot wire protection is employed. Long lines and interconnecting lines are protected using carrier and microwave waves.

The quickest and most dependable protection is installed on main transmission lines operating at 220 KV or above. On main transmission lines, carrier-pilot or high-speed distance protections must be employed, while on 33 KV circuits, directional time lag over current relays or high-speed distance relays are available. Radial feeders operating at 11 KV or lower are typically outfitted with instantaneous relays in addition to time-lag overcurrent relays. On these lines, HRC fuses alone are occasionally employed.

Protection of Feeders: The feeders are typically laid out as follows:

I. Radial feeders

II. Parallel feeders, and

III. Ring mains.

Radial Feeders:

A radial system's defining feature is that power can only travel in one direction across the line, from the supply end to the consumer end. Radial feeders are often protected against over currents by a time-graded protection scheme using definite time relays. An overcurrent relay with a predetermined minimum time has been utilized at all substations and is independent of running currents. The time is selected so that the relay at the last substation has the least time and the generating station has the most.

The relay OC5 should operate when a fault on the SS4 occurs, not any other relays; in other words, the time needed to run the relay OC4 must be shorter than the time needed to operate the relay OC3, and so on.

This demonstrates the need for appropriately graded time setting for these relays. The smallest space of time that can be permitted between two adjacent circuit breakers is determined by their own clearance times, plus a little extra time for a safety margin.

The discriminating time between adjustment breakers should be at least 0.4 seconds with a regular circuit breaker in operation. The time parameters will be 0.2 seconds, 1.5 seconds, 1.5 seconds, 1.0 seconds, 0.5 seconds, and instantaneous for relays OC1, OC2, OC3, OC4, and OC5. It is crucial that the time of operation for the severe fault should be shorter in addition to the grading system. Utilizing a time-limiting fuse in tandem with the trip coils will accomplish this, as shown in the given below Figure 1.

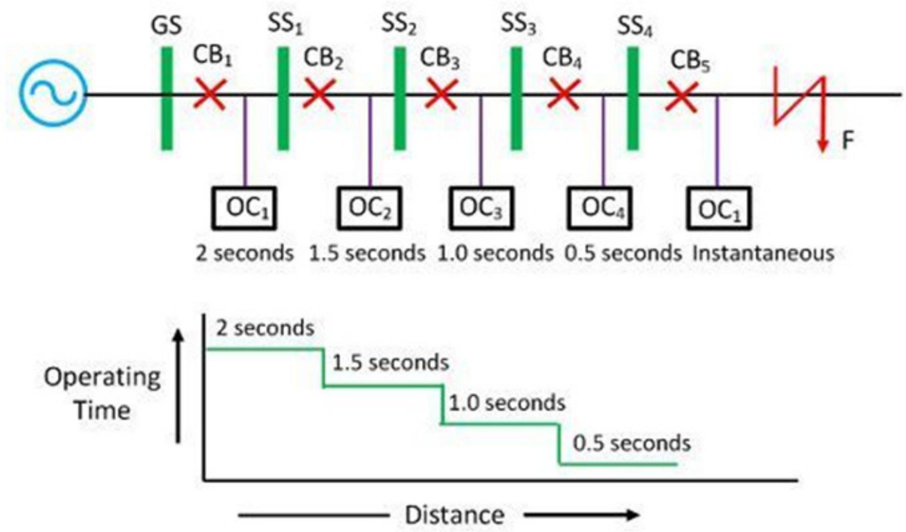

Figure 1: Illustrate the Protection of Radial Feeder.

Advantages:

1. The simplicity of construction makes radial feeders.
2. The initial investment needed is little.
3. They are quite simple to use.
4. Less switching equipment is needed.
5. The needed conductor size is smaller.

Drawbacks of a Radial Type Feeders:

1. Lower dependability.
2. Service continuity cannot be preserved.
3. The distributor's end that is closer to the feeding point is heavily loaded.
4. High voltage fluctuations occur across the consumers at the feeder's far end as a result of load variation.

Parallel Feeders:

In order to share the load and ensure supply continuity, the supply is connected in parallel. When the protective feeder develops a malfunction, the protective device will choose and isolate the problematic feeder while immediately assuming the increased load on the other. The time graded overload relay is one of the most straightforward ways to protect the relay. It has an instantaneous reverse power or directional relay at the receiving end and an inverse time characteristic at the transmitting end.

Both the transmitting end and the receiving end of the line feed electricity into the heavy fault F when it occurs on either one of the lines. Through the relay on D, which will be open, the flow of power will be reversed. Afterwards, the extra current is limited to B until its overload relay trips the circuit breaker and entirely isolates the problematic feeder, allowing power to be supplied through the healthy feeder. Only when the fault is severe and the power is reversed at D is this procedure effective. Therefore, in addition to the overloaded protection at both ends of the line, differential protection is also implemented, as shown in the picture below Figure 2.

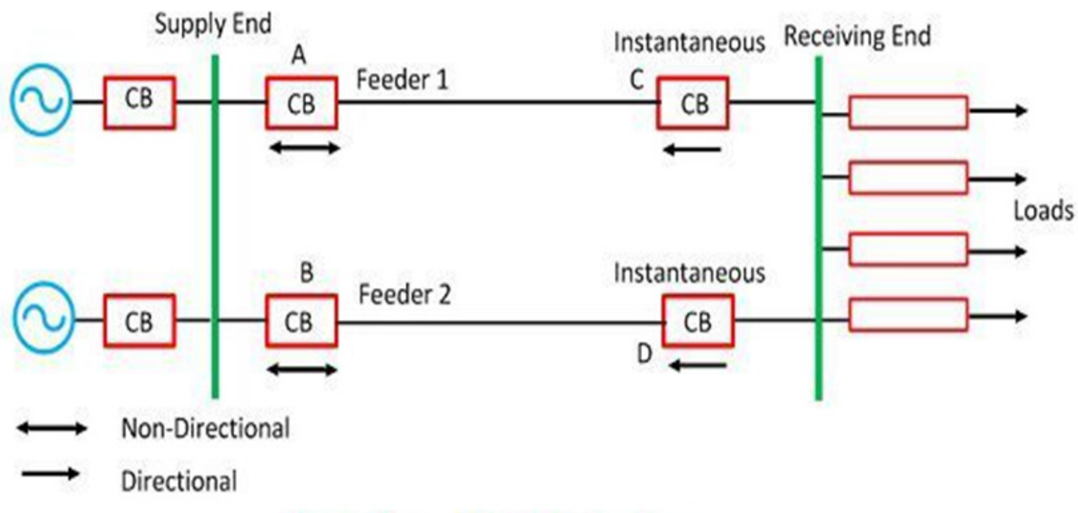

Figure 2: Illustrate Protection of Parallel Feeder

CONCLUSION

One of the most important parts of the electrical power grid are protective relays, which may either start or allow switching or simply sound an alert to create a safer, more dependable distribution system by detecting faulty equipment or other hazardous or unacceptable circumstances.

The most popular kind of protection is feeder protection, or more specifically protection for overhead wires and cables. In order for the electrical system to continue supplying electricity, safeguards must be in place. In the event of a defect, it must be stopped before it spreads to the network's stable areas.

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CHAPTER 9

STUDYING THE DYNAMIC PROPERTIES OF THE ELECTROMAGNETIC RELAY

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ABSTRACT:

The relay is a crucial piece of equipment for control and power systems. The system's dependability is strongly influenced by its dependability. To enhance the system's dependability, research into the dynamic characteristics of the relay is required. It is used in remote control, telemetry, communication, automatic control, mechatronics, and power electronic equipment. Through coupled structural finite element computation, electromagnetic finite element computation, and kinetic numerical computation, a collection of dynamic characteristics for an electromagnetic relay was uncovered.

KEYWORDS:

Dynamic Characteristics, Electromagnetic relay, Power system, Relay Protection.

INTRODUCTION

Relays that are controlled by electromagnetic force are referred to as electromagnetic relays. Even though most modern electrical protection relays are based on microprocessors, electromagnetic relays still have a place. All electromagnetic relays will need to be replaced with microprocessor-based static relays, which will take much longer. Therefore, we should review the various types of electromagnetic relays before going into detail about the protection relay system. One of the most important control elements is the relay, which is an automatic switching element with an isolation function. It is used in remote control, telemetry, communication, automatic control, mechatronics, and power electronic equipment. In most cases, the input part of a relay is an induction mechanism that can reflect a variety of input variables such as current, voltage, power, impedance, frequency, temperature, pressure, speed, light, and so on. It has an actuator that can turn the controlled circuit "on" and "off." An intermediate mechanism connects and isolates the input, performs functional processing, and drives the output part of the relay between the input and output parts [1].

Small generators were used to supply local loads in the early days of the power industries, and fuses were used as protection to separate damaged equipment from the circuit. Additionally, these fuses were efficient and delivered an acceptable performance for compact systems. However, these protection devices had the drawback of needing to be replaced before the supply could be restored, and it was undesirable for the power system supply to frequently be interrupted for any important lines. With the introduction of protective relays and circuit breakers, this undesirable condition was eliminated. Initially, hundreds of years ago, finely crafted "Swiss watch" precision electromagnetic relays were developed and installed. Solid-state or static relays became available in the 1970s, with a slight modification to the relay's function, taking the place of electromagnetic relays. Solid-state relays are unable to communicate or record events in this situation [2].

In the 1970s, a digital or numerical relay based on a microprocessor was introduced as a result of the widespread development of computer technology. This first generation of digital relays saw the development of novel algorithms and the first attempts to combine multiple protection functions into a single multifunctional relay. The ASCII protocol or proprietary serial commands were used to operate the first generation of numeric relays. However, the relay manufacturers later developed software that could generate background serial commands to program the relay components. Due to the through-hole component mounting design and poor solder joints, these relays are no longer in use and have reached the end of their useful life [3].

The circuit board's heating and cooling can also cause issues like a bad connection and an electrolytic capacitor in the power supply going bad. When a numeric relay of the first generation fails, operators are informed by built-in test routines that signal and alarm output. The electromagnetic relay and the majority of solid-state relay designs did not include this built-in test routine. Second-generation numerical relays, a new technology with improved algorithms and components, are constructed of more dependable surface-mount components and feature more powerful microprocessors. An operation that is more dependable, secure, and secure is provided by these new protection schemes.

LITERATURE REVIEW

According to Lucas Kirschbaum et al.[4] have given statement about the mass-produced consumer goods to highly specialized, safety-critical industrial systems, electromagnetic relays (EMRs) are ubiquitous in electrical systems. The limited analysis and comprehension of expressive EMR degradation indicators, as well as the accessibility and utilization of EMR life cycle data sets, are highlighted in our comprehensive literature review on EMR reliability, which focuses on the methods used to estimate the State of Health or the Remaining Useful Life. A prognostic deep learning pipeline known as the Electromagnetic Relay Useful Actuation Pipeline (EMRUA) prioritizes these unsolved issues. A Temporal Convolutional Network (TCN)-based architecture makes use of the characteristics of causal convolution to combine any length of multiple features into a useful remaining switching actuation forecast. EMR switching data (Contact-Voltage, Contact-Current) are the raw, high-volume life cycle data sets from which these features are extracted. During inference, the Monte-Carlo Dropout method is utilized to estimate uncertainty. Long sequences of multivariate time series data are selected and analyzed using a variety of approaches, including the TCN hyper parameter space. As a result, our findings demonstrate that the developed statistical feature set outperforms conventional, time-based features, as is common in the literature. Throughout the EMR's lifetime, EMRUA achieves an average forecasting mean absolute percentage error of less than 12 percent.

According to Jianqiang Liu et al.[5]talked about the high-speed train's (HST) safe and normal operation depending on the condition of electromagnetic relays. There are currently no appropriate methods for testing and evaluating the condition of electromagnetic relays. Throughout their service life, electromagnetic relays deteriorate and eventually fail, resulting in numerous potential security issues. The failure mechanisms of electromagnetic relays are examined to find solutions to these issues. The degradation models for contact resistance and closing time are deduced using the Larson-Miller method and Fick diffusion theory. An approach to calculating relay life is proposed based on these models. A test platform was designed and constructed to confirm the proposed method's efficacy. Siemens 3TH electromagnetic relays were used for the accelerated life test. Using a test platform, contact resistance and closing time was measured. With the test data, the degradation models' residual sum of squares and unknown parameters were calculated using least squares fitting. The fitting results were used to select the best degradation model. The optimal degradation model and the relay failure threshold predicted relay life at four temperature stress levels. The finding, which indicates that the electromagnetic relays have a life expectancy of 11,874 days at ambient temperature and a prediction error of approximately 5%, provides important guidance for the upkeep of electromagnetic relays.

The Authors Bo Wan et al.[6]studied on the after prolonged storage, electronic components frequently experience failure. Users reported that several electromagnetic relays' contact resistance values increased during storage. In this study, failure analysis was used to determine the underlying causes of storage failure. The mechanical damage was discovered through an internal and visual inspection. To demonstrate the state of the package and the internal gas composition, a seal test, and internal gas analysis were carried out. SEM, EDS, and XPS were used to study the morphology and composition of electromagnetic relay contacts. All tests and inspections show that the rise in the contact resistance value is caused by mechanical damage, organic contamination, and inorganic contamination.

According to Hui Min Liang et al.[7] One of the most important electronic components in aerospace electronic systems for information transfer, control, and power distribution is the electromagnetic relay. The reliability of this relay will affect the reliability of the entire aerospace electronic system. The most important method of electromagnetic relay reliability engineering is reliability design. Reliability tolerance based on mathematical models of electromagnetic force based on orthogonal design, mechanical spring force based on probability statistics theory, and matching characteristics of the electromagnetic force and mechanical spring force based on the method of stress-strength interference is presented in this synthetic analysis of current reliability design methods. Research into electromagnetic relays' reliability tolerance in aerospace yields some instructive conclusions.

According to Lanxiang Liu et al.[8]under capacitive loads, the electromagnetic relay's closing process frequently experiences contact bounce. Experiments are used the majority of the time in studies of contact characteristics. However, the experimental method cannot reveal the mechanism of contact bounce and is extremely time-consuming and complicated for structural design. To investigate the electromagnetic relay's dynamic characteristics under capacitive loads, a brand-new theoretical model is proposed. When compared to conventional simulation and experimental methods, the model makes it possible to simulate a dynamic process and collect bounce parameters straightforwardly and efficiently. The electromagnetic relay's physical mechanism for contact bounce is described. The Kelvin-Voigt viscoelastic contact model is used to evaluate the nonlinear contact force between the moving and fixed contacts. The coupling of electromagnetic and mechanical fields is taken into account when formulating the equations of motion. By comparing the experimental data to the theoretical results obtained in this study, the results are confirmed. The contact bounce is examined concerning the structural parameters, surge current, coil current, and contact resistance. By altering the contact spring's parameters and the moving contact's mass, the numerical results clearly show that the contact bounce can be effectively reduced.

According to Zhaobin Wang et al.[9] A particular kind of electromagnetic relay was chosen for the accelerated storage degradation test to obtain the data support required for the evaluation of the machine system's storage life and to address the issues of an unidentified cause of parameter degradation and an incomplete failure mechanism. Under storage conditions, the failure mode, law, and mechanism of electrical parameter change were investigated. On this basis, improvements to the reliability of the relay are proposed, which are crucial for increasing the system's and electromagnetic relay's reliability.

According to Evgeniy G. Vasilyev et al.[10]worked on both general and special-purpose engineering making extensive use of bistable relays. The construction principle divides such relays into two categories: magnetic latching relays and polarized magnetic bistable magnetic relays. There is virtually no information on the second group's relay design in the technical literature. This article uses the high-current relays of the DP-1 series, which have rated currents of 25 to 100 A and have been used for a long time in autonomous power supply systems for military equipment, as an example to highlight general design issues. The construction of the relay and the underlying principles of its operation are described in detail. The main mechanism of the electromagnetic and contact systems' kinematic schemes is taken into consideration. The relay's opposing characteristics are constructed as an illustration. The paper proposes a new method for calculating the magnetic system based on new assumptions and sections that are specific to the given relay construction.

According to Bin Xiao et al.[11]studied about the system's dependability is directly impacted by an electromagnetic relay's rated life, which is crucial for meeting the requirements of the entire machine. We looked into the mechanism that affects electromagnetic relay's rated life in light of the significant endurance disparity between batches and discovered that contact area, contact pressure, contact gap, and contactor material are the primary contributors to electromagnetic relay life failure. The test design as instructed by the design of the experiment (DOE) for the related influencing factors was carried out to improve the rated life and its consistency, obtaining a reasonable contact gap, constant contact pressure, and overrun without altering the contactors' structural design or materials. In addition, the tolerance design was used to improve the consistency of the rated life by optimizing the contact gap, constant contact pressure, and control range of overrun. The finding suggests that the DOE test can reveal the optimization scheme for the variables that affect electromagnetic relays. Additionally, the control range of the variables that have an effect can be optimized through tolerance design, which effectively increases the rated life and its consistency and, as a result, raises the quality of the product.

The authors Xue Rong Ye et al.[12]talked about during the design phase of an electromagnetic relay, the reliability tolerance design plays a crucial role in ensuring consistency in output characteristics and reliability. Internal interference, external interference, and machining dispersion are all examples of disturbing factors that can be mitigated by the reliability tolerance design. The electromagnetic relay's dynamic characteristic can better describe its operating procedure than its static characteristic. Based on the calculation of the dynamic characteristic, this article investigates the impact of three distinct disturbing factors on the dynamic characteristic of an electromagnetic relay. The dynamic reliability tolerance design method for electromagnetic relays is then discussed taking into account three distinct disturbing factors. From the very beginning of the design process, the conclusions reached can help ensure the electromagnetic relay's dependability.

According to Guofo Zhai et al.[13]designed and optimization of an electromagnetic (EM) relay is based on the quick and accurate calculation of the static and dynamic characteristics. An output space-mapping (OSM) algorithm based on the compensation factor (CF) is proposed in this paper, taking into consideration the advantages of both the magnetic equivalent circuit (MEC) method and the finite element method (FEM) for the computation of EM systems. When the dimensional parameters fluctuate within their respective ranges, this algorithm, which is based on the differentiability of the CF function about dimensional parameters, can compute the EM relay's static and dynamic characteristics quickly and accurately. The OSM algorithm's dependability is demonstrated by comparing FEM and the OSM algorithm's computations of the static attraction torque and dynamic characteristics.

According to Tongjian Wang et al.[14] A theoretical analysis model of the relay valve was created to test and verify the relay valve's reliability (with an output pressure of 12.0 MPa and a response time of 0.2 s) and investigate the impact of the relay valve's dynamic characteristics on the braking performance of the full hydraulic braking system.

The research object was a type of fully hydraulic braking system for off-road vehicles. Using the software AMESim, a simulation model of the complete hydraulic brake system was created, and the impact of the spool friction, initial cover, return spring, initial compression, and spring stiffness on braking performance was examined. Experiments demonstrated that the simulation model was accurate.

The comparison demonstrates that the hydraulic braking system's relay valve can satisfy the braking requirements with an output pressure of 12.0 MPa and a response time of 0.2 seconds. The spool's excessive friction causes the relay valve's opening pressure to rise, which in turn increases the relay valve's proportional hysteresis and affects the spool's reset performance. The relay valve orifice's initial cover determines how much friction must be removed by opening the orifice and how long the braking system's response time must be. The fine-tuning of the brake pressure can be accomplished by adjusting the stiffness and initial compression of the reset spring of the relay valve. The theoretical model and simulation model provides a solid foundation for further hydraulic braking system optimization.

DISCUSSION

Relays that work on the principle of electromagnetic attraction are called electromagnetic relays. It is a type of magnetic switch that creates a magnetic field by using a magnet. The switch is then opened and closed, and the mechanical operation is carried out by the magnetic field. The main types of electromagnetic relays can be broken down into two categories based on how they operate, as follows:

1. Electromagnetic Attraction Relay
2. Electromagnetic Induction Relay

Electromagnetic Attraction Relay

The magnet's pole attracts the armature in this relay. The square of the current flowing through the coil determines the magnitude of the electromagnetic force exerted on the moving component. Both alternating and direct currents can be handled by this relay. The electromagnetic force of an AC quantity developed is given as:

$$F_e = KI^2 = K(Imax\, sin\omega t)^2$$

$$= \frac{1}{2}K[1_{max}^2 - I_{max}^2 cos2\omega t]$$

The above equation shows that the electromagnetic relay has two components: one that is constant regardless of time and pulsates at double supply frequency, and the other that is dependent on time and is independent of time. Noise from the double supply frequency damages the relay contacts.

By splitting the flux that is developing in the electromagnetic relay, the difficulty of a double-frequency supply is overcome. Despite their distinct time phases, these fluxes were operating simultaneously. As a result, the deflecting force that results is always positive and constant. Using an electromagnet with phase-shifting networks or applying shading rings to the poles of an electromagnet allows for the splitting of fluxes. The simplest kind of relay is the electromagnetic attraction relay, which has a plunger-hinged armature, moving iron polarized relay, and rotating armature. Listed below are all of these relays.

1. Balance Beam Relay

The developed electromagnetic force varies as the square of the ampere-turn in a balanced beam relay, which compares two quantities. For this kind of relay, the ratio of operating current is low. On a fast operation, the relay will typically overreach. This is because the relay is set for fast operation, the construction of the balance beam relay is shown in the given below Figure 1.

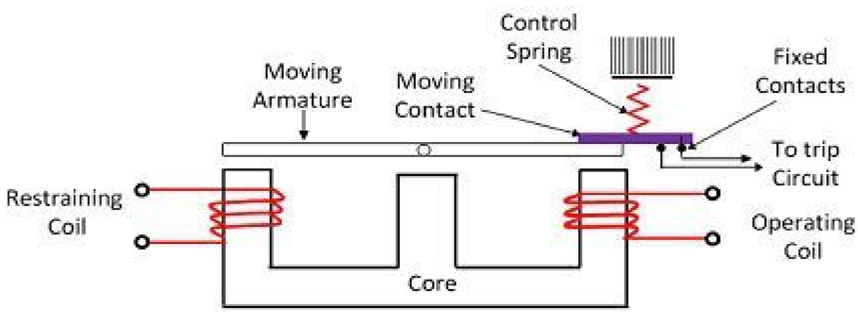

Figure 1: Illustrate the Construction of Balance Beam Relay.

2. Hinged Armature Relay

When we add a permanent magnet, which can increase the sensitivity of DC-operated relays. The polarized moving relay is another name for this relay, as shown in below Figure 2.

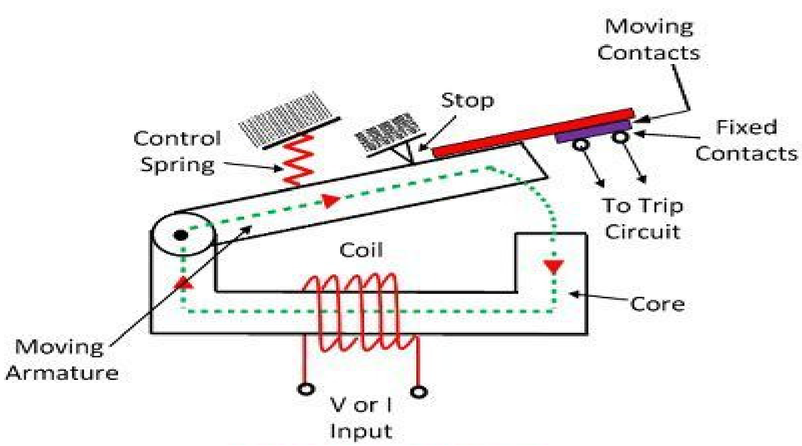

Figure 2: Illustrate the Construction of Hinged Armature Relay.

Electromagnetic Induction Relay

The electromagnetic relay is based on a split-phase induction motor's design. The non-magnetic moving element, which may be a disc or another type of rotor, experiences the initial force. Eddy current, which is induced in the rotor by these fluxes, and electromagnetic fluxes interact to create the force. The phase difference between the fluxes has been determined using a variety of structures. Shaded poles, watt-hour meter or double winding, and induction cup are the three types of structures.

1. Shaded pole structure

Current flowing through a single coil wound on a magnetic structure with an air gap typically powers this coil. A shaded ring divides the initializing current's air-gap flux into two fluxes that move through time and space. The copper ring that encircles a portion of each pole's face is what makes up the shaded ring, the structure of the shaded pole as shown in Figure 3.

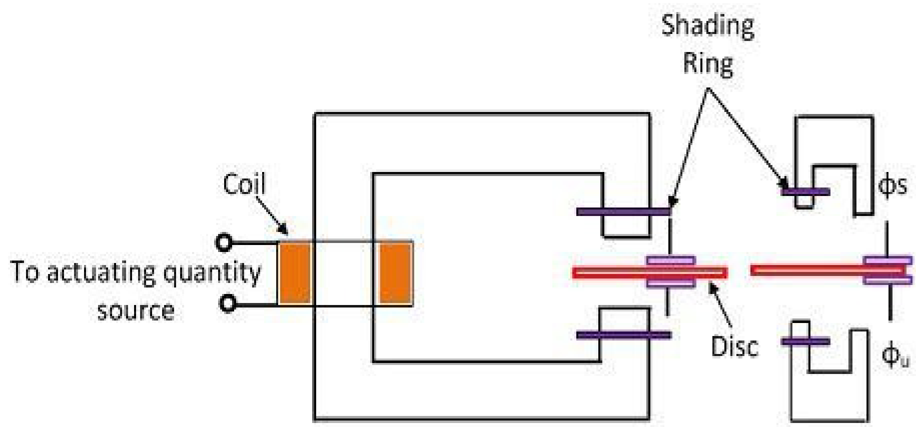

Figure 3: Illustrate the Construction of shaded pole structure.

Aluminium is used to make the disc. The aluminum disc has very little inertia, so they need less deflecting torque to move it. The alternating electromagnetic flux causes the current to flow through the two rings. The current creates a magnetic field that causes the flux in the iron ring surrounding the ring to lag in phase by 40 to 50 degrees from the flux in the pole's unshaded area.

2. Watt-hour Meter Structure or double winding

This structure has an electromagnet in the shape of an E and an electromagnet in the shape of a U separated by a disc that can rotate between them. The flux produced by the two magnets, which have different resistance and inductance for the two circuits, results in the phase displacement between the fluxes produced by the electromagnet. The primary and secondary windings are carried by the E-shaped electromagnet. The relay current I1 was carried by the primary current, and the secondary winding is connected to the U-shaped electromagnet's windings. Relay current I1 is carried by the primary winding, while the secondary current creates an EMF in the secondary and circulates the current I2 there. The flux φ1 induces in the U-shaped magnet and the E shed magnet, respectively. The angle θ at which these fluxes φ are induced in the upper and lower magnetics differs in phase, resulting in a driving torque proportional to φ1φ sinθ on the disc.

The relay's ability to open and close the secondary winding circuit is its most significant feature. The relay can be rendered inoperable if the secondary winding is opened because no torque will be produced, as the construction of a watt-hour type induction disc relay is shown in Figure 4.

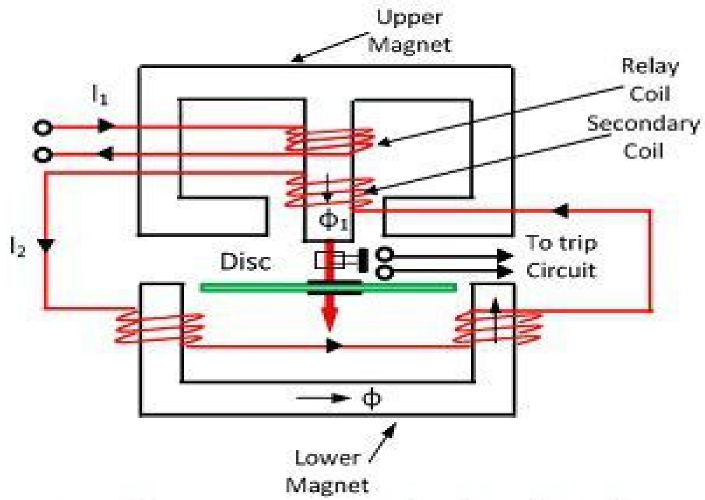

Figure 4: Illustrate the Watt-hour Meter type Induction Disc Relay

3. **Induction Cup Relay**

The induction cup relay is a type of relay that operates on the principle of electromagnetic induction. The relay coil energizes two or more electromagnets in the device. The electromagnet is sandwiched between the static iron core and is shown in the given below Figure 5.

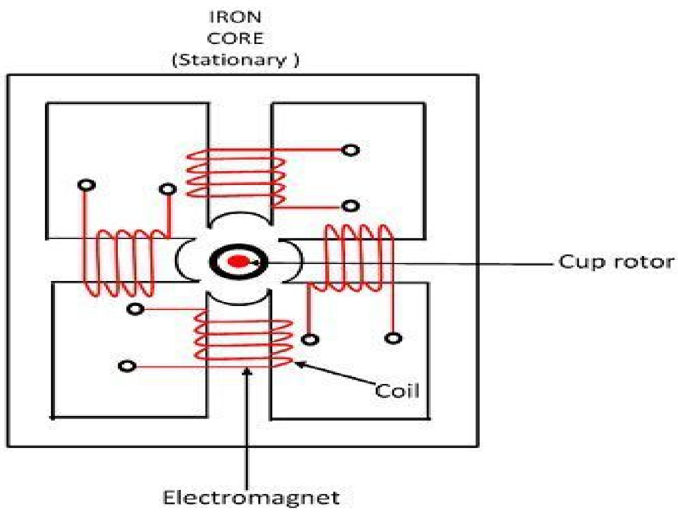

Figure 5: Illustrate the Induction Cup Relay.

The rotating magnetic field is created by the electromagnet's wound coil. The current that flows inside the cup is the result of the rotating magnetic field. The cup begins to rotate as a result. The cup rotates in the same way that the current rotates. When compared to the shaded and watt-meter types of relays, the induction cup relay generates more torque. The relay operates quickly and requires only about 0.01 seconds to operate.

Specifications of Relay

Before choosing a relay, you must take into account a variety of factors to ensure its longevity and safety. The primary variables are...

i. Coil Ratings
ii. Contact Ratings
iii. Enclosure and Mounting
iv. Change Over Time

Coil Ratings:

The electromagnet excitation voltage and coil resistance specify DC-operated relays, whereas AC-operated relays specify the AC voltage and VA ratings.

Contact Ratings:

The maximum continuous voltage and current it can handle are the most frequently used contact ratings.

Enclosure and Mounting

Open and enclosed versions of enclosure and mounting relays are available. You can use the open execution type if a device's cabinet contains relays. However, enclosed relays are preferable in situations where dust may accumulate in electrical contacts. Additionally, there is a possibility of sparks in the contacts; consequently, an appropriately enclosed relay must be selected in hazardous environments.

Change Over Time

Operation Time is another name for Change over Time. The time it takes for the relay to make an ON contact after activating the electromagnet is known as the Turn–ON time, and the time it takes for the relay to make an OFF contact after deactivating the electromagnet is known as the Turn–OFF time. These times are crucial in some applications, like UPS.

Types of Electromagnetic Relays:

Based on the working principle, electromagnetic relays can be classified into the following types as follows.

1. Attracted Armature
2. Induction Disc
3. Induction Cup
4. Balanced Beam
5. Moving coil
6. Polarized Moving Iron

Benefits of Electromagnetic Relay:

1. Electromagnetic relays are simple to operate and reset.

2. Reset and slow operation are potential outcomes.

3. It can be utilized to safeguard AC and DC equipment in both systems.

4. A few of their characteristics include being trustworthy, small, sturdy, and simple.

5. It has a millisecond-level working speed that can be achieved with electromagnetic relays.

6. It works almost immediately. The relay's operating time varies with the current, despite being instantaneous with additional arrangements like copper rings, a dashpot, and so on.

Drawbacks of Electromagnetic Relay:

1. High-burden level instrument transformers (CTs and PTs) are needed to operate electromagnetic relays rather than static relays.

2. Relay operation is impacted by dust, pollution, and component aging, which can lead to inaccurate trips.

3. An operating speed limit is set by electromagnetic relays' mechanical inertia.

4. There is no directional feature in electromagnetic relays.

5. Unlike static relays, requires routine testing and maintenance.

Applications of Electromagnetic Relay:

When large electrical loads need to be switched with a small signal, electromagnetic relays are used. In addition, relays are utilized to provide electrical isolation between high-voltage and low-voltage systems, safeguarding users and low-voltage systems.

1. Electromagnetic relays are used to protect several AC and DC instruments.

2. The defense against excessive or inadequate current and voltage for various AC and DC equipment.

3. It is utilized as additional relays in the contact systems of protective relay schemes.

4. It is helpful for protect differential protection.

5. It can be used in Automobiles sectors such as fuel pump, horns, starter motors, wind shield vipers.

6. Used for Building automation as such in access control systems, elevators, control panels.

7. It is used in Motor controllers, light controllers, power supply distribution and switching.

8. Used for Domestic appliances such as Ovens, washing machines, indoor/outdoor AC units.

CONCLUSION

The electromagnetic relay still has certain development space in the new period due to low cost, mature technology. The main development direction is miniaturization, high power, high reliability, and high ability of the environment, on the production side, as far as possible to reduce costs, and increase productivity.

This chapter analyzes the selection and reliability using of electromagnetic relays usually used in electronic machine equipment which is beneficial for designers to select and use a proper relay. Meanwhile, in the use process, it should pay attention to strengthening technical checking and maintenance to extend the life of the relay device and effectively improve system reliability, relays are important devices and it will be utilized on the basis of their applications.

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CHAPTER 10

OVERCURRENT RELAY FOR SAFEGUARD OF TRANSMISSION LINES

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ABSTRACT:

Failure of the system or natural disasters can cause faults in the power system. This could happen as a result of damage to parts of the power system, which would force them to pay for themselves and cut off power to customers. This stipulation is increasingly transmitted via transmission lines from one side to another side during this time of power exhaustion. These transmission lines may experience a variety of faults. The primary objective of this chapter is to examine and describe the various faults and their effects on the transmission line and also the role of overcurrent relay to reduce those faults that occur in the transmission line.

KEYWORDS:

Faults, Overcurrent Relay, Power System, Transmission Lines.

INTRODUCTION

The overcurrent protection relay is one of the fundamental power system protection strategies in distribution systems. Because they are less expensive than other types of relays, overcurrent relays (OCR) are the primary form of protection. OCRs are only used as backup protection in transmission power networks and on the other hand, distance relays are used as primary protection of transmission lines due to their relatively high time delays. Distance relays, on the other hand, typically aren't used in distribution networks because they are much more expensive than standard OCRs. As a result, a protection engineer's primary concern is the coordination of OCR in a power distribution network. OCRs are used in conjunction with overvoltage protection devices, over-frequency protection devices, and other devices in active networks with distributed generation units. Typically, numerical relays incorporate all of these safety features into a single device [1].

Robust protection of the distribution electric power system is required because of the accelerated expansion of the grid that supplies electric power to consumers and the requirement for increasingly dependable service that satisfies regulatory requirements. To attain a certain level of reliability and quality in the electrical power supply, it is crucial to invest in protection technologies and devices. Each component of the distribution power system must be adequately protected to avoid a power outage and its consequences regarding equipment malfunction and failure. Different power system configurations with their protection coordination philosophies have distinct benefits and drawbacks [2].

The most crucial method for meeting the above-mentioned requirements is protective relays. In the event of an abnormal condition or fault, such as a short circuit, the protective relay's job is to de-energize the faulted portion of the distribution power system and keep the rest of the system from being affected. The relays are coordinated to prevent the aforesaid occurrences and their impact on customers. Because a lack of coordination can have serious effects on the power system, such as power outages, equipment damage, and utility station malfunctions those properly coordinated relays are very important for the power distribution system.

The magnitude of the current increases whenever there is a fault in the power system. The fault current is measured by the overcurrent relays and compared to predetermined threshold values. A trip command is issued after a predetermined time delay when the current level exceeds the threshold. The corresponding circuit breaker then opens its contacts and isolates the faulted area. For a device to properly respond in the event of an emergency, protection coordination necessitates the selection of its settings. To obtain the appropriate inputs for relay protection coordination, short circuit, and load flow analysis are required. Reliability, selectivity, sensitivity, and speed of the protection relays must all be guaranteed by the coordination schemes [3].

LITERATURE REVIEW

According to Suzana Pil Ramli et al.[4] studied power plants have been incorporated into the power system as a result of the exponential rise in diverse load demand over the past decade. Due to the current flowing in both directions, causes the fault current to rise, which can cause the relays to trip unintentionally if they are not coordinated correctly. As a result, it is necessary to guarantee that the grid's relays can detect fault currents coming from either upstream or downstream. By incorporating an optimal directional overcurrent relay (DOCR) coordination scheme into the system, this can be accomplished. The various optimization methods used to achieve the best possible coordination of directional overcurrent relays (DOCRs) in integrated power networks are examined in detail in this paper. The review focuses on the benefits and drawbacks of the methods used to reduce DOCR coordination issues. This paper also discusses potential research directions for optimal DOCR coordination.

Both the authors Sethembiso Nonjabulo Langazane and Akshay Kumar Saha,[5] worked on the operational challenges posed by distribution systems, such as protection miscoordination, which continue to rise. Overcurrent relay coordination issues were initially resolved using conventional approaches. However, putting these strategies into action takes time. Particle swarm optimization and genetic algorithms have been used in recent research to solve problems with overcurrent relay coordination and increase system selectivity and operational speed. Genetic algorithms and particle swarm optimization are evolutionary algorithms that occasionally experience premature convergence as a result of inadequate control parameter selection. As a result, this paper provides a comprehensive sensitivity analysis to examine how discrete control parameters affect the behavior of overcurrent relays, genetic algorithms, and particle swarm optimizer performance. Overcurrent relay time multiplier settings are minimized and protection coordination is optimized by optimization algorithms. According to the findings, the number of iterations has little effect on particle swarm optimization, but inertia weight and swarm size have a greater impact. The findings also show that smaller population size, 30% crossover, and 2% mutation result in a faster convergence rate and an optimized fitness function, both of which boost the performance of genetic algorithms. By contrasting the results of the sensitivity analysis with those of the genetic algorithms, which show that the first parameter setting performs better, the results are confirmed. Particle swarm optimization results in a 15 percent reduction in the operational speed of the relay, maximizing system selectivity. Particle swarm optimization's optimal protection coordination demonstrated the superiority of the algorithm, as well as its consistency, efficiency, and ability to avoid premature convergence.

According to Nader Hatefi Torshizi et al.[6] have given the statement about overcurrent relays' operating times, fault current, and relay pair coordination all change when the sources' operation mode is changed. A novel adaptive approach is presented in this paper for ensuring that overcurrent relay coordination is maintained despite uncertainty regarding the presence of DGs in a distribution network. In the absence of DGs, coordination is established after the relay settings are first calculated in the base structure. The Thevenin equivalent circuit is then used to calculate the new structure's fault currents. From the perspective of the relay, voltage, and current are measured at the relay location before a fault occurs to determine the Thevenin equivalent circuit. The base structure fault currents to the new structure fault currents are then compared to create adaptive coefficients. The coordination of relay pairs is maintained and the fault currents in the new structure are transformed into the base structure's equivalent values employing these adaptive coefficients. In networks with radial, ring, and mesh configurations, the proposed adaptive relay coordination is contrasted with conventional relay coordination. The simulation results demonstrate that the proposed approach is superior when it comes to maintaining coordination.

According to Michele Rojnic et al. [7] have stated protection coordination of distribution networks involves the optimization of overcurrent relay operation. This usually refers to medium-voltage networks because they are protected by numerical relay devices, whereas utility operators allocate fuses in low-voltage networks. Due to significant changes in the passive operation of their networks over the past two decades, the correct setting of relays and optimal coordination is increasingly becoming significant challenges for Distribution Network Operators worldwide. The development of a protection philosophy for distribution networks has been indirectly influenced by distributed generation units, a growing liberalized electricity market, and more stringent state regulatory bodies' legislation governing the planning and operation of distribution networks. From a theoretical and practical perspective, the traditional optimization problem of overcurrent relay operation will be addressed and critically examined in this paper. The optimization function, constraints, and relay parameters will all be observed and compared, and their modifications and enhancements will be proposed and elaborated in detail concerning solutions that are utilized in distribution networks.

According to S. Karupiah et al.[8] talked in the order to safeguard the power system, an important role is played by the overcurrent relay. Relays must be properly coordinated with the appropriate settings for protection. Taking into account the fault current at the relay location, the best Time Multiplier Setting (TMS) and Plug Setting (PS) can be chosen for coordination. To guarantee the correct sequential operation of the relays, Continuous Time Intervals (CTI) must be maintained between the primary relay and the secondary relay. However, secondary relay trips faster than primary relay can lead to miscoordination. Using the MATLAB Artificial Neural Network (ANN) algorithm, a method for predicting overcurrent relay miscoordination time is presented in this paper. On a 17-bus test system, the proposed method's efficacy was successfully tested. According to the simulation results, the ANN Levenber-Maequardt algorithm can predict the miscoordination time between the primary and secondary relay operating times.

According to the author Mahamad Nabab Alam[9] the coordination of the existing protection schemes is put at risk by dynamically changing operating conditions of the distribution system. Using a commercial AMPL-based Interior Point optimization (IPOPT) solver and numerical directional overcurrent relays (DOCRs), this paper proposes an online adaptive protection coordination scheme. In addition, the proposed plan makes use of intelligent electronic devices and a communication channel to obtain real-time information about the system and update the settings of the relays. The system's various operating conditions, including load, generation, and line loss, can be handled by the presented method. Miscoordination brought on by distributed generation injections is also addressed. Under a variety of operating conditions, the proposed method has been tested on the IEEE 14-bus system with and without DG. The improvement in overall system reliability brought about by the proposed strategy has been evaluated in terms of the amount of energy that is not supplied. In addition, the metaheuristic genetic algorithm and differential evolution as well as the General Algebraic Modeling System-based Sparse Nonlinear optimizer solver, OPTI Toolbox-based IPOPT solver, MATLAB-based interior point method, and AMPL-based IPOPT solver were used to compare the optimal DOCR settings. The proposed coordination method found to be suitable for the adaptive protection scheme because it achieves satisfactory results in a manageable amount of time.

According to M. H. Hussain et al.[10]overcurrent relay coordination in protection systems and protective relays is discussed in detail in this paper. All of the methods used to coordinate overcurrent relays have been included. It includes conventional methods for protecting against overcurrent in addition to AI and the Nature Inspire Algorithm (NIA) techniques. Conventional techniques are briefly mentioned, but the use of AI and NIA to protect overcurrent relays is given more attention. This paper provides a brief synopsis of the research and a set of references to all relevant papers. The outcomes of these methods are also provided in the appropriate references.

Mahmood Sadoughi et al.[11]studied the need to design microgrids grows as distributed generation resources become more prevalent in distribution networks. Microgrids can operate independently or connected to the grid. Economic power exchange with the upstream grid occurs when a microgrid is connected to the main grid. The microgrid, on the other hand, can meet its local demand in islanded mode. There are a few concerns regarding the protection of distribution systems, in addition to the technical and financial advantages brought about by the presence of microgrids. The short circuit level in both islanded and grid-connected modes of operation is the most significant issue. A smart overcurrent relay that can adapt to the modes of operation of a microgrid is proposed in this paper. An adaptive algorithm is used by this relay to determine the microgrid's mode of operation. The optimized accuracy and faster algorithm execution speed for determining the micro-grid operation mode are the suggested adaptive method's two main features. Based on the corresponding mode, the relay then activates the optimal setting that has been predefined. By sampling the voltage and current of the relay line, the entire processing is carried out within the relay itself. As a result, no communication infrastructure is required to install or use this relay in any network location. The proposed approach is finally implemented on a microgrid. The smart relay's superior coordination performance over conventional overcurrent relays is demonstrated by the numerical results.

Authors Hossein Farzin et al.[12]worked on due to the proliferation of nonlinear loads and the increased penetration of power electronic-interfaced resources like wind turbines, photovoltaic systems, and energy storage units, the number of harmonic-producing sources in the power grid is rapidly expanding. Non-sinusoidal waveforms have been the subject of a lot of research into the performance of various kinds of protective relays, and some of the problems they found were related to harmonics. A comprehensive Markov model that accounts for the various ways harmonics affect the dependability of overcurrent relays is presented in this paper. This model takes into account new harmonic-related aspects, such as loss of protection coordination as a result of harmonic distortion, non-fault disturbances with high harmonic contents that cause relay malfunction, and human errors during component restoration following the loss of protection coordination. In addition, a method for estimating model transition rates is presented, and a four-state classified model is introduced to make the proposed reliability model easier to use. Case studies are also provided to show how the proposed model can be used and to identify the main factors that affect overcurrent relays' reliability in harmonically polluted environments.

According to M. Zellagui et al.[13]talked about an Inverse Definite Minimum Time (IDMT) and Directional Overcurrent Relay (DOCR) based International Electro-technical Commission (IEC) standard characteristic curve protects transmission line parameters from apparent reactance by series Flexible AC Transmission System (FACTS) i.e. Thyristor Controlled Series Capacitor (TCSC). A 400 kV transmission line of the Algerian transmission networks owned by the Algerian Company of Electrical and Gas is protected by the DOCR. In the presence of a phase-to-earth fault with fault resistance, a three-case study examines the effects of TCSC on protected transmission line parameters, fault current, and DOCR operation time.

According to the authors Huaiqiang Li et al.[14] Line protection equipment is severely impacted by a potential circuit open. The majority of functions, including distance and directional functions, will be disabled whenever there is a complete or partial loss of AC potential circuits. During an AC potential circuit loss, the overcurrent protection, which typically consists of phase current elements and zero-sequence current elements, is activated for micro-processor-based protection equipment to ensure consistent operation. The paper concludes that overcurrent protection with opened TV is highly desirable to cooperate with pilot protection that phase overcurrent element should be set less than the maximum load, and that zero-sequence current element should protect the entire line in light of the practical protection scheme for 220 kV-500 kV networks in Northwest China.

Both the authors J. W. Homeyer and M. Etezadi-Amoli[15] worked on the same physical pole structures, it is common practice to construct two circuits unrelated to one another. It is possible for a ground fault in one of the mutually coupled pair's lines to generate sufficient current in the remaining line to result in a false trip. The zero sequence current has this effect. Three pairs of 120 kV transmission lines from an active transmission system were chosen for the investigation. With and without mutual coupling, double and single line-to-ground faults were simulated. The time-over-current settings of the directional ground overcurrent relays that protect these lines were compared to the resulting ground currents reported at these relays. The common bus is not where the intact line reaches its maximum current. It occurs at the point where the lines that are mutually coupled split. When designing the protection plan, this phenomenon must be taken into account.

DISCUSSION

Overcurrent Relay is a type of protective relay that kicks in when the circuit's current reaches a predetermined level. The pick-up value of the relay is the predetermined value of the current at which it starts working when a trip signal is sent. Overcurrent relays are the most commonly used protective relays in a power system because it is essential to shield all electrical equipment from overcurrent. Overcurrent relays are used to protect industrial systems, large motors, power equipment, distribution lines, and other systems. Electromagnetic overcurrent relays make up the majority of overcurrent protection devices. However, numerical overcurrent relays based on microprocessors or microcontrollers are now utilized for overcurrent protection due to the rapid advancement of technology.

When the power system functions properly balanced clauses carry their respective components. Normal bus potential and load current, with the outlined limits. A failure that is consistent with the normal current flow can lead to the formation of a circuit fault. When the insulation in the system fails as a result of the low impedance, the itinerary between phases and ground or phases a short. Short circuit faults fall into the following categories one is Symmetrical faults and another one is Unsymmetrical faults.

Symmetrical faults

Symmetrical faults are those in which all phases short circuit either to earth or to one another. These faults are regarded as a balanced case, suggesting that the system continues to be symmetrical.

The maximum current is the most serious kind of fault, so the calculations for a balanced short circuit case are done to find these maximum currents.

Unsymmetrical faults

The unsymmetrical fault had only one or two phases. This line becomes unbalanced when faults of this kind occur.

These kinds of faults occur between lines or between lines and the ground. Unsymmetrical shunt faults are regarded as unbalanced in the line impedances, whereas unsymmetrical series faults occur between phases and ground or phases. The three phases of a shunt fault are as follows:

i. Single line to ground fault (L-G)
ii. Double lines faults (L-L)
iii. Double line to ground fault (L-L-G)
iv. Triple line fault (L-L-L)
v. The triple line to ground fault (L-L-L-G)

Overcurrent Relays (ORs) of Various Types:

Overcurrent relays can be divided into the following types based on the operating time characteristics of the relay:

1. Definite time OR
2. Instantaneous OR
3. Inverse time OR
4. Inverse definite minimum time (IDMT) overcurrent relay
5. Very inverse time OR
6. Extremely inverse time OR

When the pick value is less than the current, the relay will not work. The distribution lines are protected by the relay. The relay's characteristic curve is depicted in the below Figure 1.

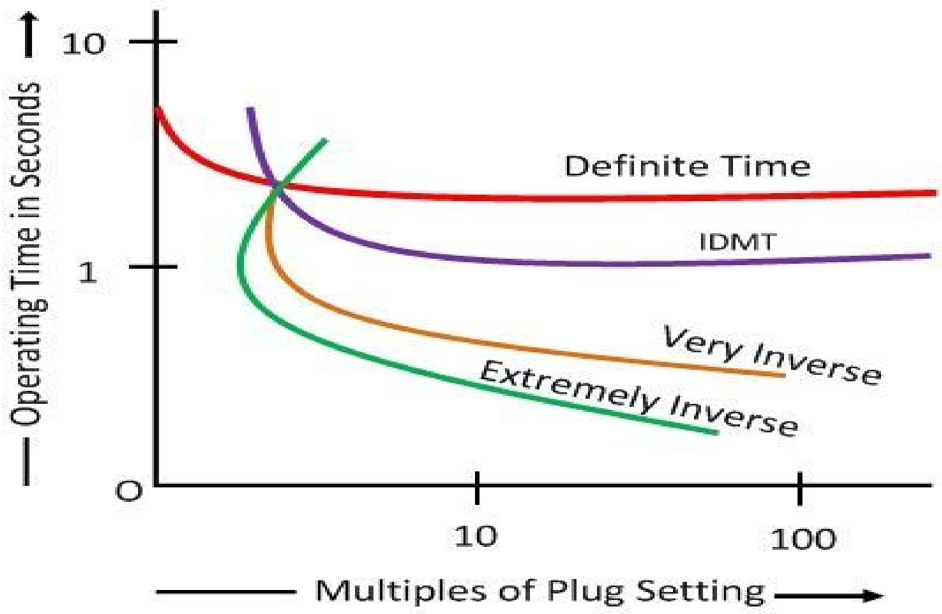

Figure 1: Illustrate the Characteristics of Overcurrent Relay.

There are basically three types of Inverse time relay, as follows:

1. **Inverse Definite Minimum Time (IDMT) Relay**

The IDMT relay is a type of relay whose operating time is roughly proportional to the fault current. By adjusting the time delay setting, the relay's operating time is maintained. The electromagnetic core is used in the IDMT relay because it can easily saturate for currents with a greater magnitude than the pick-up current. The distribution line's protection is provided by the relay.

2. **Very Inverse Relay**

Relay with a Very Inverse Characteristic as shown in the above Figure 1. The relay's inverse property is greater than the IDMT. On long transmission lines and in the feeder, this kind of relay is utilized.

The relay is utilized in locations where the distance from the source causes the magnitude of the short-circuit current to rapidly decrease. It is used to detect fault currents that are not associated with the fault location.

3. **Extremely Inverse Relay**

In comparison to the IDMT and the Very Inverse Relay, the characteristic time of the Extremely Inverse Relay is extremely large. The cable, transformer, and other components are safeguarded by this relay. When the current pickup value exceeds the relay setting time, the relay can operate immediately. Even in the presence of the fault current, the relay operates more quickly. It is used to detect machines that are getting too hot. Distribution networks and power plants employ the inverse time relay. Due to their fault time characteristic, the relay operates quickly in fault conditions.

Overcurrent Relay's Function

The primary function of an overcurrent relay is to safeguard electrical circuits and devices from the adverse effects of excessive current. The relay trips or opens the circuit when an overcurrent condition is detected, preventing damage to the electrical components. Overcurrent events can harm delicate electronic components or cause wires to overheat and melt. Overcurrent can even result in an electrical fire in some instances. The overcurrent relay prevents this damage from occurring by tripping the circuit upon detection of an overcurrent. The overcurrent monitoring relay's ability to prevent the loss of expensive equipment and save lives is crucial in numerous applications.

Applications of Overcurrent Relays:

Overcurrent relays are utilized in numerous industrial and commercial applications. For both voltage and current overloads, the relay is typically utilized in conjunction with other electrical protection devices. The following are some of the most prevalent uses for overcurrent relays:

i. Overcurrent Protection for Motor

Overcurrent monitoring relays are frequently utilized to safeguard motors against damage caused by high currents. Overloading a motor can cause it to draw too much current and overheat, which can damage the insulation in the windings. The circuit includes an overcurrent relay switch, which allows the relay to trip the circuit in the event of an excessive current. This prevents damage to the motor.

ii. Transformer Overcurrent Protection

Overcurrent monitoring or overcurrent protection relays are also utilized to safeguard transformers against damage resulting from high currents. The relays are typically set to trip at a current that is lower than what is required to trip the circuit breaker in these situations. The overcurrent relay is protected from damage by tripping first in this manner.

iii. Distribution Line Overcurrent Protection

Overcurrent relays are a cost-effective method for preventing damage to distribution circuits caused by high currents. The overcurrent relay is frequently the only circuit-installed protection device. Ground faults, phase-to-phase faults, and phase-to-ground faults can all be avoided with the help of the relays.

Advantages and Disadvantages of Overcurrent Relay

Overcurrent monitoring relays, like all electrical devices, have both advantages and disadvantages that make them more or less suitable for various applications. It is essential to take into account both the benefits and drawbacks of using an overcurrent relay before making a decision about whether or not to do so.

Benefits of Overcurrent Relay:

Benefits of Using an Overcurrent Relay One of the main benefits of using an overcurrent relay is that it can help prevent electrical faults by quickly cutting off the current source. This may assist in minimizing the risk of fire and equipment damage. Overcurrent relays are less expensive than many other types of electrical protection devices due to their simplicity, which is another advantage. The current relay is utilized in numerous applications, including transmission line protection, motor current monitoring, and more. Because of this, they can be used as protection devices in a variety of power systems.

Drawbacks of Overcurrent Relay:

Overcurrent relay applications have several drawbacks that every electrician or facility owner should be aware of in addition to their benefits. One of them is that relays can occasionally result in false trips, which can cause inordinate amounts of downtime. Additionally, it is possible that an overcurrent relay won't adequately safeguard against all kinds of electrical faults. Therefore, it is common practice to install it alongside other essential security devices when using one.

CONCLUSION

Electrical protection devices known as overcurrent relays are intended to open or trip a circuit when the level of current passing through it is higher than a predetermined threshold. Overcurrent relays come in a variety of shapes and sizes, each designed for a particular purpose. When choosing which type of relay to use, electricians should therefore be familiar with these relays and their applications. It is cooperative for the protection of transmission lines from faults.

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CHAPTER 11

PROTECTION OF TRANSMISSION LINES USING DISTANCE RELAY

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ABSTRACT:

The chapter's concept is based on using distance relays to protect transmission lines. When overcurrent relaying is either too slow or not selective, distance relaying should be considered. On sub-transmission lines, transmission lines where high-speed automatic reclosing is not required to maintain stability and where the short time delay for end-zone faults can be tolerated, and for phase-fault primary and back-up protection, distance relays are typically utilized.

KEYWORDS:

Back-up Protection, Distance Relay, Overcurrent, Transmission Lines.

INTRODUCTION

Because of its inherent simplicity, over-current protection is very appealing. It protects low voltage (LV) distribution lines first and foremost. However, it malfunctions due to a number of significant flaws. Relays that malfunction in LV systems, on the other hand, can be tolerated. In LV systems, only the continuity of supply to customers is taken into account. However, errors cannot be tolerated in EHV systems. This is due to the fact that EHV lines are connected to a grid. The electric grid's stability is jeopardized by any malfunctioning of these systems.[1]

For the safety of the power system, it is essential to clear faults on high voltage transmission lines selectively and quickly. Because the transmission system is a mesh network, overcurrent relays are unable to provide coordinated, quick protection. The requirements can be met by line current differential relays, but they require costly and complicated communication links. A distance relay is one of a kind because it measures the apparent impedance derived from locally measured voltage and current. A transmission line typically has a uniform distribution of impedance along its length. By measuring apparent impedance during a fault and thus providing a "zone" of protection, a distance relay can distinguish between a fault that is internal to the line and one that is external with relatively good accuracy. Distance relays are preferred to overcurrent relays because they are much less affected by changes in generating capacity and system configuration than overcurrent relays are by changes in short-circuit current magnitude. This is due to the fact that distance relays achieve selectivity based on impedance rather than current.[2]

Phase-fault back-up protection at generator terminals is provided by single-step distance relays. Additionally, power-transformer banks may benefit from the use of single-step distance relays for back-up protection however, inverse-time overcurrent relays currently provide this protection. If we consider phase distance relays are adjusted based on the positive phase sequence impedance that exists between the location of the relay and the location of the fault, which is the point at which the operation of a particular relay unit should cease. Ground distance relays are set in the same way, but some may react to the impedance with no phase sequence. The "reach" of the relay or unit is the impedance that corresponds to the distance. For open transmission line construction, it is common practice to disregard resistance and assume a positive phase sequence reactance value of approximately 0.8 ohms per mile for a rough approximation.[3]

The following formula is used to convert the primary impedance to a secondary value that can be used to adjust a phase or ground distance relay:

Z sec = Z pri x CT ratio / VT ratio

Hence, under balanced three-phase conditions, wherein the CT ratio is the ratio of the high-voltage phase current to the relay phase current and the VT ratio is the ratio of the high-voltage phase-to-phase voltage to the relay phase-to-phase voltage.

LITERATURE REVIEW

According to both the Authors Cholleti Sriram and Y. Kusumalatha[4] most of the time, distance relays are used to protect the transmission lines from power system failures. The resistance (R) and reactance (X) characteristics of distance relays are unique. It is necessary to coordinate the various distance relays just for the circuit breaker to function quickly, several different distance relays are tripping circuit breakers that are attached to individual buses that are far apart. The distance between the fault that occurred and the relay location will be taken into consideration when operating these relays. Co-ordination of distance relays and circuit breakers with faults placed at various locations of an IEEE 9 bus system using the MATLAB/Simulink GUI environment is demonstrated in this paper for the detection of three zones using relay characteristics. About severe faults at various locations on the IEEE 9 bus system, a comparison was also made between the performance of the relays and the operation of the circuit breaker that trips them.

According to Loai Mohamed Ali El-Sayed et al.[5] A transient phenomenon of the power system can occur for a variety of reasons, including faults, line switching, line outages, sudden increases or decreases in load, and so on referred to as power swing. Distance relay malfunction is caused by unnecessary tripping during power swing and blocking for faults during power swing. Distance relay failure has resulted in numerous cascading outages as well as significant global blackouts. A method for supervising distance relays during power swing is proposed in this paper. The proposed online method accurately differentiates between actual faults and power swing. The current and voltage differences (ΔI-ΔV) between the two ends of the protected line must be represented by a locus diagram. Utilizing synchrophasor measurements at the line's sending and receiving ends, the locus is estimated at each power frequency cycle to continuously monitor the line's state. Using MATLAB software, the proposed method is tested for a two-area, four-machine power system with faults at various locations in the zone-1 and zone-2 regions using fault resistances, fault inception angles, and slip frequencies. The results of the simulation demonstrated that the distance relay performed better when handling power swing blocking and unblocking actions.

According to Sa'Ad Ahmed S. Al Kazzaz et al.[6]have given the statement about using an adaptive neuro-fuzzy inference system algorithm (ANFIS), this paper aims to create a three-phase distance relay. The power transmission lines, which are continuously affected by faults, are protected by the proposed relay. Power system equipment can sustain significant damage as a result of the high electric current that these faults may generate. The relay measures the voltage and current values for each phase to identify faults in the transmission line. Then, the line impedance is calculated to find the faults and send an instant trip signal to the circuit breaker. This allows the transmission line's fault zone to be separated without interfering with the work of other relays. Relays were trained with the adaptive neuro-fuzzy inference system (ANFIS) to isolate the defective line without affecting the network's other lines. This study's findings demonstrate that the designated distance relay employing the ANFIS algorithm is capable of isolating only the fault zone without interfering with the operation of other relays in the system and recognizing faults from disturbances.

According to Yujie Yin et al.[7]worked on protection of microgrids at the Point of Interconnection (POI) is a challenging task. Particularly, single-line-to-ground (SLG) faults on interconnection lines are difficult to detect using the fault current detection relays if the microgrid is ungrounded at utility side of its interconnection transformer such microgrid contributes very low fault current, which disappears once the utility feeder breaker opens. Other common schemes for protection of microgrid interconnection line against SLG faults include Direct Transfer Trip (DTT) and over-voltage relay (59G). The main challenges associated with these methods are installation and maintenance costs of high-speed communication system, sensitivity of relay settings, and delayed fault clearing time due to selectivity requirements. To address such concerns, this paper proposes the use of a distance relay at the microgrid /LV side of the interconnection transformer to provide protection against SLG faults on the interconnection line at the utility/HV side. The designed distance relay executes an enhanced apparent impedance calculation using residual voltage compensation to correctly detect the fault, properly measure the fault location, and timely isolate the fault. In this paper, various scenarios are analyzed using ASPEN and PSCAD simulation tools to demonstrate the effectiveness of the proposed method for protecting the microgrid interconnection line under different fault scenarios.

According to both the Authors Mahmoud A. Allam and Khaled A. Saleh[8] worked on numerous obstacles to overcome when detecting faults in DC microgrids, including the need for rapid detection, sensitivity to both low- and high-resistance faults, and selectivity. For DC microgrids, a novel local-measurement-based DC distance relay is proposed in this paper to address these issues. An inductor is incorporated into the power circuit of the relay at the end of each line. Additionally, it makes use of auxiliary components and a peak detection circuit (PDC) to simultaneously capture and process various waveforms when a fault occurs. Local measurements of the relay voltages and currents are used to quickly estimate the location of local forward faults and identify them. In addition, the relay serves as a backup safeguard against forward external faults on adjacent lines. On a basic feeder, the idea is first tested. The proposed scheme's performance is then further checked and evaluated using a PSCAD/EMTDC-modeled meshed DC microgrid. The relay's performance under various fault conditions is examined using a variety of fault scenarios. The findings emphasize the proposed method's speed, selectivity, and sensitivity to bolted, low- and high-resistance faults.

Both the Authors M. Kiruthika and S. Bindu[9] talked about a transmission line's distance relay is one of the most crucial protection components in protection schemes. If the relay cannot differentiate faults from stressed system conditions, it may fail. The primary goal of this work is to securely improve the distance relay's performance using a two-phase classification data mining strategy. Level 1 classifier distinguishes between a three-phase fault and the persistence of the power swing condition when there is a power swing. Level 2 classifier is activated when there is a power swing. The protection scheme in the zone where the fault occurred is activated in both phases. The proposed method is tested on an IEEE 9-bus system with data collected from optimally placed phasor measurement units. Because it addresses costs, communication infrastructure issues, maintenance, and complexity, optimal PMU placement is cost-effective. With fewer PMUs, the results demonstrated that the proposed method is efficient, accurate, and effective.

According to Ramin Vakili et al.[10]power system behavior is governed by the dynamic characteristics of its assets and protection schemes following major disturbances. Therefore, accurate stability studies necessitate modeling protection devices. Due to the limitations of current stability software and the difficulty of updating the setting data for thousands of protection devices, modeling all of the protection devices in a bulk power system is impossible. Distance relaying is one of the crucial protection mechanisms that stability studies do not adequately model. In order to identify the critical distance relays that need to be modeled in stability studies, this paper proposes an iterative algorithm that employs two approaches: 1) the monitoring of apparent impedance, and 2) the evaluation of the minimum voltage (MVE). Stability studies are carried out with the help of the GE positive sequence load flow analysis (PSLF) software, which is used in the implementation of the Python 3.6 algorithm. The Western Electricity Coordinating Council (WECC) system data for the summer-peak load of 2018 are used to evaluate the algorithm's performance. Modeling the critical distance relays identified by the algorithm is sufficient for an accurate assessment of system behavior, as demonstrated by the case studies' findings, and modeling all distance relays is unnecessary.

According to Azriyenni and Mohd Wazir Mustafa[11] transmission protection made use of the hybrid intelligent techniques in electric power systems. ANFIS was utilized for transmission line-specific distance relay protection. If an unintended fault occurs during the identification of the transmission line, power delivery to the customer suffers. As a result, it would need to offer a different approach to solving this issue. The purpose of this paper is to determine how long distance relay will protect channel spacing using impedance transmission line. With the Sugeno ANFIS application, it has been distance relays when a transmission line fault occurs. The simulation demonstrates that its excellent testing results can be attributed to a different algorithm, indicating that it performs well in protecting transmission line systems. MATLAB software are used for the application purpose.

According to Amir Ghorbani et al.[12] For faults at the end of the line, the distance relay zone-2 element's delayed operation is excessive. It is one of the main factors that can threaten the stability of the power system because it slows down the process of clearing faults. An impedance-based method for distinguishing between the relay zone-2 covered adjacent line faults and the last 20% of line length faults is proposed in this paper. For the accelerated zone-2 operation of distance relays, the non-pilot scheme that has been proposed makes use of a modified formula for fault location. After the remote circuit breaker (CB) is activated, the precise location of the fault is determined by utilizing the negative and zero-sequence components of local signals. The proposed algorithm can clearly distinguish between internal faults and line faults that are adjacent, and it is independent of fault resistance, power flow direction, and pre-fault condition. For a variety of fault locations, fault types, fault resistances, and load angles, simulation results demonstrate that the proposed method can quickly identify the remote CB operation and accelerate the tripping of zone-2. In addition, faults have been precisely located under all simulation conditions.

According to Mengxiao Chen et al.[13] A wide-area backup protection (WABP) algorithm based on distance relays for transmission lines is described in this paper. The local substation and immediate neighboring substations are where the proposed WABP collects the statuses of zone 2 and zone 3 distance relays. The WABP determines whether a fault is on the protected transmission line or somewhere else when a fault occurs. Then, in conjunction with conventional distance relays, it determines the appropriate time delay before tripping. The setting of conventional distance relays can be made easier with the proposed WABP equipped. It is possible to lessen the need for conventional relays to work together and make setting calculations easier. The simulation results demonstrate that the proposed WABP is able to coordinate with conventional distance relays that are set in various ways, detect faults accurately, and contribute to the reduction of blackout area through fault tolerance.

According to Naga Chaitanya Munukutla et al.[14] During the system's postfault power oscillations, distance relays may malfunction. Relays' unintended operation may result in a power outage. It's because they can't tell a stable power swing from an unstable one or make the right decision when they trip. For distance relays, this study proposes a quick, wavelet-based method for identifying stable and unstable power swings. Using measurements taken at a bus, the proposed method determines an equivalent machine's angular velocity. Transmission line relays will benefit from the energy in the low frequency band of the equivalent machine angular velocity when power swings occur. The advantage of this approach over the conventional blinder method is that it requires less hardware and takes less time to determine whether the power oscillations that result from fault clearing will be stable or not. Various test scenarios were used to evaluate the proposed method's performance on 5-bus, WSCC 9-bus, IEEE 14-bus, and 30-bus systems. The findings demonstrate that employing this strategy enhances the capability of distance relays to detect both stable and unstable power swings.

According to Yu Chen et al.[15]talked on the overreach issue is caused by transients in the coupling capacitor voltage transformer (CCVT), which have an effect on distance relay performance. The virtual digital CCVT can be used to speed up the operation of distance relays and reduce the impact of CCVT transients, both of which are based on the equal transfer process of transmission lines (ETPTL) theory. The actual CCVT and the virtual digital CCVT must share the same transient characteristics. A straightforward and universal design strategy for virtual digital CCVT is proposed in this paper. This paper proposes an improved numerical distance relay algorithm based on the ETPTL theory and CCVT transient characteristic matching to prevent the overreach problem of distance relays without sacrificing their operation speed under internal fault conditions. The proposed distance relay is effective under a variety of fault conditions, as demonstrated by an extensive performance evaluation carried out with the help of a PSCAD/EMTDC simulation. Finally, a real-time digital simulator (RTDS) hardware in loop test is used to evaluate a prototype device based on the proposed distance relay.

DISCUSSION

The magnitude of the protection circuit's current or voltage determines how the relays operate. The operation of distance relays is determined by the impedance, which is the ratio between voltage and current. As a result, distance relays are commonly referred to as impedance relays. A simple electrical measure of the distance along a transmission line is the impedance. When the ratio V/I, or impedance, falls below a predetermined value, the relay turns on. These relays are also referred to as ratio relays because their performance is influenced by the ratio V/I. Distance relays can be divided into three categories based on the ratio of V to I:

1. The measurement of impedance Z serves as the foundation for an impedance relay.

2. Reactance relay whose measurement of reactance X serves as its foundation.

3. Admittance or Mho relay, based on the measurement of the admittance component Y.

Simply put, a distance relay is one whose performance is determined by measuring the line's impedance, reactance, or admittance between the relay's location and the fault location.

As a result, distance relays act as the air conditioner's primary protection as well as its backup protection, transmission and distribution lines against the following issues:

i. Three phase faults
ii. Phase-to-phase faults
iii. Phase-to-earth faults.

Zones of Protection:

1. **Zone 1:** This activates immediately and is configured to protect between 80% and AB of the line length. To assure selectivity since mistakes and transients may exist in the voltage and current transformers, this "underreach" value has been purposefully adjusted to prevent "over-reaching" into the following line segment. Manufacturing tolerances further restrict the relays' precision in measuring.
2. **Zone 2:** This has a time delay of t2 and is set to protect 100% of the line length AB in addition to at least 20% of the shortest adjacent line BC.(≈0.5s) Not only does it cover the remaining 20 percent of the line, but it also serves as backup for the next section of the line.
3. **Zone 3:** This operates with a time delay of t3 and is set to protect 100% of the two lines AB and BC, in addition to approximately 25% of the third line CD. (≈1.5s)

Now in the given below shows the protection of Zones in the Figure 1:

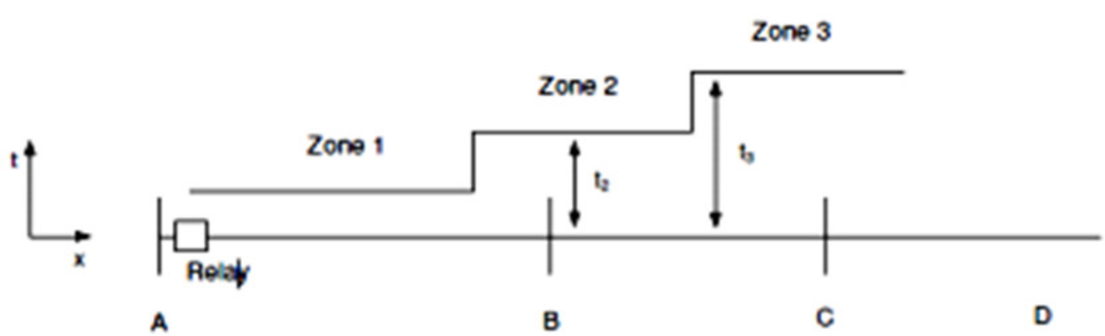

Figure 1: Illustration of Protection of Zones

The basic principle of Distance Relay:

A distance relay can detect a fault within a predetermined distance from its location along a power cable or transmission line. Since the design and construction of each power line determine its resistance and reactance per kilometer, its total impedance will be proportional to its length. As a result, Ohm's law is used by a distance relay to compare voltage and current. A relay capable of measuring the impedance of a line up to a predetermined point is appropriate for distance measurement because the impedance of a transmission line is proportional to its length. The distance relay is constructed to operate only for faults that occur between the relay's location and a predetermined point, allowing for fault discrimination across various line sections. The division of the voltage at the relaying point by the measured current is the fundamental principle of distance protection. The reach point impedance is contrasted with the calculated apparent impedance. It is assumed that there is a fault in the line connecting the relay and the reach point if the measured impedance is lower than the reach point impedance, correct position of Distance relay as shown in the Figure 2.

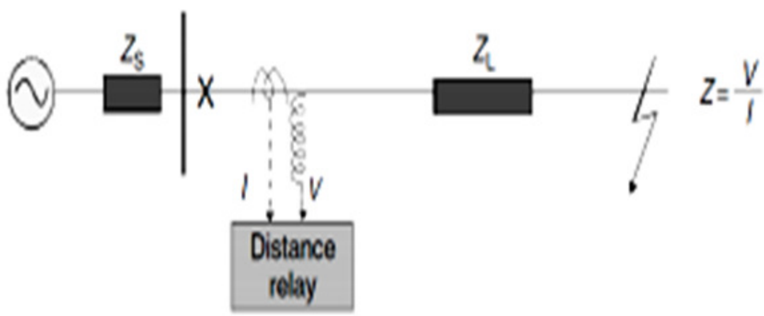

Figure 2: Illustrate the position of Distance Relay

Working of Relay:

The voltage from the potential transformer and the current from the current transformer are used to calculate the impedance. Two significant torques are crucial to the relay's operation. Both of them are restoring torque and deflecting torque. The relay's operation is most dependent on these two torques. In distance relay, the secondary current of the current transformer generates the deflecting torque, while the voltage of the potential transformer generates the restoring torque. The restoring torque is greater than the deflecting torque under normal operating conditions.

As a result, the relay does not switch on at all. But when there is a fault, the fault currents get bigger, which makes the deflecting torque go up. As a result, the relay starts working when the deflecting torque exceeds the restoring torque. It closed the circuit by moving its dynamic parts once the deflecting torque was increased. The trip circuit has been shut down. The circuit breaker is turned on when the trip circuit is closed. The circuit tripping may essentially function as an electromagnetic switch. The breaker's closed contacts open when the circuit is energized. The faulty line and the system's healthy part are separated when the contacts are opened. The fault line is isolated in this manner. An arc is formed between the contacts when they open, and this arc needs to be destroyed.

Types of Distance Relay:

There are three types of distance relays because the distance relay depends on the ratio of voltage and current values, as follows:

1. **Impedance Relay**
   A relay which is dependent on the impedance Z appropriate for transmission line phase fault protection at a length of medium size.
   Advantages:
   The addition of the directional element can improve performance.
   Drawbacks:
   1. This is a non-directional relay that will respond to faults on either side of the CT.
   2. The characteristics curve is too large, which makes it possible for the relay to malfunction.
   3. It cannot be used for long transmission lines.

2. **Reactance Relay**
   A Relay of this type is dependent on reactance X value suited for line ground fault protection. Advantages of Reactance Relay that it is able to quickly identify a fault and will not respond to ARC. It can be used on small transmission lines. Because of its negative reactance characteristics, it is not suitable for the long transmission line and cannot be used as a fault locating relay. It will not be able to differentiate between a fault at our station and one at another station.

3. **Admittance or MHO Relay**
   This kind of relay is dependent on the admittance Y value and is used to safeguard lengthy transmission lines from phase faults in areas with frequent severe power surges.

   Advantages:
   1. The fault area is clearly defined as it is directional, so it can be set up to work only on one side.
   2. It can be used on long transmission lines.
   3. It can handle both reactive and resistive faults.

   Disadvantages:
   1. It only use for medium and long transmission lines not useful for short transmission line.

   When a fault occurs, the distance relay begins to operate based on the impedance, admittance, or reactance values, then relay is divided into two more types:

   Definite Distance Relays
   When the reactance or admittance value falls below the relay's predetermined impedance value, this sort of relay begins to operate. These relays are of the mho, impedance, reactance, admittance, or type.
   Time Distance Relays

The amount of impedance determines how well this type of relay functions. This means that the distance between the fault and the relay point affects how well it operates. In situations where the problem is closer to the relay point, it operates more quickly and efficiently. These are classified as reactance, impedance, or mho type relays.

Characteristics of Distance Relay:

The characteristics of the distance relay under operating conditions are depicted below. The X-axis depicts the current, while the Y-axis depicts the voltage. In a fault condition, the positive torque is produced above the operating characteristic line if the impedance of the transmission line is greater than that of the relay. In a similar vein, negative torque is generated when the fault condition's line impedance is lower than the relay's impedance,

The RX diagram provides an explanation of the distance relay's characteristics. The diameter of the circle is a representation of the transmission line's impedance. The phase angle between R and X, also known as an impedance angle, is used to represent the position of the vector theta in the image. There are two axes to the characteristics. The X-axis and the R axis are the two. For positive R and positive X, the vector position is depicted in the Figure 3.

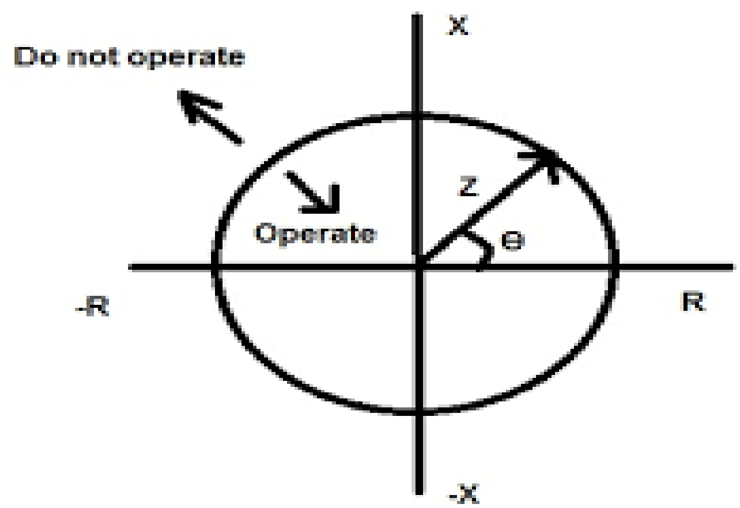

Figure 3: Operating Characteristic of Distance Relay

Four quadrants can be used to describe the operation. If R is positive and X is positive in the first quadrant, this indicates that the fault impedance is greater than the normal impedance. As a result, the relay will work. The angle is negative in the second quadrant, so the relay won't work there. In a similar manner, the relay will function in the third quadrant. The restoring torque is greater than the deflecting torque in the region where the relay is unable to function. Additionally, the deflecting torque is greater than the restoring torque in the operating region. Short, medium, and long transmission lines use distance relays.

The distance relays offer several advantages, including:

1. Facilitates operation and has greater instantaneous trip coverage with security
2. Easier to coordinate as well as for setting calculations
3. Reduced impact of fault current and level magnitudes
4. It allows for heavy line loading.
5. Permanent settings can be made in response to adjustments that are required.
6. It has fixed zones of protection that are relatively impedance of the system change.

The drawbacks of an impedance or distance relay are outlined below:

1. Because it works on both sides of a line's faults, it is called non-directional.
2. Internal and external faults distinguishing is not possible in the line by distance relay.
3. The distance relay's function is affected by the resistance of the arc of a fault line because when the fault occurs anywhere, there is an arc.
4. Due to the large area covered by the circle on the sides of the R-X plane and the limited measurement capacity of fault resistance, power swings have an impact on the distance relay's performance.

Applications of Distance Relay are:

1. Most of the time, these are used to protect distribution and transmission lines from high AC voltages.
2. Provide AC voltage backup protection against a variety of distribution and transmission line faults in three phases, phase to phase, and phase to ground.
3. Because they provide distance protection for all kinds of transmission line faults such as short, medium, long, and main, static distance relays are widely used.

CONCLUSION

In this chapter we see that how distance relay protect our transmission line. When fault protection and backup protection are required at high speeds in transmission and distribution lines, as well as when overcurrent relaying is extremely slow, this type of relay is most frequently utilized. This chapter provides in-depth information about the various distance relays.

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