SUBSTATION MAINTENANCE & PROTECTION

A Project report is submitted in partial fulfillment of the requirements for the award of Degree of Bachelor of Science in Electrical and Electronic Engineering.

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MARCH, 2023

DECLARATION

I hereby declare that this project "**SUBSTATION MAINTENANCE & PROTECTION**" represents my own work which has been done in the laboratories of the Department of Electrical and Electronic Engineering under the Faculty of Engineering of Daffodil International University in partial fulfillment of the requirements for the degree of Bachelor of Science in Electrical and Electronic Engineering, and has not been previously included in a thesis or dissertation submitted to this or any other institution for a degree, diploma or other qualifications. I have attempted to identify all the risks related to this research that may arise in conducting this research, obtained the relevant ethical and/or safety approval (where applicable), and acknowledged my obligations and the rights of the participants.

Signature of the candidates

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APPROVAL

The project entitled **"SUBSTATION MAINTENANCE & PROTECTION"** submitted by **Sabik Ahnaf Ahmed (191-33-4978)** has been done under my supervision and accepted as satisfactory in partial fulfillment of the requirements for the degree of **Bachelor of Science in Electrical and Electronic Engineering in March, 2023.**

Signed

27.08.23

Mr. Naimur Rahman

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Dedicated

To

My Parents

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ABSTRACT

A substation is an electrical system with a high voltage capacity that is used for the control of electrical circuits, generators, and other pieces of equipment. Utilization of substations may assist in lowering the high voltage of the electrical power that is being transported. Substation maintenance is the process of periodic, planned inspection, repair, and replacement of all switchgear, buildings, and ancillary equipment in substation installations. A substation's planned maintenance has many benefits; it can save money and prevent equipment wear and tear. Modern power systems are very complex in nature and produce transients during various operations. Backup protection units can be used to solve the problem when a protection device happens to fail. SABP can increase the range of information sharing in a substation area and help to improve the overall performance of the protection system.

Key Words: Electrical System, Substation, Protection, Maintenance, High Voltage.

CHAPTER 1
INTRODUCTION

1.1 Motivation:

A substation is an electrical system with a high voltage capacity that is used for the control of electrical circuits, generators, and other pieces of equipment. One of the functions of a substation is to reduce the voltage, but it may also be used to create electrical voltage, transfer electrical voltage, and distribute electrical voltage. Utilization of substations may assist in lowering the high voltage of the electrical power that is being transported, therefore rendering it appropriate for use by the consumer. During both the transmission of electrical power and its creation, the substation makes use of a variety of different pieces of equipment. In the substation, there are devices known as transformers that are used to adjust the voltage levels, and there are devices known as circuit breakers that are used to safeguard the electrical circuit from any harm that may be caused by overloads of power in the substation. Since there is a significant amount of power transmission, the substations are monitored and controlled remotely the vast majority of the time. The ownership and management of substation maintenance firms may be split between an electrical utility and a commercial client. Substation maintenance is a process of periodic, planned inspection of and, if necessary, repair, and replacement of all switchgear, buildings, and ancillary equipment in substation installations. In simple terms, substation maintenance is a regimen of regular preventative checks and actions carried out to ensure substations are kept in good working order. This process typically consists of a series of stringent visual and physical inspections and actions carried out according to a set schedule. Equipment replacement may be standard procedure or only upon detection of wear, damage, or substandard operation. All inspection and actions during substation maintenance should be accurately documented and stored for further reference.

1.2 Problem Statement and /or Proposed solution(s):

The maintenance of the substation equipment brings about workplace safety. Maintenance makes replacing the faulty and old circuit breakers and transformers easy. A substation technician can identify issues affecting the different equipment early enough, and they will be able to sort the problem instead of waiting for the equipment to break down.

1.3 Aims:

There are generally two phases in which sub-station maintenance is carried out – Primary Testing and Secondary Testing. If these issues are ignored, you can end up facing breakdowns and even safety issues. To make things worse, you'll have to foot the costs that come with these issues. Your best bet at avoiding trouble is to carry out regular maintenance.

1.4 Brief Methodology:

The nerve center of every electrical grid is the power substation. Specifically, its primary function is to take electricity from a higher voltage source (66 or 33 kV) and transform it into a lower voltage (11 kV) for distribution in a sub distribution system. Typically, these substations may be found on the fringes of major cities, close to load centers. Indoor or outdoor, air insulated (AIS) or gas insulated, the highest capacity for a 33/11 kV substation will be 60 MVA (GIS). Each of these substations has been built to comply with Indian standards and other laws and regulations issued by the Central Electricity Authority of India (CEA). There will be no more than two transformers in a 33/11 kV substation, and ideally there would be two separate incoming feeds. Each feeder supplies its own portion of the 33/11 kV substation, and these sections are separated by a bus coupler or isolator in cases when both feeders come from the same source. The 33 kV and 11 kV transformers and incoming feeds at each substation should be controlled by separate circuit breakers. Typically, a distribution substation will include the following types of equipment and auxiliary services.

1. Surge/lightning arrester
2. Instrument transformer (current transformer (CT) and potential transformer (PT))
3. Circuit breaker
4. Isolator and earth switch
5. Bus bar
6. Battery and battery charger
7. Earth grid and earthing system
8. Transformer

CHAPTER 2
LITERATURE REVIEW

2.1 Introduction:

A power system's electrical substation is the part of the system that converts high voltage to low voltage and low voltage to high voltage for transmission, distribution, transformation, and switching. Substations' principal duty is to convert AC current into DC current (direct current). Substation maintenance includes checking the switchgear, buildings, and ancillary equipment in substation installations on a regular basis and fixing or replacing any faulty or obsolete parts as needed. A substation's electrical components and circuits need to be safeguarded against overcurrent and overvoltage to prevent costly damage. Substation-originated refers to an outage that began at a switching station or substation. Any number of the system's generators, lines, and loads might be impacted by this kind of outage. It is critical to understand that there are numerous potential failure modes at a substation. Protection and control in substations and power grids is the process of providing all of the technological means and facilities required for the best monitoring, protection, control, and administration of all system components and equipment in high- and medium-voltage power systems. This is the guardian and controller's first and foremost duty. Substations for generating electricity come in a wide range of forms, from thermal to atomic to hydroelectric. Due to the availability of varied resources, substations are being built in a wide range of places, some of which may not be geographically closer to load centers than others. The load center is equipped to measure actual power consumption. Thus, it is crucial to get the power from the substation to the different load center locations. Therefore, this task needs long-distance, high-capacity transmission networks. Substation Information, Control, and Protection (SICAP) technologies are the ones undergoing the most rapid transformation at the moment. The NGC's operational units as well as its control, protection, and monitoring equipment providers worked closely together to develop a strategy for this technical area.

2.2 Related Research/ Works:

This article presents a proposal for an integrated control, protection, condition monitoring, condition supervision, asset management, and outage management system. This system guarantees a greater availability of plants and enhances the overall performance of utilities. The most significant shift is anticipated to take place in the information, control, and protection technologies of "intelligent substations," which will be comprised entirely of electronic components and will almost do away with the need for copper wire. The following three important locations are where most of the predicted shifts will take place:

- Free and easy access to all substation details
- Methodologies for operation and upkeep
- Integration of safeguards and administrative oversight

The data base converter will be performed by the substation information management unit, which is the most important component. A new method of maintenance for T&D equipment is made possible by the SA infrastructure, which consists of numerical protection and control devices. This method is also more cost-effective. There will be a decrease in expenses associated with operation and maintenance, as well as an improvement in service quality and overall availability of the power system. The early signals of incipient system defects, which allow operators to take preventative steps in order to avert threatening system collapses, are one of the benefits of power system protection ideas [1].

The strategy for bringing our vision into existence in the near to medium term, as well as the first measures that have been taken, have been detailed. In the next few months, more stages will be put into place, and preparations are already being made to deliver a comprehensive demonstration of all of the primary SICAP modifications at a single operating location. The process of formulating a strategy accounts for the fact that it will be required to conduct regular assessments of technological developments and, if necessary, adjust our long-term objectives in light of the findings of these assessments. Spending the time and effort at the start to develop a viable approach should reduce any subsequent revisions to fine tuning. The technologies that deal with substation information, control, and protection (SICAP) are the ones that are changing the fastest. NGC's operational divisions and the companies that provide its control, protection, and monitoring equipment worked closely together to develop a plan for this technical sector. The SICAP approach is designed to bring about benefits for the company, but in order to realize these advantages, a number of measures need to be taken first. It is possible to unlock non-operational data, have it analyzed, and then make it accessible to users who would not typically have access to this kind of information if an open approach is used to the data that is stored in substations. This is one of the advantages of taking such an approach. On the longer term, the data that is accessible from the substation legacy systems is likely to be merged with business data, such as asset register data, documentation systems, fault records, and maintenance planning systems, to provide a holistic picture of asset health, performance, and dependability [4].

This study offered evidence that businesses that generate power have the challenge of lowering their overall maintenance costs while simultaneously increasing the degree to which they can guarantee the availability and dependability of their equipment. The occurrence of a breakdown in the equipment that makes up the electrical system not only causes significant damage to the equipment, but it also offers significant dangers to the regular production of a large number of industries and the way people live their lives. The most important objectives for the growth of enterprises that offer electricity are to increase the effectiveness of power generation, raise the degree of automation, assure the dependability of power supply, and cut the number of instances in which equipment fails or becomes obsolete. The substation is the most important part of the electric power network since it acts as a central hub for the transmission and distribution of electric power. As a result, it is of the utmost importance to guarantee the secure and consistent functioning of the substation equipment. Maintenance that is condition-based is preventive maintenance that is performed on the basis of condition information obtained through monitoring, diagnosis, and assessment of the equipment. Another way to put this is that condition-based maintenance is preventive maintenance that is performed in accordance with the operational condition and healthy status. The advancement of computer technology and artificial intelligence has resulted in the development of diagnostic equipment in the form of an expert system. This has replaced the traditional method of identifying equipment malfunctions based on years of data on tests, operations, and maintenance, among other things. Several calls to the accident records are made in order to conduct comparative analysis. When sophisticated technologies of condition-based maintenance and management are brought into the insulation diagnostics of electrical equipment and used, the process becomes more accurate and dependable [5].

According to this paper's analysis of the technical scheme and design objectives of China's cutting-edge substations, a number of issues exist when it comes to researching how to effectively overhaul and test equipment, and the actual mastery of technical methods and professional personnel lags behind what's required to keep up with technological advances. In order to improve the running environment of power systems in our country and guarantee the application quality, it is essential that the electric power industry integrates the country's accumulated experience with a proposed new repair and test method, actively cultivates high-quality, high-level talents, and considers the long-term effects of power system operations. substation operations, bolstering power system monitoring, prioritizing preventative maintenance and testing, and incorporating lessons learned from the past all contribute to a set of recommendations for improving substation reliability. significant studies using the IT platform for fundamental apparatus testing and upkeep. That's a solid foundation for making sure electric power companies are there for the long haul [8].

First explained the basic framework and features of a smart substation, and then we provided the application idea of SABP. This type of protection system can implement the backup protection function for each electrical element inside a smart substation based on the comprehensive treatment and judgment of the digital information of the whole substation, including voltage and current samplings of multiple bays, the status of circuit breakers, etc. In addition, SABP's protection algorithm and application structure, as well as its coordination connection with main protection, may effectively promote a substation area range of data information exchange and aid in strengthening the overall protection system's operating performance. Given the above, it is reasonable to conclude that implementing SABP may facilitate data exchange throughout a wider substation region, hence improving the overall performance of the protection system. Of course, there is a long way to go before SABP can be used in the real world; many concerns remain, including how to best develop and refine a protection algorithm, how to optimize an application's structure, and how to build a mathematical model for analyzing dependability. It is expected that these responsibilities will be fulfilled in the near future [2].

2.4 Summary:

"Intelligent substations" will be comprised entirely of electronic components and will almost do away with the need for copper wire. A new method of maintenance for T&D equipment is made possible by numerical protection and control devices. There will be a decrease in expenses associated with operation and maintenance, as well as an improvement in service quality and overall availability. The substation is the most important part of the electric power network since it acts as a central hub for the transmission and distribution of electric power. It is of the utmost importance to guarantee the secure and consistent functioning of the substation equipment. The goal of the SICAP approach is to cut down on overall maintenance costs while making sure that their equipment is more reliable and available.

CHAPTER 3
MATERIALS AND METHODS

3.1 INTRODUCTION:

The nerve center of every electrical grid is the power substation. Its primary function is to take electricity from a higher voltage source and transform it into a lower voltage (11 kV). Typically, these substations may be found on the fringes of major cities, close to load centers. Indoor or outdoor, air insulated (AIS) or gas insulated, the highest capacity for a 33/11kV substation will be 60 MVA (GIS).

3.2 Methods and Materials and Components:

3.2.1 Surge/Lightning Arresters:

A lightning arrester (LA) safeguards substation equipment by discharging lightning and switching voltages to the ground. It comprises of a sequence of spark gaps and a number of nonlinear resistances, such as thyrite and metrosil, among others. A nonlinear resistor is one whose resistance is inversely proportional to the applied voltage and quickly falls as the voltage across it increases. The high surge voltage appears and permits the flow of heavy currents on the order of thousands of amperes**,** quickly dissipates energy and recovers, and presents a high resistance value to the normal line voltage as soon as the surge has vanished, so that any tendency for the arc to continue is immediately suppressed. In a system with a properly grounded neutral, the rated voltage of the arrester is often calculated as 80 percent of its maximum line-to-line voltage. In an unearthed system, line-to-line voltage is assumed to be 100 percent because, during fault circumstances, when one line is earthed, the arrester attached to the other two lines is exposed to full line–line potential.

LA should be fitted with a 33 kV, 10 kA discharge current rating for the protection of switchgear, transformers, related equipment, and 33 kV lines. On the buses, high-voltage and voltage sides of all transformers, and on the incoming terminations of 33 kV lines, station-class, heavy-duty, gapless metal oxide (ZnO)-type surge diverters will be installed. The arresting officers will adhere to IS 3070.

As per IS: 4004, the RMS voltage of LA will be 9 kV, and the earthing coefficient will not exceed 80%, with all transformer neutrals directly earthed.

3.2.2 Maintenance of Surge Arresters:

The following are the usual causes for the failure of a surge arrester.

1. According to the case histories provided by POWERGRID, around forty LAs were unsuccessful because of moisture intrusion.

2. Based on measurements of the third harmonic resistive current, about fifty local area networks (LAs) have been deleted. Throughout the course of the investigations, it was determined that the primary cause of THDC breaches was the presence of moisture.

3. The majority of the 80 LAs that failed did so during the changeover process.

4. During the PIR removal field testing, the LAs did not conduct even once under the worst circumstances (1.95–2.05 PU), which indicates that the switching surge current was more than 70–80 A.

5. During the assessment of failures conducted with manufacturers in 2003 and 2004, the majority of LA failures were found to be the result of moisture intrusion rather than ageing or conduction.

6. Because the TOV criteria for transformer/reactor LAs are lower than those for line LAs, the rating for the two types of LAs might be different from one another. In addition, for transformers, only the residual surge makes its way to the transformer in the vast majority of situations.

3.2.3 Causes and Nature of Failure:

There is no lag in the response time when the surge/lightning arrester detects an overvoltage condition.

The rated voltage, continuous operating voltage, energy handling capabilities, nominal discharge current, and any other parameters of the LA arrester will be determined in accordance with the system requirements. Normally, there is only a small chance of a LA failing, but this one is Surge/Lightning Arresters 79 specifically intended for a limited number of operations. When choosing a LA, the same thing has to have the appropriate checks done on it. On a daily basis, the number of the discharge cycle counter need to be monitored, and if the counter enters the "RED" zone, the setting ought to be modified immediately after reaching that point. Under the event that the surge arrester is employed in abnormal service circumstances, such as heavy deposits of smoke, dirt, salt spray, or any other conducting substance, the surge may be bypassed, and the arrester will prevent the failure of the equipment.

3.3.1 Primitive Maintenance of LA:

A lightning arrester does not, in most cases, undergo any kind of rudimentary maintenance. When it breaks down, it has to be replaced immediately. Nevertheless, once the porcelain insulator has been punctured, it has to be replaced. Fixing the problem with the nonlinear resistance in Los Angeles will need to be done. Therefore, in the event that this endeavor is unsuccessful, the LA as a whole will need to be replaced. During the selection process, it is essential to pick the LA that corresponds to the class and rating that is suitable, particularly with regard to the environmental circumstances.

3.3.2 Predictive Maintenance:

After routinely collecting performance records of the surge diverter, it is vital to immediately replace the arrester whenever it is discovered that the counter has entered the red zone. This should take place as soon as possible.

3.4.1 Instrument Transformer (CT and PT):

Metering and protection are the two primary functions served by the instrument transformer, which works by reducing the high voltage or current coming from a transmission or distribution system to a lower value. These transformers bring the high current or high voltage that is linked to their main windings down to the usual low values that are found in their secondary windings. During the course of their service life, it is anticipated that they will need no maintenance. They are of the minimal oil kind and hermetically sealed. Furthermore, from the perspective of application, they may be broken down into three primary types.

3.4.2 Metering Type:

The performance of the CT must be maintained within the range that is generally 5–120% of the rated current in order to meet the specifications. In order to prevent the instrument from being harmed when it is subjected to fault circumstances, the CT cores should be designed in such a way that they reach saturation at the instrument security factor (ISF). It is necessary for the PT that was intended for metering to work as stated during the voltage range that is close to the typical rated voltage, which is between 80 and 120%.

3.4.3 Protection Type:

The primary requirement for the performance of protection class CTs is that their cores must not become saturated below their accuracy limiting factor (ALF), which is the point at which the primary current must be faithfully transformed to the secondary current while maintaining the specified accuracy. In fault situations, the primary of the CT carries a very high current, and the initial few cycles contain a DC component, both of which have the potential to saturate the core. The behavior of the cores in such a circumstance should be such that they avoid getting magnetic and that they revert to normality (the demagnetized stage) shortly after the fault has been cleared.

3.4.4 Load Survey Type:

This is a combination of the two categories mentioned above, and it is often utilized for the efficient control of industrial loads. The output of this CT is coupled with a variety of different distribution management systems.

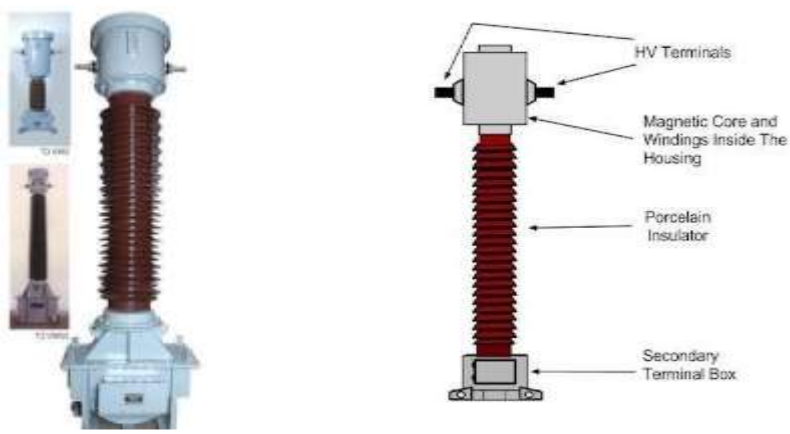
3.4.5 Outdoor Type Instrument Transformer:

At most cases, they are installed in electricity substations (Fig.). When designing, the following considerations are given priority throughout the process.

1. The influence of the atmosphere and the environment

2. An insulating layer that can resist fluctuations in the network.

3. These are oil-filled to prevent moisture from entering the inside.



(a) Current Transformer(CT) (b) Potential Transformer (PT)

Figure 1 Current transformer and potential transformer

3.4.6 CT Type:

1. Window CT: This kind of CT does not have a primary winding structure and is located close to the main conductor.

2. Bushing CT: Window CT is inaccessible due to the proximity of bushing, which was installed nearby.

3. Bar CT: Similar to a window CT, but it contains a principal conductor in the form of a bar that is permanently fixed.

4. Wound Current Transformer: The wound current transformer, similar to a regular transformer, has primary and secondary winding. This CT is most commonly used for lower conversion ratios of current and is generally applicable in matching various CT summing ratios to compensate for lower current in CT secondary circuits or to separate similar CT circuits. In addition, this CT is most commonly used for lower conversion ratios of voltage.

Because the instrument transformer is not expected to need any maintenance over its lifespan, there will be no need for oil filtration or replacement during that time. Because of this, it is very necessary to hermetically enclose the transformer in order to prevent it from inhaling outside air.

5. Accuracy Limit Factor (ALF): It is the ratio of the current value that is the greatest to the current that the CT is rated for up to which it must maintain the prescribed accuracy. Example: –CT –5P20, 5 VA, ALF = 20.

6. Identification of the CT Core according to Class:

0.1 second, 0.5 second, and one second classes: the metering core

2. Class— 5P10, 5P20, and so on: the backup protection core (O/C and E/F protection)

3. Primary protection core, classified as Class-PS (differential, distance, REF, etc.)

3.4.7 Causes and Nature of Failure:

In general, none of this machinery will need any kind of maintenance for its entire career. The following elements, however, contribute to the ineffectiveness of this tool. Some of these gadgets are meant to be used outside and are constructed to be weatherproof and resistant to the elements. Insulators made of porcelain are being used in order to achieve external separation between live and ground. They serve as an exterior shell that protects against all elements of the environment, such as precipitation, dust, chemical contamination, wind, and sunlight, among others. However, it is not uncommon for the connections between the insulator and the tank to become loose, for the washers that link the two to get damaged, and for oil to escape from the tank. It is essential that regular maintenance be performed on this apparatus.

Switching, sparking, and other types of network disruptions may cause a significant number of power surges to be produced inside a power system, which can occur rather often. These environmental factors produce core saturation, which in the end causes harm to the device by disrupting its ability to make accurate measurements. These power surges cause the insulation that is located between the main and secondary circuits to get destroyed, which in turn causes the equipment to become damaged.

3.4.8 Primitive Maintenance of Instrument Transformers:

It is essential that all of the equipment be kept in good health over its entire lifespan in order to provide a smooth and dependable power supply. Because of this, each piece of machinery that develops a fault has to be replaced as quickly as possible.

3.4.9 Classification of Circuit Breaker:

The arc quenching medium, application, and site usage of circuit breakers are three of the criteria that may be used to categorize these devices. It is possible to categorize it as follows depending on how the breaker was used.

1. An outdoor-type breaker: The earth quenching mechanism in breakers may be found in the switch yard. Inside the control room, the only thing that can be found is the device that controls the circuit breakers.

2. Indoor-type circuit breaker: In circuit breakers of this kind, the mechanism for earth quenching is located inside the control room. Within the confines of the control room is where the high-voltage circuits are sent to the circuit breaker working chamber.

However, depending on the various arc quenching processes they use, circuit breakers may be broken down into the following categories.

1. The bulk oil circuit breaker consists of contacts that are separated by an oil-filled steel tank that is utilized for arc quenching.

2. **The minimum oil circuit breaker:** The contacts are separated inside of an insulated housing (interrupter) that is filled with transformer oil. This oil is utilized for arc quenching.

3. **Air blast circuit breaker:** This kind of circuit breaker uses high-pressure compressed air to extinguish electrical arcs.

4. **Sulphur–hexafluoride gas circuit breaker:** This kind of circuit breaker uses Sulphur–hexafluoride gas to extinguish electrical arcs. The SF6 breaker has the benefit of having a rate of limiting voltage that is zero, which means that the burning of male/female contacts is reduced to a lesser extent. There are two distinct varieties of the operating mechanism:

1. The motion of the contacts is controlled by a spring mechanism, also known as a spring-operated mechanism.

2. The pressure of the air is what controls the movement of the contacts (pneumatic operated).

5. Vacuum Circuit Breaker: The contacts for this kind of breaker are contained inside a vacuum interrupter that is hermetically sealed permanently. As the contacts are separated in the high vacuum environment, the arc is extinguished.

3.4.10 Causes and Nature of Failure:

An operator is able to open or shut circuit breakers when the machine is in normal operation circumstances for the purposes of switching and maintenance. In the event that abnormal or defective circumstances exist, the relay will detect the faults and will cause the trip circuit of the breaker to shut; the breaker will then proceed to open the circuit. While the relay contacts are closing the trip circuit, the operational mechanism of the circuit breaker is opening the contacts, which causes an arc to be drawn between the two sets of contacts. At the point that the natural current zero of the AC wave is reached, the arc is extinguished. The process of interrupting the flow of current is finished when the arc has been extinguished and the current has reached its ultimate zero value.

Carbon, on the other hand, gets deposited all over the arcing contacts, main contacts, and auxiliary interlocking contacts while the process is going on. In the end, this results in a delay in the fault clearing time since it creates a delay in the execution of the trip instruction. The contacts have either completely burned out, worn out, or become excessively abrasive as a result of constant usage.

Under these circumstances, the contacts must be swapped out with brand-new versions. Because the spring is continually compressed or expanded as a result of constant usage, it eventually gets crooked, which causes a lag in the mechanism that controls operation. This needs to be verified and brought up to date. For movement that is smooth and unimpeded at all moving contacts, the appropriate lubricant should be applied. In the construction of the circuit breaker, a variety of nuts, bolts, and washers are used. It is possible for these washers and nuts to become loose as a result of a highly rapid movement with a significant amount of power. This would result in the equipment being moved away from its intended path. It is necessary to tighten these in order to ensure that the movement is both smooth and precise. The circuit breaker is responsible for a significant amount of discharge current. Checking the equipment's earth connections at regular intervals is necessary to ensure that it operates safely and has a long lifespan.

3.4.11 Primitive Maintenance of Circuit Breaker:

Quenching medium is required in a certain amount and at a certain pressure for oil, SF6 gas, and air blast circuits in order to ensure dependable and smooth operation. At consistent intervals, the quantity and pressure should be monitored and maintained. On a consistent basis, records should be kept of the indicator monitoring of these parameters. The circuit breaker contacts either need to be broken down or bent, and this has to be done as soon as possible. When it comes to the vacuum circuit breaker, the contact force is something that has to be evaluated on a regular basis and any required adjustments made. On the electricity distribution network, the most significant protection device is the circuit breaker. The importance that should be given to its preventative maintenance is as high as possible.

3.4.12 Predictive Maintenance:

A counter that keeps track of the number of times the circuit breaker has been used is built into each of them. It is made abundantly apparent in the user handbook provided by the manufacturer that the arc quenching medium must be changed after it has been used for a certain amount of cycles. It is essential that the relevant instructions included in the user manual provided by the manufacturer be adhered to in a stringent manner. It is necessary to do an accurate check on the delay in time between the recording of the fault and the breaking of the circuit. In order to achieve a greater delay time, the relay settings as well as the operation duration will need to be verified and adjusted.

3.3 Isolators and Earth Switch:

3.3.1 Classification of Isolators:

Isolators are the devices that are used to create and break circuits when there is no load present. The purpose of the isolators that are installed in the substation is to allow the line and the equipment to be disconnected from the bus bar or from incoming or outgoing lines. These are off-load switches, not load break switches, and should not be utilized as such. The following is a list of the numerous kinds of isolators.

(a) Center Break Rotating Kind Isolator: An isolator of this type is used for bus bars as well as incoming lines. The break is made in the middle with this design thanks to the rotation of both of the side insulators.

(b) Double Break Rotating Kind Isolator: This type of isolator is utilized for connecting or disconnecting the line from the substation, as well as connecting or disconnecting the bus bar and equipment. The copper tube or blade functions as the moving contact in this configuration, which has a rotating central insulator. The connections on the other two side insulators are permanent, and the insulators themselves are fixed. When the switch is opened, the central insulator will spin, which will allow for a double break action.

Figure 2 Isolator

(c) Pantograph Kind Isolator: A break in this type of isolator will be in a vertical orientation. When the isolator is in the ON position, it makes contact with a bus bar. When it is switched to the OFF position, however, it descends vertically, breaking the connection to the bus bar. Isolators of this sort may be found operating in our system at a number of substations rated at 400 kV.

(d) Earthing Isolators: When the power is turned off, the earthing isolators are supposed to earth the line in order to discharge the capacitive voltage that is stored in the line to the ground. When personnel are working on the lines for maintenance reasons, it is highly crucial that this be done. The earthing blades are connected to the incoming or outgoing feeder isolators; however, in order for them to become active, the line isolator must first be turned off. These kinds of interlocks are very essential for preventing the earthing of a live line.

Causes and Nature of Failure:

Isolators are off-load switches, and when they are functioning normally, a large amount of electricity will flow through them. However, even a little space between the contacts of the isolator may cause a shower of sparks and the contacts of the isolator to burn. In most cases, the male/female contact of the isolator will erode and burn out over time, which will finally result in high sparks and the breaking of the isolator's moving contact. Because the handle, the spinning rod, and the moving mechanism are all outside mechanical equipment, their condition deteriorates together with the isolator's age. This will result in the contacts, nuts, bolts, and other similar components being more lose.

Primitive Maintenance of Isolators:

After a defect has been reported in any of the isolator's components, the isolators may be maintained. It is necessary to always ensure that the contacts are in good health and operating correctly. After a burning mark or corrosion has been established on an isolator contact, it is essential to clean the contacts on a regular basis or replace the corroded contacts in order to ensure smoother operations. Changing the corroded contacts is also an option. During the operation of the isolator, whether it be manual or motorized, the moving portion will deteriorate, which will cause contacts to become loose, poor alignment, and other issues. Regularly adjusting the tightness of the nuts, bolts, and washers will keep this from becoming an issue. Additionally, the degradation impact may be mitigated by performing routine lubrication on all of the moving components.

Predictive Maintenance:

After receiving a bad result from the isolator during the Mongering of earth resistance, it is vital to check for the loose route of earth. It is necessary to rectify and maintain the health of all of the nuts, bolts, and connections. Whenever incorrect contacts are discovered during the course of regularly planned maintenance, it is imperative that they be replaced with a new component that is a matched replacement. This will eventually result in the gap being rendered irrelevant under the closed condition, which will result in the isolating of a spark.

3.4 Bus Bar:

Figure 3 Bus Bar

There is a common misconception that a power system's bus bars are where the electricity really originates. All of the loads are connected to one another and are grounded by insulators; their construction is similar to that of electrical wiring. The bus bar connects the generator to the transformer in power plants and is used in electrical substations to connect the substation's incoming and outgoing lines. Industrial settings often use bus bars of the aluminum smelting kind. Huge amounts of power are carried in these bars for use in electrolytic processes. The maximum amount of current that may flow through a bus bar is determined by its capacity, which is determined by the size of the bus bar. The necessary cross-sectional area of the bus bar is established by the application. For low current applications, a bus bar with a cross-sectional area of 10 mm2 is employed, whereas electrical substations utilize bus bars with a cross-sectional area of 1000 mm2 or more. The bus bar has a variable cross-sectional area. A bus bar structure may be supported by insulation either underneath it or totally around it. The bus bar shown in Fig. 1.6 is protected from accidental touch by being enclosed in metal or raised above ground level. Since they are securely secured to the metal chassis, the earth bus bars are safe from potential damage. Busducts, segregated phase busducts, isolated phase busducts, etc., may be used to enclose the bus bar construction. The majority of the time, clamps or bolts are used to connect bus bars to other electrical components. In order to reduce contact resistance, silver plating is done in high current bus joints. Because corona may cause electromagnetic interference between nearby connections at high voltages, special connection fittings are developed for use with extra-high voltages over 300 kV. A stranded conductor connects the various metal frame constructions inside the substation, and porcelain insulators are employed for the rigid bus bar. Bus bars are often made from aluminum or copper. Short-circuits between neighboring phases may be avoided when an insulator is used to support the insulated phase bus bar and a grounded metal shield is placed around the whole assembly. Bus bars insulated with Sulphur hexafluoride consist of large metal tubes filled with the gas under high pressure.

Major types of bus bars:

Serial No	Type of bus bar	Usage
1	Rigid Bus bar	Low, Medium and High Voltage.
2	Strain bus bar	Mainly for high voltage.
3	Insulated-phase bus bar	Medium voltage.
4	Sulphur hexafluoride (SF6)-insulated bus bar	Medium and High Voltage system

Preventive maintenance schedule of bus bar.

Inspection Frequency	Item to be inspected	Inspection Notes	Action required for unsatisfactory conditions
Weekly	Physical Inspection. Burnt mark, Color of bus bar	Visual inspection of health. All the joints are proper collected. During visual inspection joints on the bus bar to be checked.	- Spark may be checked on bus bar.
Quarterly		Mongering to be done for measuring the connectivity between devices. Inspection of all jointing equipment and check joints.	- -

3.5 Battery and Battery Charger:

Classification of Battery Types:

Figure 4 Battery and Battery Charger.

The battery facilitates the electrochemical conversion of chemical energy into electrical energy. A battery's primary component is its cell; many cells are linked together in series or parallel to create a single battery.

Even though they're tiny, the battery and battery charger play a crucial role in electrical substations. A DC supply is utilized instead of the standard AC supply because it is more stable. In the event of a power outage, all electrical safety measures will be rendered ineffective. Avoiding this kind of problem is the primary motivation for switching to DC power. Batteries provide DC power, and the charger maintains battery health by charging in float or boost mode as needed.

Most substations rely on batteries to power the supply relay and breaker tripping mechanism. Successful functioning of these monitoring devices is guaranteed by using a dependable battery power source. As a result, it is essential to ensure the correct functioning of the monitoring equipment by inspecting the battery supply regularly. The capacity of a cell or battery is the total amount of charge it can hold, measured in amp-hours.

The capacity of a battery is measured by discharging it at a steady current rate and multiplying the elapsed time by 1.75 V, the battery's terminal voltage. Standard battery voltage ratings of 30, 110, or 220 volts are used for storage in a substation with a 33/11 and 66/11 kV rating system. In order to handle the substation's necessary load, the batteries typically have a minimum rating of 45 Ah at 24 V. The table below compares common battery types and lists the cell voltage of each.

Typically, distribution substations will employ one of the following battery types.

1. Lead-acid batteries that were flooded

2. Nickel-cadmium was flooded.

3. AGM lead-acid VRLA

4. Lead-acid gel VRLA

Different voltage levels of batteries:

S. No.	Nominal voltage rating of batteries (V)	Nominal single cell voltage (V)	Float cell voltage (V)	Number of cells	Permissible DC voltage variation (V)	End of discharge cell voltage (min) (V)
1.	24	1.2	1.4-1.42	19	21.7-27	1.14
2.	30	1.2	1.4-1.42	23	26.2-32.7	1.14
3.	110	1.2	1.4-1.42	87	99.2-123.5	1.14
4.	220	1.2	1,4-1.42	170	193.8-241.4	1.14

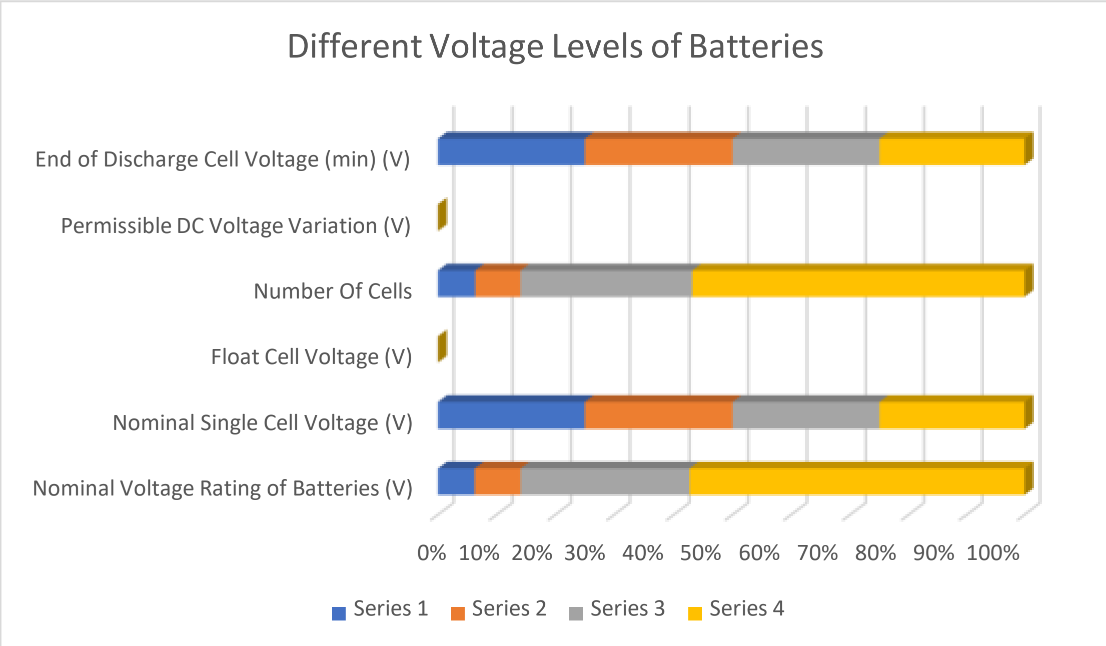


Figure 5 Different Voltage level of Batteries

Comparison between different types of batteries:

S. No.	Leaking Lead-Acid Batteries	A Nickel-Cadmium Flood	Replacement Deep Cycle AGM/VRLA Batteries
1	When it comes to stationary applications (such a substation in a transmission and distribution network), battery technology is superior.	This is a top-notch marine, bicycle, and vehicle battery.	cheap starting point
2	Expensive	Getting things going, particularly in very hot or cold places	There's no requirement for spill control.
3	Needs maintenance; batteries lose performance if they aren't regularly checked and serviced.	Cadmium's toxicity raises environmental concerns.	Reduces the need for a larger floor space.
4	Need a comfortable temperature and air flow	Poor lifespan, expensive initial investment, high cost.	Denser power

5	Spill containment, big footprint	Unlike lead-acid batteries, Ni-Cd batteries may be used in very cold or hot temperatures without losing performance, and their overall cost throughout their lifetime is far lower.	There is no longer any need for a separate room, and upkeep is easier and safer.
6	Not recommended for use in distribution substations.		Due to technological constraints including corrosion, negative polarization, thermal run-away, and dry out, the lifespan is inevitably shortened.
7	-	-	needs a regulated temperature setting
8	-	-	need a lot of upkeep and checking
9	-	-	Easily irritated by incorrect charging

Figure 6 Comparison between different types of batteries

3.6 Common Causes of Fault and Best Practices for Battery Maintenance:

Find a charger that can meet your battery's needs:

Since batteries are costly, taking good care of them is crucial to prolonging their useful life. A battery's health and lifespan may be greatly improved by following best charging practices. Depending on the use case, the battery must be charged and discharged for a certain amount of time, operated within a certain temperature range, and have a certain number of cells maintained.

Constant Voltage Charging:

When a battery is being charged, it enters a condition known as the constant-voltage region mode, during which the input voltage to the charging process remains constant regardless of the battery's capacity. Because of the larger initial potential difference between the battery and charger, more current flows to the battery at this time. Because of this method, the battery may be charged more quickly.

Avoiding Over discharge:

The number of lead-acid batteries would rise if their use was restricted to only when fully charged. Lead-acid batteries have a normal cutoff voltage of 1.75 V, and this value is directly proportional to the battery's operating temperature and discharge rate. Over discharging, however, may reduce battery life and make charging more difficult. Lead precipitation in the separator due to over discharging may also result in an intra- or inter-cell short.

Cleaning:

Maintaining the battery's extended life necessitates keeping it clean and clear of dirt and grime. Corrosion and grime may add a significant cost to replacing a battery, and this would help alleviate that cost. During typical usage, the battery accumulates a layer of dry dirt, which may be a fire hazard since it turns the battery's stationary current into a conductive flow.

Avoiding High Temperature:

Battery temperature is a negative metric that should be kept below 55 degrees Celsius. Batteries become hotter due to internal factors including corrosion, metal components, chemical catalyst processes, and self-discharges.

Safety Precautions:

Lead-acid batteries need special care because they may emit dangerous sulfuric acid; a combination of hydrogen and oxygen might generate a massive explosion and produce deadly gases like arsine and stibine if they were to leak. Working with battery acid components has unique challenges, but these may be overcome by taking the necessary safety measures, such as donning a face mask, apron, and gloves. In the event that battery acid comes into contact with the eyes, it is crucial to immediately cleanse the area with clean water and seek medical attention.

3.7 Earth Grid and Earthing System:

Safe use of protective gear relies on several factors, one of which is its ability to be earthed properly. The procedure of earthing not only serves to maintain a steady voltage profile but also helps to reduce voltage fluctuations in the case of a malfunction. All earth electrodes should be linked to the primary earthing ring that surrounds an outdoor substation [19]. Transformers, circuit breakers, and the like should be placed such that the ring has the shortest possible connection.

Types of Earthing:

In this case, we have two categories: neutral and equipment earthing. To keep neutral points at earth potential and provide a return channel for the neutral current, neutral earthing ensures that the system is earthed in a neutral state. The neutral terminal of the transformer must be earthed to two unique ground electrodes that are in turn connected to the earth mat in the substation.

For the sake of worker safety and lightning protection, it is important to ground the equipment's noncurrent-carrying components. All non-current-carrying metallic components of equipment, buildings, enclosures, overhead shielding wires, bushing flanges, transformer cores, cable sheaths, earthed screens, pipelines, portable appliances, fences, doors, and screens should be grounded.

3.8 Transformer

Although you may choose between a regular, slow, and extremely slow speed ratio, all fuses have the same temporal current characteristic (TCC) and inverse curves.

When compared to utilizing a relay on a circuit switcher or breaker, the sensitivity to detect lo-side SLG faults is low. Since we used DELTA/WYE linked transformers, the phase current on the 115 kV is mitigated by the 3 rather than a three phase failure. Damaged fuses may eventually explode at a higher load. When a single 115 kilovolt (kV) fuse bursts, distribution voltages to the customer drop. For instance, the phase-to-neutral distribution voltages on two 13.8 kV phases drop to half their usual levels. Similar to utilizing a circuit switcher, but with several significant benefits:

The one shown below has a higher interrupting capacity of 40kAIC.

When compared to a circuit switcher, it trips more quickly (3 cycles vs. 6 – 8 cycles).

It may need less repairs than a conventional circuit switch.

To protect the transformer and its high-side bushings from damage caused by a failure on the bus, the CTs would be mounted on the breaker.

3.9 MAINTENANCE OF POWER TRANSFORMER:

This kind of upkeep is based on a reactive strategy. This means you should only do maintenance on broken pieces of equipment.

Everyday Upkeep:

As part of this upkeep, you should visually evaluate your equipment at regular intervals and perform any required repairs, alterations, or replacements.

Maintenance that is performed on a regular basis (preventative maintenance) includes both predictive and remedial tasks. Frequent inspections and tune-ups are a part of the preventative maintenance plan. In contrast to corrective maintenance, which is repairing and restoring transformer integrity to its original state if exacerbated abnormalities are detected, predictive maintenance entails doing further monitoring and testing.

The following are some of the mainstays of this upkeep:

Preserve coating that prevents damage to transformers

Conduct insulation tests and routine maintenance on transformers.

Transformer ancillary equipment inspection and servicing

Power transformer temperature regulation

The bushing insulation of a transformer must be kept in good condition.

Depending on the kind of power transformer, routine maintenance may be performed once a day, once a month, once every three months, once every six months, or once a year.

3.10 Summary:

A lightning arrester should be fitted with a 33 kV, 10 kA discharge current rating for the protection of switchgear. Stationary-class, heavy-duty, gapless metal oxide (ZnO)-type surge diverters will be installed. The arresting officers will adhere to IS 3070, and the RMS voltage of LA will be 9 kV. About fifty local area networks (LANs) have been deleted. The majority of the 80 LAs that failed did so during the changeover process. There is no lag in the response time when the surge/lightning arrester detects an overvoltage condition. It is vital to immediately replace the arrester whenever it is discovered that the counter has entered the red zone. Metering and protection are the two primary functions served by the instrument transformer. The performance of the CT must be maintained within the range that is generally 5–120% of the rated current.

CHAPTER 4
IMPACT ASSESSMENT

4.1 Economical, Societal and Global Impact:

To a large extent, the expansion of the global economy may be attributed to the increased productivity of businesses and the proliferation of international trade. The quality of life and literacy rate of a nation rises in tandem with its economic progress. Deforestation and the massive use of nonrenewable fossil fuels and natural resources have both been assisted by globalization. Studies of economic effect attempt to calculate how much money, new employment, and family income will be added to an economy. As the world's economies have advanced, globalization has aided underdeveloped nations in keeping up. Potential problems with reliance and loss of sovereignty are among the drawbacks. The term "economic globalization" describes the growing interconnectedness of national economies throughout the globe. It's a consequence of the ever-increasing volume of worldwide commodity and service exchanges, the movement of vast amounts of wealth across national boundaries, and the lightning-fast dissemination of cutting-edge technology. The following are some of the most critical forces propelling globalization.

4.2 Environmental and Ethical Issues

Substations are crucial to the electric grid because they connect transmission and distribution lines. Anywhere from the center of a field to the middle of a city block is a suitable location for a substation. When choosing on a location for a substation, other factors are also important to consider. Construction and maintenance of electrical substations may have some temporary consequences on surrounding populations and the environment. Large substations sometimes need environmental modifications, such as the installation of rainwater detention ponds, berms, and other transmission equipment. Some of the short-lived consequences include mechanical noise, airborne dust, and brief disruptions to local power supplies. Substations for transmitting electricity are often designed purely for function. Residents may be more tolerant of the facilities' evident visual impact in more rural locations. Some locals may feel that transformers, switches, and fences detract from an otherwise pleasant neighborhood. Substations may have a detrimental effect on the character and attractiveness of the adjacent residential area unless they are suitably landscaped or constructed to be less apparent. Light pollution may be a nuisance in cities and a detriment to the night sky in the country. Building and operating the substation might have devastating effects on the habitats and populations of endangered species. Wisconsin's Public Service Commission is responsible for regulating the state's utility companies. Anyone considering making Wisconsin their permanent home should get in touch with the state's DNR. In addition to the loss of grassland or woodland, substation construction may result in the displacement of non-listed species of birds, animals, reptiles, and other organisms. Substation applications in Wisconsin are reviewed by the PSCW, which takes into account factors such the project's expected cost, the urgency with which it is required, and the potential for negative social and environmental impacts. The Commission has final say over the substation's construction, location, and conditions.

4.3 CT & PT

While a PT converts high voltage values into lower ones, a CT decreases current signals for measurement reasons. The transformers are intended to test the safety and accuracy of electricity systems. Moreover, the CT and PT transformers lower the voltage and current from a high value to a low value.

There are a number of drawbacks to current transformers (CTs) that should be taken into account before choosing and employing them. Among the most significant drawbacks are: The current range of CTs is constrained. They may not be accurate outside of the range for which they are intended to measure current. CTs have the potential to cause measurement mistakes. The CT core's saturation, core loss, and winding resistance are a few examples of the variables that can contribute to these problems. CTs are susceptible to interference from outside electromagnetic fields. This may result in inaccurate measurements or possibly cause harm to the CT. CTs can be very costly. The price of CTs may play a sizable role in the total cost of a measurement system. CTs need to be installed and maintained carefully. The connections must be tight, and they must be installed properly. A potential transformer's advantages and disadvantages are an ammeter and voltmeter can be connected to high-voltage lines to measure current and voltage, respectively. Whether voltage or current is sensed, the low-range meter's level can be changed using a potential transformer. These instruments control many different kinds of safety equipment, such as relays and pilot lights. One potential transformer is capable of controlling numerous instruments. Due to the device's effectiveness, there aren't many drawbacks. The key drawback of a potential transformer is that it would only allow this configuration on AC networks and could not be used on DC circuits.

4.4 Bus Bar

A bus-bar is a type of electrical connection that transmits electricity from the entering feeders to the departing feeders. A bus-bar's primary function is to transport and distribute electricity. The systems are improved through the introduction of bus bars. The single bus-bar, main and auxiliary bus-bar, double bus-bar, double main and auxiliary bus-bar, and one and a half breaker schema are the bus-bar schemes that are frequently employed at substations. The key benefit is the ability to switch the load to a different type in the event of continuity loss. Repair and upkeep are less expensive. The bus's potential can be used to operate relays. It is relatively simple to transfer the cargo to another bus. As the entire system utilizes two bus bars, the price would increase. If there is a problem with any part of the bus, the entire system could fail.

4.5 Isolator

A manually operated mechanical switch called an isolator is used to isolate the substation's problematic area. In order to prevent the occurrence of serious flaws, it is used to divide a damaged section that needs to be repaired from a healthy piece. The dis-connector or disconnecting switch are other names for it. In substations, high-voltage isolation switches are used to enable the isolation of equipment like transformers and circuit breakers. The dis-connector switch is typically recommended for isolation rather than circuit control. It is a two-port non-reciprocal device that uses low attenuation to pass signals in one direction while blocking them with high attenuation in the other. The isolator reduces changes in the source's output power when it is connected between the source and the load because it prevents reflections from the load from returning to the source. Moreover, it prevents frequency pulling brought on by shifting loads. The RF isolator is used extensively in test and measurement to safeguard T&M equipment from harm caused by overload or high reflected power while conducting tests and measurements. As shown in Figure 2 below, an RF isolator can be employed in RF circuit design. According to this design, all frequencies are passed from the input port to the output port, while any frequencies traveling in the opposite direction are blocked. In this way, it safeguards tiny, miniature RF components like mixers, amplifiers, etc.

4.6 Circuit Breaker: The substation's transformer serves as its beating heart. The relationship between the entering voltage and current and the output voltage and current is altered by the transformer. Transformers used in substations are graded according to how well their primary and secondary voltages match up and how much power they can handle. A fantastic alternative to fuses that operate mechanically is a circuit-breaker. Circuit breakers are very trustworthy. Circuit-breakers perform better. A circuit breaker only needs to be fixed once, is simple to reset, and is durable. Testing may be more difficult than it seems. The circuit breaker must do more than just block access to a certain service. One-off circuits are challenging to create. They need an infrastructure management system that can control the on/off switching, such as a service mesh.

CHAPTER 5

CONCLUSION

5.1 Conclusion

Condition-based maintenance is preventive maintenance based on condition information provided by equipment monitoring, diagnosis, and assessment, or, in other words, preventive maintenance according to the operational condition and healthy status. SABP can increase the range of information sharing in a substation area and help to improve the overall operation performance of the protection system. A substation's planned maintenance has many benefits; it can save money and prevent equipment wear and tear. Modern power systems are very complex in nature and produce transients during various operations. Backup protection units can be used to solve the problem when a protection device happens to fail. The SA infrastructure comprising numerical protection and control devices allows a new maintenance approach for T&D equipment. Further steps are in the process of being implemented in the coming months, and plans are in hand to produce a complete demonstration of all the SICAP main changes at a single operational site.

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