M.Tech. (Power System) HITESH AGARWAL 2022

PROTECTION COORDINATION OF DISTRIBUTION SYSTEM WITH DISTRIBUTED GENERATION

DISSERTATION/THESIS

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS

FOR THE AWARD OF THE DEGREE

OF

MASTER OF TECHNOLOGY

IN

POWER SYSTEM

Submitted by:

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I, HITESH AGARWAL, Roll No. 2K20/PSY/09 student of M.Tech. (Power System), hereby declare that the project Dissertation titled "PROTECTION COORDINATION OF DISTRIBUTION SYSTEM WITH DISTRIBUTED GENERATION" which is submitted by me to the Department of Electrical Engineering Department, Delhi Technological University, Delhi in partial fulfillment of the requirement for the award of the degree of Master of Technology, is original and not copied from any source without proper citation. This work has not previously formed the basis for the award of any Degree, Diploma Associate ship, Fellowship or other similar title or recognition.

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CERTIFICATE

I, HITESH AGARWAL, Roll No. 2K20/PSY/09 student of M.Tech. (POWER SYSTEM), hereby declare that the dissertation/project titled "PROTECTION COORDINATION OF DISTRIBUTION SYSTEM WITH DISTRIBUTED GENERATION" under the supervision of Prof. J.N. RAI and Dr. Prem Prakash of Electrical Engineering Department, Delhi Technological University in partial fulfillment of the requirement for the award of the degree of Master of Technology has not been submitted elsewhere for the award of any Degree.

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ACKNOWLEDGMENT

I would like to express my gratitude towards all the people who have combined their precious time and effort to help me without whom it would not have been possible for me to understand and complete the project.

I would like to thank Prof. J.N. RAI and Dr. Prem Prakash, Department of Electrical Engineering, DTU Delhi, my Project guides, support, motivation and encouragement throughout the period this work was carried out. Their readiness for consultation at all times, their educative comments, their concerns and assistance even with practical things have been invaluable.

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ABSTRACT

The purpose of this research is to provide an effective technique for overcoming the implications that distributed generator (DG) integration has on the coordination among protective devices. The integration of DGs has a significant amount of impact on the recloser-fuse coordination. The most significant affects that DGs have on a normal distribution system are an increase in the size of fault currents as well as changes in the directions in which electricity flows. In the event that a transient fault occurs, the findings of the simulation suggest that it is possible to reestablish coordination among the protective devices by designing a fuse saving strategy that involves the rapid functioning of the recloser. The plan that was devised also functions adequately for isolating a portion of the feeder that is permanently faulty. For the purpose of establishing the optimal values of TDS of overcurrent relays and, by extension, the working duration of circuit breaker CB, the approach that was suggested made use of an Algorithm. As a result, it is necessary to compute and prescribe a technique of setting the relay in order to cut down on the amount of time that the relays are required to operate and also to prevent their improper functioning. The viability of this method has been shown by simulation results carried out on a genuine radial distribution system, with the findings pertaining to a variety of fault sites and DG sizes.

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NOMENCLATURE

LL - Line to Line

LG - Line to ground,

LLG - Double line to ground

LLL - Triple line

LLLG - Triple line to ground

PT - Potential Transformer

CT - Current Transformer

VT - Voltage Transformer

MV - Medium Voltage

HV - High Voltage

KA - Kilo Ampere

KVAr - Kilo-Volt Ampere Reactive

OCR - Overcurrent Relay

SC - Short Circuit

DR - Differential Relay

TMS - Time multiplier Setting

TD - Time delay

CB - Circuit Breaker

LV - Low Voltage

HRC - High rupturing capacity cartridge fuse

NO - Normally open

NC - Normally Closed

MMF - Magneto motive force

OCMR - Overcurrent Motor Relay

ANSI - American National Standard Institute

IEC - International Electrotechnical Commission

PSM - Plug Setting Multiplier

CHAPTER 1

INTRODUCTION TO DISTRIBUTED SYSTEM

1.1 INTRODUCTION

Because of the growing dependence on electricity at local and commercial bodies, in both developed and developing countries, it is becoming increasingly important for every type of customer to achieve a respectable level of reliability, power quality, and safety measures at the lowest possible price. It is preferable for any electrical power supply system that it should be well constructed and carefully maintained in order to meet a number of faults that may occur within a power system. This is because faults may occur for a variety of reasons. The protective system in this system is the most significant part of it since it separates faulty systems from healthy systems and, as a result, reduces the amount of damage done to the equipment. Lightning discharge, a tree that fell on transmission lines, overloading, and loss of insulation are the primary causes of the failure. After crossing certain key electrical quantities, we are able to measure electrical quantities by using protective relays, which are then followed by a current and voltage transformer. This allows us to make decisions on the operation of circuit breakers.

A power system is not as straightforward as it may first seem; it consists of numerous series and parallel branches, followed by a bus bar, a transformer, a transmission line, reactors, and compensators, amongst many other components. The protective system that has been installed includes HRC fuses, reclosers, an overcurrent relay, an over and under Voltage relay, an under and over frequency relay, distance protection, backup protection, and a great deal of other components. The task of a protection engineer is not limited to just putting together protective devices like these. To a protection engineer, each and every parameter is necessary for the purpose of coordination, and the engineer is responsible for ensuring that an electricity distribution network can fulfil the current requirements for the safety of individual pieces of equipment, the public, and the system as a whole. Automatic is essential in the modern world in order to cut down on the amount of power that is wasted.

1.2 Categorization of electric power distribution based on the feeder connection:

1. Radial Distributed System
2. Ring main distribution system
3. Parallel Feeder Distribution System
4. Interconnected Distribution System

1.2.1 Radial Distributed System:

When the customer is in the vicinity of the subsystem, the electricity board radial distribution system is activated. The numerous feeders in this electrical power distribution system receive electrical power from a substation (also known as a source or producing station) and then distribute that electricity to distributors that are situated in close proximity to the substation. The flow of electricity in this distribution system is unidirectional, meaning that it goes from the source to the load. This distinguishes it from other distribution systems. The Electricity Distribution Board favours this sort of connection due to its ease of use and inexpensive cost; but, when compared to other systems, it does not have particularly high levels of reliability. It is not trustworthy due to the fact that if a malfunction occurs at any portion of the feeder, then the supply may be interrupted or prone to fail, both of which are outcomes that are undesirable from the perspective of the consumer. The electrical radial distribution system is seen in Fig. 1.1; electricity is sent into the system from one end (sometimes referred to as the Source Side), and sinks may be found in a number of different places. In this distribution system, the electricity might be fed to the load end by either one or more transformers operating in parallel.

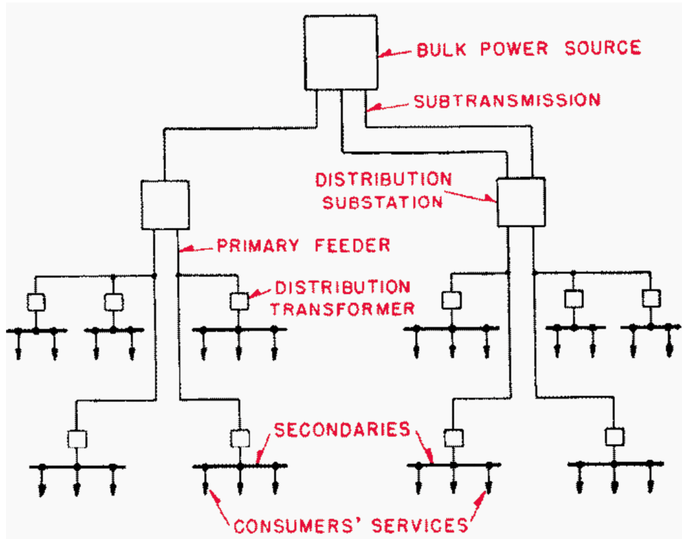


Figure 1.1: Radial Distribution System

1.2.2 Ring Main Distribution System:

In comparison to the radial and parallel feeder systems, it is one of the most dependable systems. It consists of a single source and distributers or load centres, as seen in fig. 1.2. Every distributer and load centre has a connection to two methods of power supply from both ends. This ensures that if one feeder is not functioning properly, power can be obtained from the other feeder, and if line repair is undertaken, energy may be distributed without disrupting any loads. It would seem that this mechanism has generated a feedback loop in the flow of electricity.

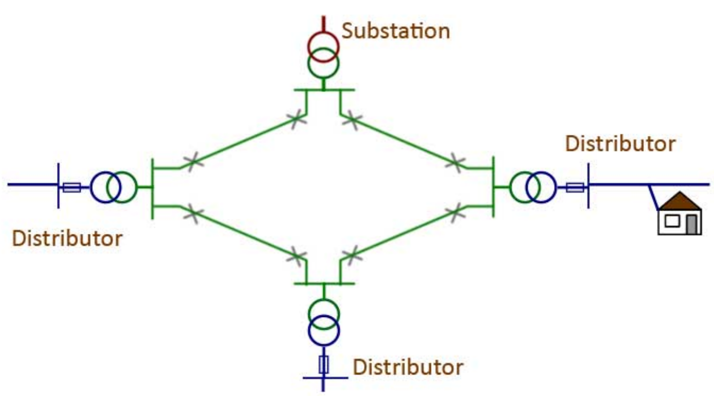


Figure 1.2: Ring main Distribution System

1.2.3 Parallel Feeder Distribution System:

The disadvantage of a radial distribution systems may be mitigated to some extent by using parallel feeder distribution systems; for example, in this context, one might use many parallel distribution systems rather than a single feeder line distribution board. When the cost of a parallel feeder system is compared to the cost of a radial feeder system, the parallel feeder system has a higher cost; however, it enhances system dependability by having many feeders, so even if one feeder stops working, the remaining feeders may still deliver electricity to the load end. When the load is high and dependability is a vital consideration, this system is the one that should be used.

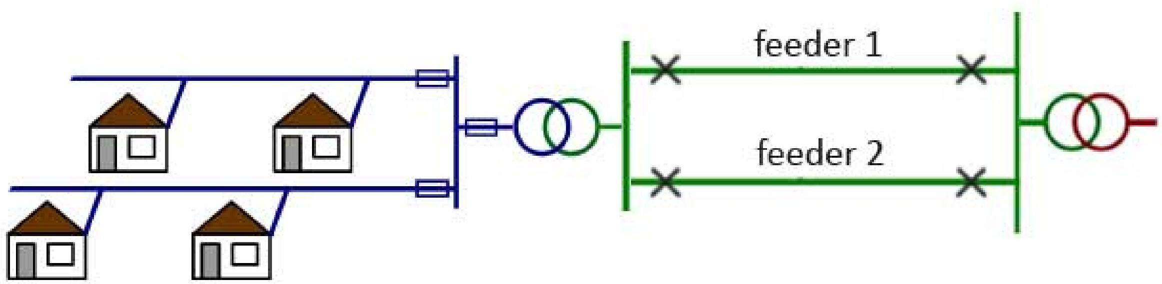


Figure 1.3: Parallel Feeder Distribution System

1.2.4 Interconnected Distribution System:

When a ring main electric distribution feeder is electrified by two or more local generators or utility grids, this becomes an integrated distribution system. This is a unique instance of the ring main feeder system. The system's dependability is satisfactory, but it requires more safeguards and more careful coordination in order to be adequately protected. If one of the generators fails to deliver power, the electricity may be fed from the other producing station if this distribution system is used, which is one of the most significant and significant advantages of choosing this distribution system.

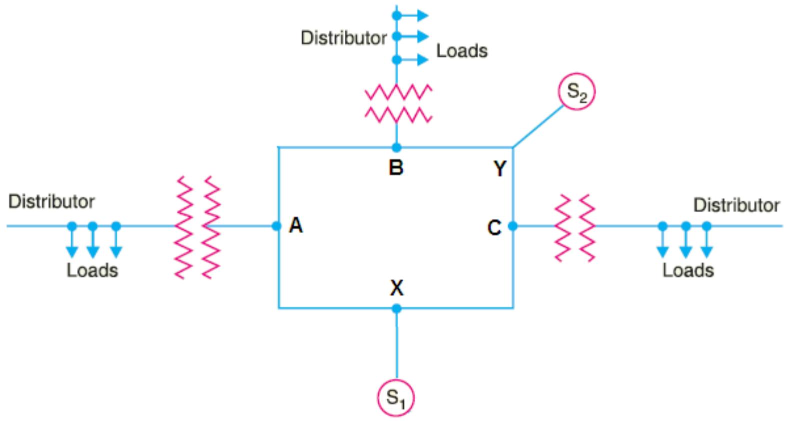


Figure 1.4: Interconnected Distribution System

In this configuration, the power for the feeder ring comes from two or more than two producing stations, which are serviced by substations. The picture depicts a single line diagram of an AC linked system. In this design, the enclosed feeder ring ABCA is being supplied by two producing or substations S1, and S2, which are located at points X and Y, respectively. The feeder is linked to the distributors at points A, B, and C respectively.

1.3 PROTECTING ELECTRICAL POWER SYSTEM

To ensure rapid separation of electrical equipment in order to prevent damage is the primary and most significant goal of preserving the electric power system. This goal was chosen since it is the most fundamental. It ought to be obvious that protective measures kick in whenever the sensing numbers reach an unacceptable level. The following is an explanation of some of the fundamental features of the employment of relays throughout the complete power system.

- Fast Operation
- Economical
- Simplicity and Clarity
- Selectivity
- Reliability

1.4 ELECTRICAL PROTECTION EQUIPMENTS

For the safety of a power system, certain devices must detect the operating quantity, break the circuit if violations occur (Circuit Breaker), and close if the system becomes healthy. Below are the equipments:

1.4.1 Overcurrent Relays:

It is a switch that is electrically controlled, and it generates a choice, such as open or shut, based on the logic that is sent into it. It senses the relay input, which includes current and voltage. There are a number of different kinds of relays, including electromagnetic, solid state, and microprocessor (Numerical/Digital-based) relays. These relays assess voltage, current, phase, and frequency in order to identify uncertainty in electrical lines and equipment. Specifically, these relays are developed to detect uncertainty in electrical lines and equipment. Samuel Thomson developed the electromagnetic relay in 1835 for use in the electric telegraph. These relays were used in long-distance telegraph circuits as amplifiers. Electromagnetic relays were quite popular up until 1960, which is before the advent of the static relay. When manufacturing electromagnetic relays, the producer will employ several coils so that they may cater to a number of different relay applications. In the 1960s, solid state relays were first introduced, and their popularity continued until 1969. This relay makes use of several electronic components such as transistors, resistors, capacitors, and inductors. Relays that are based on microprocessors employ ICs and the microprocessors. The user of these relays has the ability to adjust the curve, settings, and time dial, as well as choosing from a wide variety of relay functions all contained inside a single device. Because of their preciseness, precision, ability to self-medicate in the event of a mistake, and speed of operation, they are very recommended for use in high-power applications and expensive equipment.

It is not sufficient to regulate the circuitry by using both relays and circuit breakers; in addition, it requires certain additional external equipment, such as CT's and PT's. These two things provide input to relays, which allow them to perceive both the voltage and the current (5A) (110V). The ABB digital multifunction relay is seen in fig 1.5. At each feeder, transformer (both the HT and LT side), transmission line (at both ends employs differential overcurrent and overcurrent), and generator, relays are provided to protect against overcurrent and differential overcurrent. The security of expensive and very important pieces of equipment often involves making use of both main and secondary layers of defence, known respectively as backup and primary protection.

Figure 1.5: ABB REU615 Digital Realy

1.4.2 Circuit Breaker:

It is a switch in the electrical system that is sent into motion when it receives a signal to do so from the relay. When the relay signal is activated, the breaker will either open or shut using a secondary means such as a motor or manually; to put it another way, this switch is controlled by a secondary means. This switch is often activated if there is uncertainty present in the line or part that has been chosen. The signal from the relay will cause it to perform its primary job, which is to severe the connection in the line. Despite the fact that these devices are utilised in a variety of settings, including homes, colleges' industries, and even distribution and power generation facilities, their dimensions and shapes vary. It comes in low voltage (1000V), middle voltage (72KV), and high voltage (all of which are accessible) (above 72KV). As the voltage increases, its form expands, it makes more use of insulating oil and insulating gas, and it makes the mechanism easier to operate. Its capacity to supply electricity is far higher than its actual consumption.

Every circuit breaker has the same basic function, which is either NO or NC. However, each model has its own unique set of features, which might include delay time, current capacity, voltage, arc flash, open and close resistance, and leakage current. Fig. 1.6 shows an ABB air circuit breaker operating at 11 kilovolts of phase voltage.

Figure 1.6: ABB circuit breaker

1.4.3 Reclosers:

This device has the capability to detect both phase and line overcurrent conditions, and it is used to automatically reclose and energise the circuit breaker when a fault has been detected. After the recloser has finished operating, the circuit breaker will once again trip for a certain amount of time if the current is still too high. After that, it will check the current once again. Following a predetermined recloser period, this recloser will eventually permanently isolate the defective area until it is reset. The nature of around 80–95 percent of faults is transient, but only 5 percent of faults are permanent and, as a result, need particular care. It can open and shut the circuit breaker for a total of three times thanks to the way it was created.

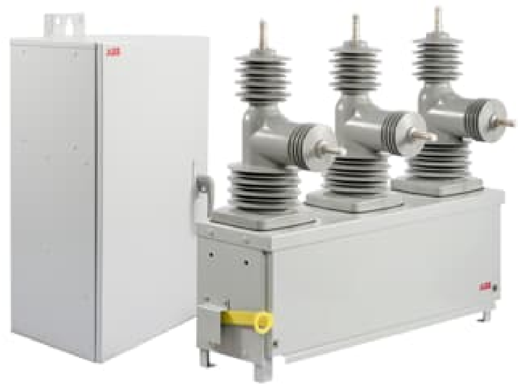


Figure 1.7: Reclosers

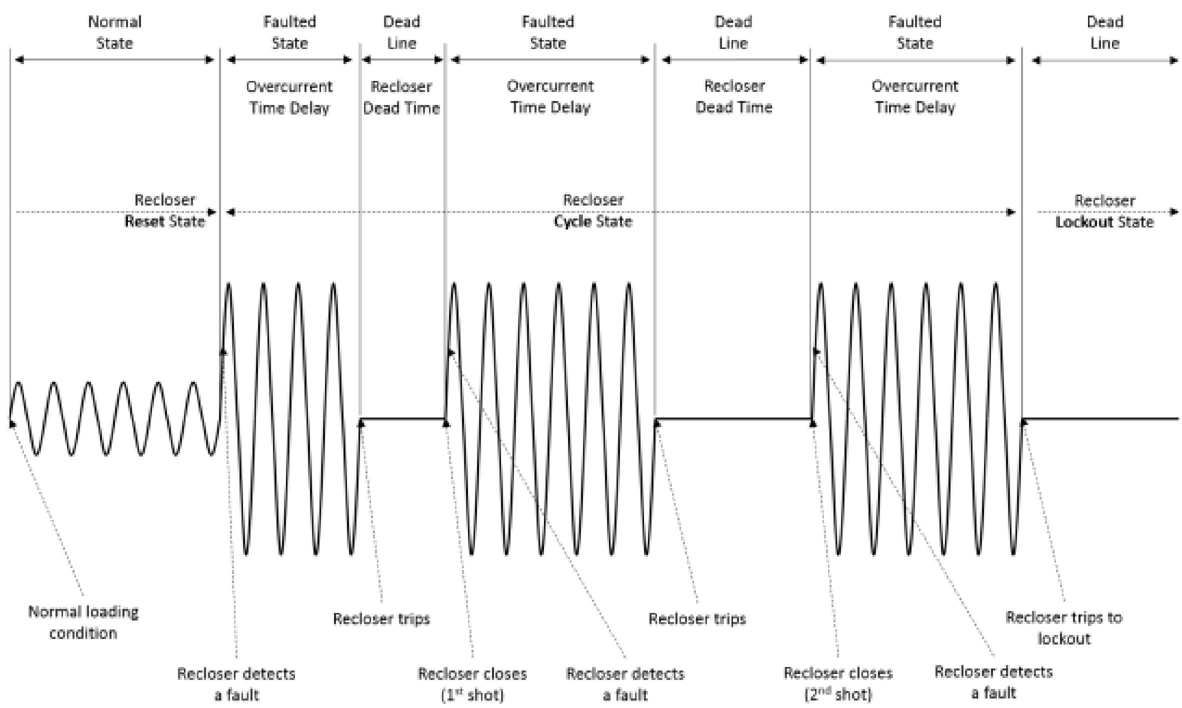


Figure 1.8: Reclosing Operation

1.4.4 Fuses:

In comparison to other types of interrupting devices used for overload and short circuit protection, fuses are the most straightforward. Up to 33 kilovolts may be applied to it

(Medium voltage). The modern High Rupturing Capacity Cartridge Fuses, often known as HRC, have qualities that are both dependable and accurate. It is also referred to as ADS, which stands for "Automatic Disconnection of Supply," since it automatically cuts power to the circuit if there is an excessive amount of current flowing through it.

1.4.4.1 Types of fuses:

A. **Cartridge Type:** The elements of these sorts of fuses are completely encased in a container and have end-to-end contact on both sides.

Figure 1.9: Cartridge type fuse

B. **High Rupturing Capacity Cartridge Fuse:** A cartridge fuse link has a high breaking capability that is more than the prescribed values (i.e. above 16KA).

Figure 1.10: HRC NH type fuse

C. **Rewirable Type Fuse:** After a fuse has blown, it is possible to take it out, replace it, and then rewire it. Fuse types like these may be found inside homes.

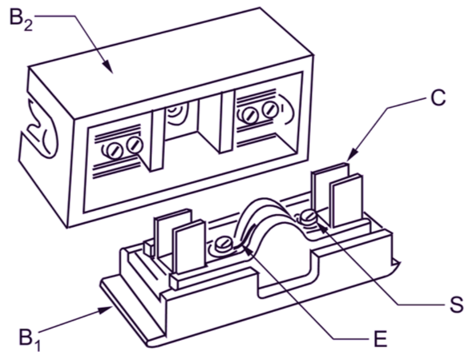


Figure 1.11: Rewirable Fuse (Kit Kat Fuse) with base units

D. **Striker Fuses:** It is a mechanism that integrates fuses and mechanical devices, and its action frees the striker by applying pressure and moving it. The striker's primary function is that of a signalling the device.

Figure 1.12: H.R.C.H.T. Fuse with Striker Pin

E. **Resettable Fuses:**

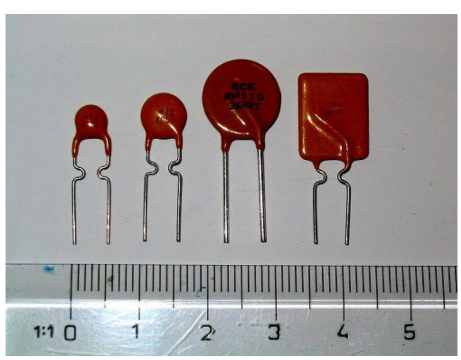


Figure 1.13: Resettable Fuses

A device known as a resettable fuse is one that may be used several times before needing to be replaced. They disconnect the circuit when anything that causes an excessive current level happens, and then they reconnect it after a certain amount of time has passed. A polymeric positive temperature coefficient device, also known as a resettable fuse, poly-switch, or poly-fuse, is a passive electronic component that is used to protect electronic circuits from short current faults. Other names for this component include polymeric positive temperature coefficient device (PPTC).

In situations where manually changing fuses is difficult or almost impossible, such as in a nuclear or aerospace system, the use of resettable fuses is a solution that allows for the problem to be circumvented.

CHAPTER 2

LITERATURE REVIEW

In this study work, a significant attention is placed on current setting, current set point, curve characteristics, time dial, and other relay qualities that are vital for relay selection. These elements include curve characteristics, time dial, and others. Additionally, ETAP is used to verify coordination in accordance with IEEE and ANSI standards, and curves are sometimes changed. Acting time may be altered by adjusting the time dial (which would result in time grading), the present setting (which would result in current grading), or the curve characteristics. The proposed model is validated first by a load flow analysis, and then voltages at each node are kept stable through the careful selection of the appropriate admittance of the power system's components. The NEC and ANSI standards have validated each and every one of these components. Certain settings are chosen for you automatically, while others need manual input from the user. The guidelines established by ETAP must not be broken by either the voltage or the current. If any value is found to be in violation of these guidelines, the report will emphasise it in a shade of dark red. The following is a selection of the literature review that was based on the load flow analysis and overcurrent coordination.

After doing a load flow analysis, the Star view is proposed as an option for the protection of the power system. Relays are chosen in accordance with the application requirements, which means that for each and every element, ETAP has generated a library link. Users may then access these libraries from the respective locations. Users choose the relay setting they want to employ based on a correlation to the value that is determined based on the amount that is being acquired. Various applications call for the selection of a variety of qualities, all of which will be detailed in the subsequent chapter of the suggested model. Any faults could be imposed by the user on the feeders, lines, and equipments with their own intended purposes, and the operating sequence could be viewed. When these strategies for coordination are altered, there is a possibility that coordination may grow better.

2.1 MATHEMATICAL MODELING FOR FAULT SETTINGS

2.1.1 PLUG SETTING MULTIPLIER (PSM) AND TIME SETTING MULTIPLIER (TSM):

Both the PSM and the Time Setting Multiplier are crucial components of electromechanical relays. These concepts or parameters are not so employed in Numerical Relays but they have been theoretically used and included in Numerical Relays also but the technique of their implementation is rather dissimilar from those of the Electromechanical Relays. In this article we will concentrate on the idea and execution of PSM and TSM for Electro - mechanical Relays.

We are aware how an electromechanical relay consists of a coil, and that this coil, when powered, causes the relay to function and alter its contact state. However, there must be a minimum current that, when it passes through the relay coil, generates sufficient magnetic force to pull a lever and change the contact. There is a flapper-like component that is connected to the lever. This component works in conjunction with the lever. The contacts, in their turn, are coupled to the lever. Therefore, in order to provide sufficient magnetic pull to draw the flapper and lever in order to run the Relay, a certain current must first pass through the relay coil. Only then will it produce this amount of pull. The diagram that follows provides an easy-to-understand illustration of a relay, illustrating both its construction and its function.

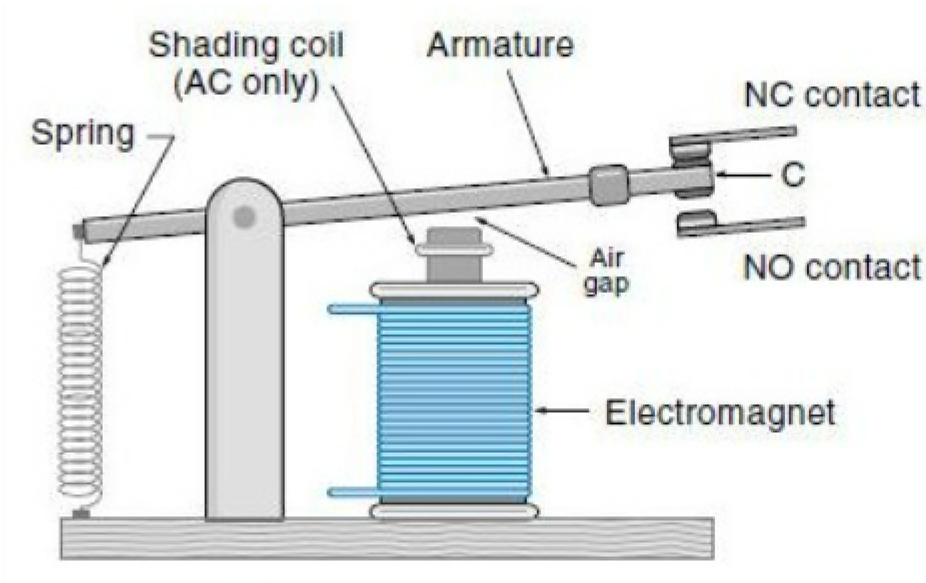


Figure 2.1: Electro-magnetic relay

The term "Pick-up Current" refers to the minimal current that must be present in the relay coil for the device to begin operating. If there is less current flowing through the relay coil than the pick-up value, then the relay will not activate. On the other hand, the Relay will work if the current that is flowing through the Relay coil is greater than the current that is flowing through the Pick-up. In order to determine whether or not relays are in good condition, an industry would often conduct a test known as the Relay Pick-up and Drop-off Test.

2.1.1.1 Current Setting of Electromechanical Relays:

Adjusting the pick-up value of the relay is the only thing involved in changing its current setting. Let's say we're working with a CT that has a ratio of 1000/1 A, and we need to make sure the pick-up current is set at 1.2 A. Then, all that's left to do is turn the plug that's given on the relay coil to 1.2, which is equivalent to 120 percent.

$$Pickup\ current\ =\ Plug\ Position\ *\ Rated\ CT\ Secondary\ Current$$

2.1.1.2 Plug Setting Multiplier (PSM):

The Plug Setting Multiplier, or PSM, is calculated as the proportion of the relay's pick-up current to the fault current.

$$PSM = \frac{Fault\ Current}{Pick\text{−}up\ Current}$$

$$PSM = \frac{Fault\ Current}{(Plug\ Position * Rated\ CT\ Secondary\ Current)}$$

Suppose we are using CT of 100/1 A, a fault current of, say 5000 A is flowing through the network protected by the relay.

$$Fault\ Current\ in\ CT\ secondary = \frac{(5000*1)}{100} = 50\ A$$

Assume that Current Setting or the position of plug is at 5 then

$$PSM = \frac{50}{(1*5)} = 10$$

2.1.1.3 Time Setting Multiplier (TSM):

In most cases, a control is included with a relay, allowing the user to alter the amount of time the relay is active. This setting is referred to as the Time Setting Multiplier, or TSM for short. A Time Setting Dial is often supplied, and it is measured from 0 to 1 second, with a step size of 0.05 seconds.

Let's say the plug is at 5, and the TSM is at 0.5 seconds. We have to refer to the Graph in between Operation and PSM in order to determine the real amount of time that the relay has been operating. This graph is often shown on the actual cover of the Relay device. Consider the following graph, which depicts the relationship amongst Operating Time and PSM:

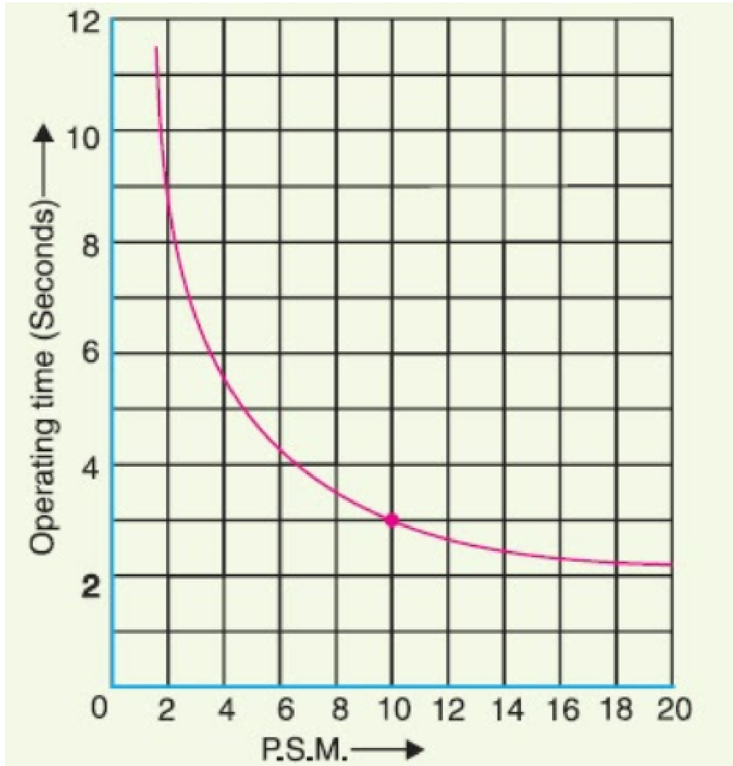


Figure 2.2: Graph between operating time and PSM

For our case, PSM = 10 (as calculated above) and TSM = 0.5 s.
From the Graph, the time of operation of Relay for PSM = 10 is 3 s.
Therefore,

$$Actual\ Time\ of\ Operation\ of\ Relay\ =\ 3s\ *\ TSM$$

$$Actual\ Time\ of\ Operation\ of\ Relay\ =\ 3\ *\ 0.5\,s\ =\ 1.5\,s$$

Therefore, we can conclude that the real time of operations of Relay is directly proportional to the time acquired from the Operating time & PSM Graph multiplied by TSM. This allows us to state that the actual time of operations of Relay is equal to the time.

2.2 Time Setting of Instruments(IEEE, IEC)

The equations for the curves that were obtained from the British Standard 142, the Texas Instruments standards, and the ANSI standards are given below in tables 2.1, 2.2, and 2.3.

When TMS, A, B, and C are each given different values, it is possible to generate a wide variety of curves.

Table 2.1: Curve calculated from BS 142

Relay Characteristics	**IEC equation**
Standard Inverse	$T = TMS * \frac{0.14}{(I_R^{0.2} - 1)}$
Very Inverse	$T = TMS * \frac{13.5}{(I_R - 1)}$
Extremely Inverse(EI)	$T = TMS * \frac{80}{(I_R^{0.2} - 1)}$
Long time Inverse	$T = TMS * \frac{120}{(I_R - 1)}$

Table 2.2: Curve calculated from ANSI standards

Relay Characteristics	**IEEE Equation**
IEEE Moderately Inverse	$T = \frac{TD}{7} [\{\frac{.0155}{(I_r^{02} - 1)} +.114\}]$
IEEE Very Inverse	$T = \frac{TD}{7} [\{\frac{19.61}{(I_r^{2} - 1)} +.491\}]$
Extremely Inverse	$T = \frac{TD}{7} [\{\frac{28.2}{(I_r^{2} - 1)} +.1217\}]$
US CO_8 Inverse	$T = \frac{TD}{7} [\{\frac{5.95}{(I_r^{2} - 1)} +.18\}]$
US CO_2 Sort time Inverse	$T = \frac{TD}{7} [\{\frac{.02394}{(I_r^{02} - 1)} +.01694\}]$

Where, TD – time delay

I_r = Ratio of fault current.

TMS=Time multiplier setting

When it comes to understanding load behaviour, these many distinct kinds of curves are put to use in a variety of contexts. These curves may be modified and altered in several of the relays in the system. Therefore, there is a good possibility that we will achieve precision in our cooperation.

2.2.1 Texas Instruments timing:

There are a number of rules, like ANSI C37.90, IEC255-4, IEC60255-3, and IAC, among others, that limit the response time of the protective relay to the fault situations that may occur at any position in the radial feeder scheme. The relay delay time graph used by Texas Instruments is derived using the company's own proprietary methodology. Typically, these response characteristics are shown as curves on the output graphs that are referred to as Inverse Definite Minimum Time Lag (IDMTL). IDMTL is a reaction period measure developed by NPR.

$$T_{res} = DMF * \frac{A}{(\frac{I_R}{I_{set}})^B - C}$$

Where, T_{res} = Response time

DMF = Delay Multiplier Factor

I_r = Read Current

I_{set} = set current value

Table 2.3: Texas Instruments timing

Delay Type	A	B	C
LTI Long-time inverse	.086	.185	.02
LTVI Long-time very inverse	28.55	.712	2
LTEI Long-time extremely inverse	64.07	.250	2
MI Moderately inverse	.0515	.1140	.02
VI Very inverse	19.61	.491	2
EI Extremely inverse	28.2	.1217	2
STI Short-time inverse	.16758	.11858	.02

CHAPTER 3

RADIAL FEEDER PROTECTION

3.1 Protection of the Radial feeder with the Use of an Overcurrent Relay:

In electrical power system, overcurrent relays are quite widespread and serve the purpose of protecting radial feeders and other feeder systems from the effects of excessive current in feeders. Installing circuit breakers and relays at several places closer to the load, as well as the feeder and the transmission line, is one way to ensure that radial feeders are adequately protected. These overcurrent relays are connected to current transformers (CTs) at the infeed, load, and feeder locations, respectively. Circuit breakers are provided at the infeed of each feeder segment, as shown in fig. 3.1. This is done so that the process may be simplified. The majority of the statistics in this exercise have been streamlined. At the substation buses A, B, and C, the power transformer as well as the fuses have been removed.

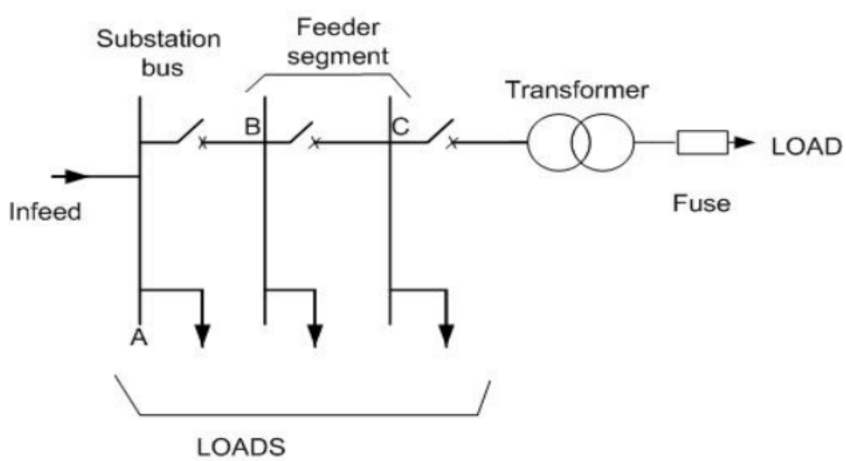


Figure 3.1: A radial feeder with overcurrent protection installed at feeders A, B, and C, shown as a single-line diagram

Use of protective components along the feeder line is required in a radial feeder protection system to use the appropriate and selective protection that complies to the load. It should be linked in such a way that under abnormal situations, the faulty portion is forced to be disconnected from the healthy part, which in turn minimises the number of loads that are lost. It is never acceptable that for a huge and high load feeder some protection devices are built or that a single relay is put in above fig. 3.1. This is due to the fact that if a fault occurs, the whole feeder is taken out of operation, even if the problem is on the fuse side.

In order to achieve correct selective operation of the circuit breaker and relays, it is necessary to have appropriate and coordinated timing for the operation of the relays and the circuit breaker delay. This process is known as relay coordinating, and it is sometimes referred to as relay grading. In a nutshell, it is proposed that in the event of a fault situation, the circuit breaker that is physically located closest to the fault should be tripped using appropriate characteristics such as IDMT, inverse, very inverse, definite, and highly inverse characteristics (some are given in appendix III). For the problem shown in the image below, which is closer to the transformer, the first circuit breaker C must be acted upon, followed by the circuit breaker B, and lastly the circuit breaker for the feeder must be acted upon, although with a certain amount of delay and characteristic. The delay to trip is selected in such a way that it must be in sequence to bring down the minimal loss of load. Additionally, the delay to trip cannot be uncoordinated in any circumstance or have a defect at any point.

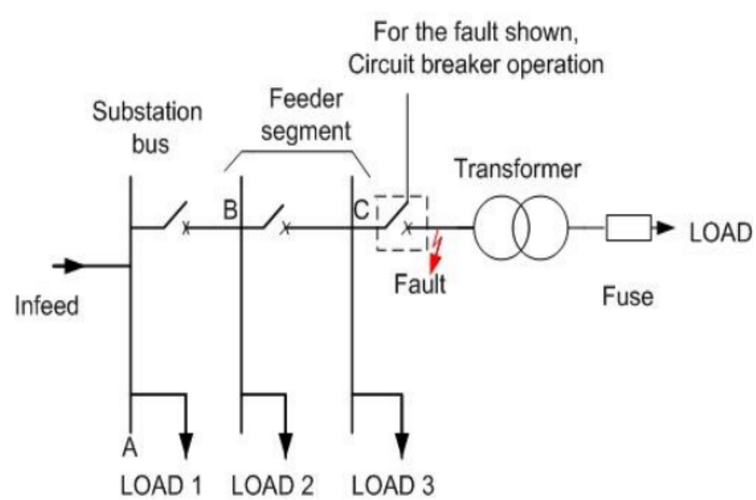


Figure 3.2: Operations that take place in the event of a malfunction closer to the feeder relay-C

3.2 Coordination Discrimination in Current:

As the name implies, the primary sensing quantity of an overcurrent relay is line current, which is compared to a predetermined stored value with the appropriate characteristic. Current coordination and grading are other terms for current coordination. Current grading is always based on the notion that as the relay to fault distance increases, the quantity of fault current reduces, or as the impedance increases. Current coordination is always feasible if various feeder segments have enough resistance to allow current fault values to vary throughout the radial feeder; otherwise, it is illogical and irresponsible. The current value at the furthest end of the feeder or transmission line is determined by the Revy setting. This is to detect any potential current flow inside the protected region. Relays with inverse characteristics trip quickly when the fault is close by and late when the fault is far away. In the event of a simultaneous relay trip, regardless of how distant the fault is located. In light of the above fig's current setting, the current setting near to the fault should be lower than the current value at the infeed. As you go closer to the end of the radial line, the current setting should decrease.

Current setting of feeder relay A > Current setting of feeder relay B > Current setting of feeder relay C

The following is a summary of some of the disadvantages of using discrimination in radial feeder systems based on the existing coordination:

- When the infeed of a radial feeder protection system is comprised of more than one transformer, and if one of those transformers is removed as a result of uncertainty, a defect, or servicing, then the quantity of the short circuit rating will drop. For example, if one of two transformers with the same rating is removed, the short circuit rating of the infeed will drop all the way down to half its previous level.
- Fault somewhere at end of the feeder section, also known as the beginning of a new section, has to be adequately distinguished, despite the fact that there could or might not be more than one relay placed. These two places may be separated by a very short distance, which may be comparable to little more than the distance travelled via a substation bus and circuit breaker. This was shown in fig. 3.3, and it is possible that the distance between them is quite small. A discriminated finding might be made using the same method as the

percentage rule. It is necessary to have the relay setting in the instantaneous relay as correct as possible.

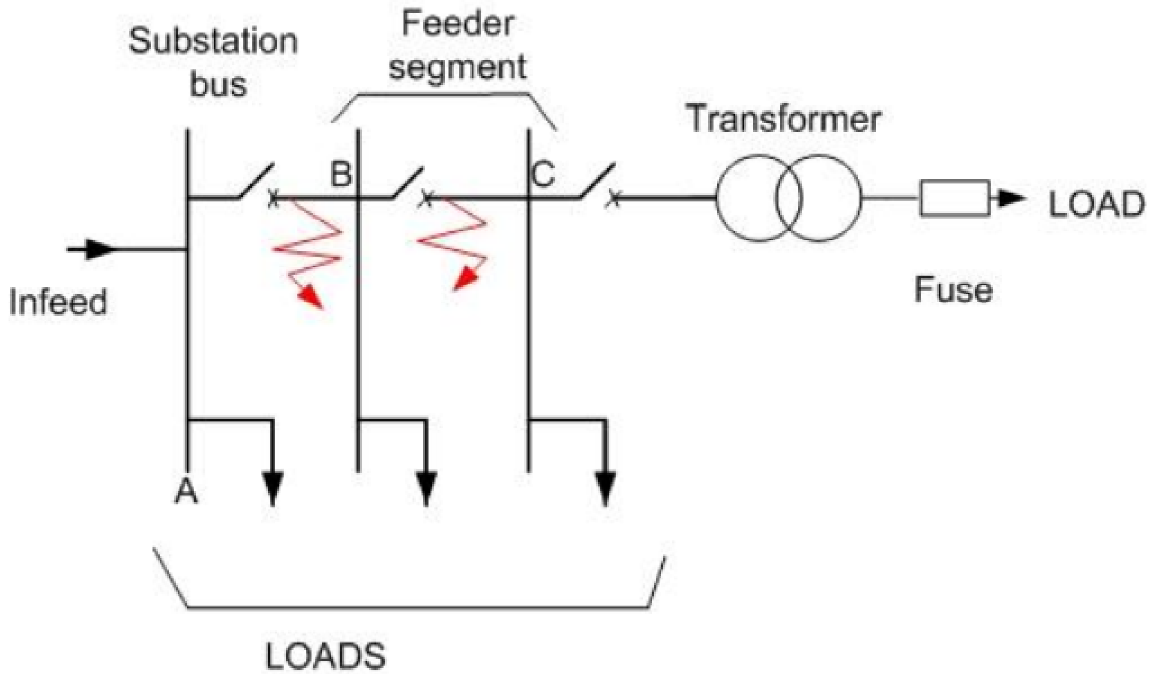


Figure 3.3: Discrimination of faults that are too close together

3.3 Coordination discrimination on Time:

The practise of assigning points depending on how much time has elapsed between events in a relay is also known as time coordination or time grading. It is feasible to do this by building radial feeder relays that are located the furthest away from the infeed feeder. These relays need to be run in the lowest time possible, and as they move closer to the infeed feeder, the operating time should rise. The relay that is physically closest to the problem should trip more quickly than other relays. While moving away from the problem, the relay should trip with a time delay in comparison to the relay that is closest to the problem. The time-current characteristics of the relay determine how these timing features are determined. The difference between two relays that are immediately nearby is called the grading margin.

3.3.1 Time Setting:

The timer setting on the relay should be adjusted such that it counts down from the farthest point away from the infeed to the nearest point. In the radial feeder protection system, the grading margin is what is utilised to decide the setting of just about every relay. The compression of two curves along the vertical axis provides a clear indication of the grading margin, as seen in the fig. 3.4.

3.3.2 Current Setting:

The curent-setting of each and every overcurrent relay is determined by the current flowing through the main or secondary windings of the current transformer and is multiplied by the turn's ratio. The current setting is adjusted such that it is higher than the line's maximum load current and above the line's minimum fault level current, and this adjustment is made regardless of where on the line the relay is located. This is to ensure that the relay does not activate under normal circumstances or under high load situations (within limits).

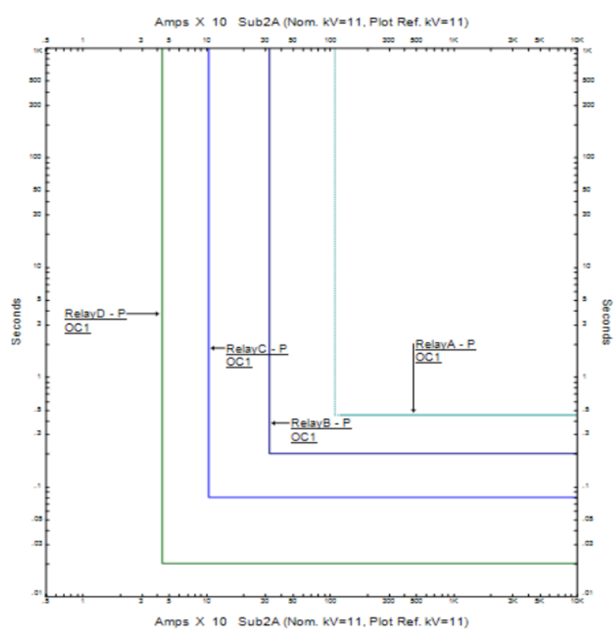


Figure 3.4: TCC of definite time overcurrent relay

The timing and current settings of the four relays A, B, C, and D are shown in fig. 3.4, which can be found above. The time dial is located all the way to the right of fig. 3.4, and the current setting may be seen along the horizontal axis. The most significant downside of this method is that if a fault occurs at a location that is closer to the relay, it will continue to function at the same time as a failure at a location that is farther away on another feeder. Each industry that produces relays utilises a separate set of equations, each of which has a unique set of curve characteristics. Additionally, each industry's curve is unique in comparison to the curves produced by other industries, which are often parallel. Relays may now be purchased with programmable clock dials and a variety of programmable curve features.

3.4 Software-based approaches for the setting of overcurrent relays:

It is relatively easy to change the relay setting for an electromechanical relay type, but the setting for a numerical or microcontroller-based relay is somewhat different; using software technology, the user may alter the curve current setting, dial time, and a variety of other settings and functions. Electromechanical relays provide strong coordination, but they are not useful for complicated systems; in order to make them useful, the user may need to utilise a large number of coils (torque) in order to get the desired level of coordination. This becomes cumbersome; however, using software technology might make the system simple to use and install; also, these relays include a number of relays; therefore, this is a benefit in comparison to electrometrical system. It makes little difference whether topologies are utilised since software can be modified by utilising its burner; this suggests that a single relay would be adequate. With the help of this particular kind of relay, both current and voltage may be monitored and saved.

There are three stages involved in the setting up of the numerical relay:

1. Determine the location of the fault, determine the fault and over current, and collect the current needed to set up the relays.
2. Determine which numerical relays need to be coordinated, select which one should act

first, and which one should act last or for backup protection, and look for those numerical relays. The setting need to be correct in line with the requirements.

3. Compare the setting with the standards or use a simulator to evaluate whether or not the system is synchronised; if it isn't, the method should be redone with a larger margin, or a different relay should be attempted.

   In the process of carrying out the downloading of software, in addition to taking into consideration the present setting, it is necessary to take into account the time dial; the user may change the curve in order to get the appropriate level of coordination.

CHAPTER 4

PROTECTION SCHEMES

INTRODUCTION:

In an electric power system, it can be difficult to determine the precise protection schemes that need to be accepted in order to protect a distribution system. On the other hand, there are a huge number of protection schemes that can be utilised in order to safeguard probably each section and every device. When choosing a protection plan, there are a few factors that need to be considered. These include the fact that the plan must be cost-effective, that it must provide a substantial level of protection, that it must take into account the available response time, and, most importantly, that it must be intelligent. The use of expensive equipment is not only a poor plan, but it is also not a method that can be considered economically sound. 15–20 percent of the total cost of an electrical power system is allocated just to the system's protection.

4.1 GENERATOR PROTECTION:

4.1.1 For Small Generator up to 5MVA:

Since it is the primary source, also known as the "Generator," the security of this component is of the utmost significance to ensure its continued operation. A technical characteristic such as power, voltage, power factor, and earthing arrangements plays an essential part in ensuring the dependability of the protection provided to the system, the client, and the machines. Since the generator is the most expensive and crucial component of an electrical system, ensuring its safety is of the utmost importance. There is a sophisticated protection system in place, which works to keep the generator and load both secure even under the most adverse of circumstances. The security of the generator itself accounts for around two to four percent of the total cost; such a significant expense need to be justified for every modest generator. As may be seen in the following image 22, more than 15 different protection mechanisms have been fitted only for the purpose of protecting the generator. It is essential to put in place the most effective and cost-effective protection system. For smaller generators, generally up to 5MVA, less protection is required, like 87, 86, 51G, 46, 51V, 32, 40, 49, etc.; nonetheless, it is still important for the scheme to contain the following components:

- Protection against internal faults—sometimes the windings are short circuited, and as a result, sparking may cause the system to overheat or create an explosion.
- Small generators too requires Back-up protection in the event of external problems, such as at its terminal; hence, the need of overcurrent relays with voltages constraint
- When a problem occurs at the input of the generator, then the power flows in the other direction; thus, it requires protection against reverse power.
- Protection against earth faults via the use of an overcurrent relay Protection against overloads through the use of thermal relays

4.1.2 Large generators:

For large generators, such as those with a capacity of over 5MVA, the protection, which is depicted in Fig. 4.1, should typically include a wide variety of safety features. Some examples of these features include internal faults, reverse power, under/over voltage, over current, frequencies, phase sequence, and out of step.

Some of these safeguards are detailed in table 5.1, which may be seen below.

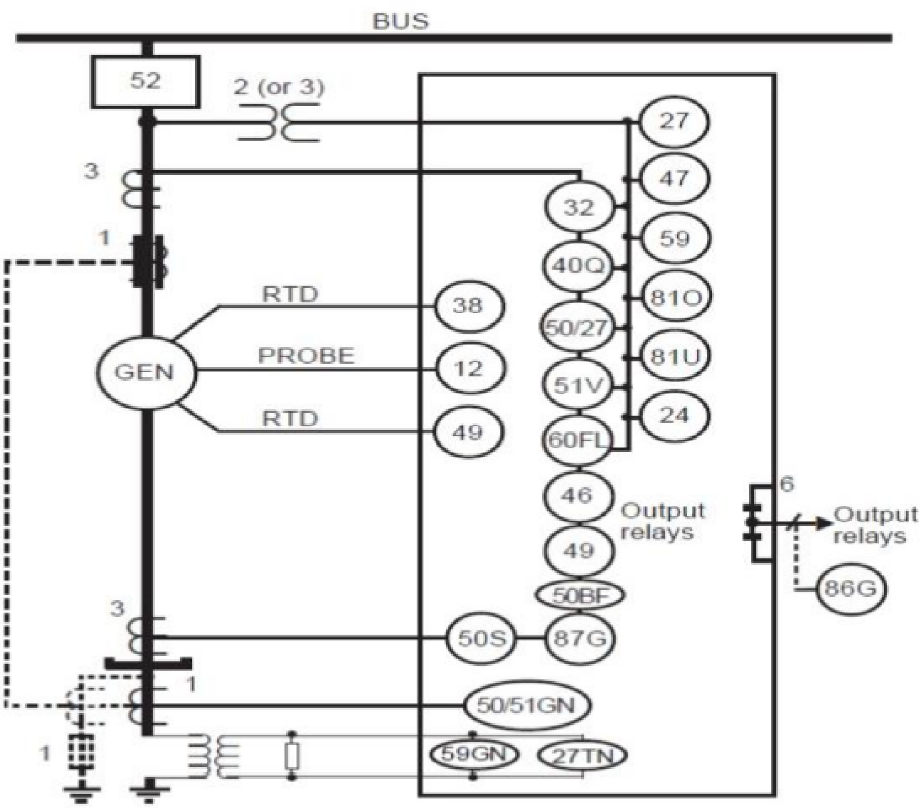


Figure 4.1: Layout of Generator Protection system

Table 4.1: List of Generator Protection device

S. No.	Protection device Number	Device Name
1.	12	Over speed relay
2.	24	Over excitation relay Volt/Hz
3.	27	Under Voltage relay
4.	50/27	Inadvertent generator energization relay
5.	32	Reverse power for anti-motoring relay
6.	38	Bearing over temperature relay

7.	39	Bearing vibration relay
8.	40Q	Loss of field relay
9.	46	Negative sequence overcurrent relay
10.	47	Voltage phase reversal relay
11.	49	Stator thermal relay
12.	50BF	Breaker failure detection relay
13.	50S	Instantaneous overcurrent relay
14.	50/51GN	Instantaneous or definite time overcurrent relay
15.	51V	Voltage restrained phase overcurrent relay
16.	59	Over voltage relay
17.	59GN	Stator ground relay
18.	60FL	VT fuse failure detection relay
19.	81	Over and under frequency relay
20.	87G	Phase differential relay
21.	86G	Lock out auxiliary relay

4.2 Relay Coordination Modeling on SCADA:

The term "relay co-ordination" refers to the process of tripping a protective relay in an electrical power system in a certain sequence or order. The issue of relay coordination presents significant challenges for relay engineers. Isolating the malfunctioning component while minimising the amount of work done by the relays and circuit breakers calls for careful coordination of the relays.

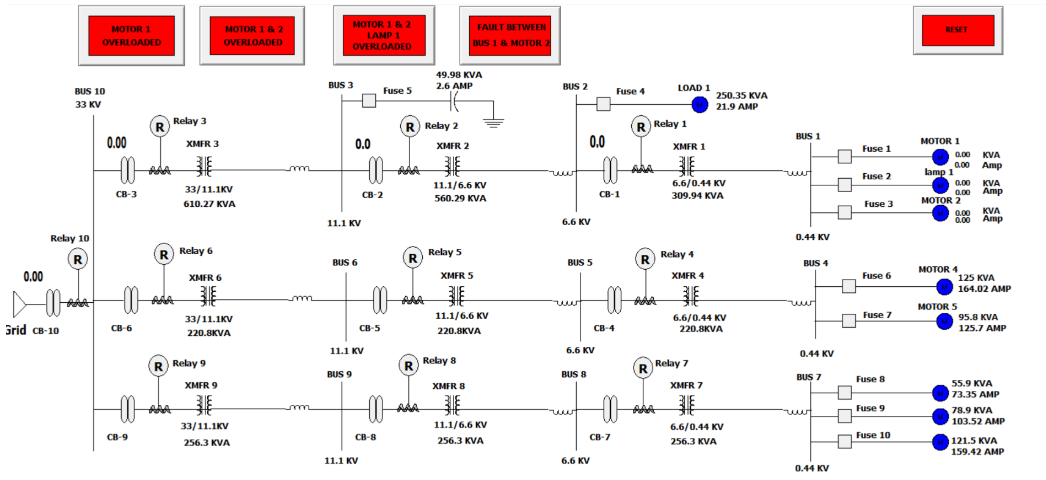


Figure 4.2: Radial Feeder Distribution System

Case 1: When Mtr1 is overloaded:

When mtr1 is overloaded, whether it is due to a fault or because the current is extremely high when starting an induction motor, which causes overloading, fuse1 trips instantly. Relay 1, Relay 2, Relay 3, and Relay 10 are utilised as backup relays. These relays each had their unique trip time, which was used to characterise them. This time was determined by the fault current measured at the relay's own CT secondary.

As can be seen from the fig. 4.3, if the overload does not clear itself within the trip time of Relay 1, then CB-1 will function as a backup protection following Fuse 1, and then CB-2 will function after that, and so on.

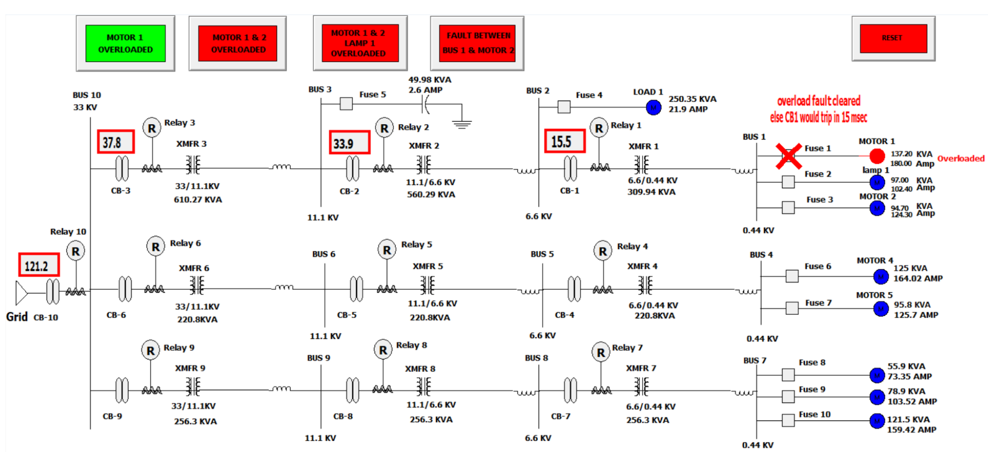


Figure 4.3: Mtr1 overloaded

Case 2: When Mtr1 and Mtr2 are overloaded simultaneously:

When mtr1 and mtr2 are overloaded simultaneously, whether it is due to a fault or because the current is extremely high when starting an induction motor, which causes overloading, fuse1 and fuse3 trips instantly. Relay 1, Relay 2, Relay 3, and Relay 10 are utilised as backup relays. These relays each had their unique trip time, which was used to characterise them. This time was determined by the fault current measured at the relay's own CT secondary. As the overload current increases, the time it takes for each CB to trip down gradually reduces.

As can be seen from the fig. 4.4, if the overload does not clear itself within the trip time of Relay 1, then CB-1 will function as a backup protection following Fuse 1 and Fuse 3, and then CB-2 will function after that, and so on.

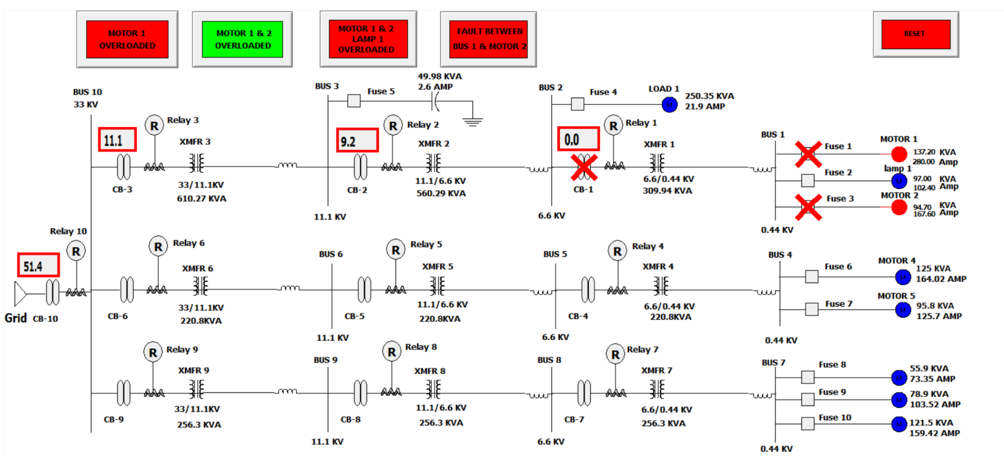


Figure 4.4: Mtr1 and Mtr2 are overloaded simultaneously

Case 3: When Mtr1, Mtr2 and Lamp1 are overloaded simultaneously:

When mtr1, mtr2 and Lamp1 are overloaded simultaneously, fuse1 and fuse2 and fuse3 trips instantly. Relay 1, Relay 2, Relay 3, and Relay 10 are utilised as backup relays. These relays each had their unique trip time, which was used to characterise them. This time was determined by the fault current measured at the relay's own CT secondary. As the overload current increases more and more, the time it takes for each CB to trip down gradually reduces. As can be seen from the fig. 4.5, if the overload does not clear itself within the trip time of Relay 1, then CB-1 will function as a backup protection following Fuse 1 and Fuse

2 and Fuse 3, and then CB-2 will function after that, and so on.

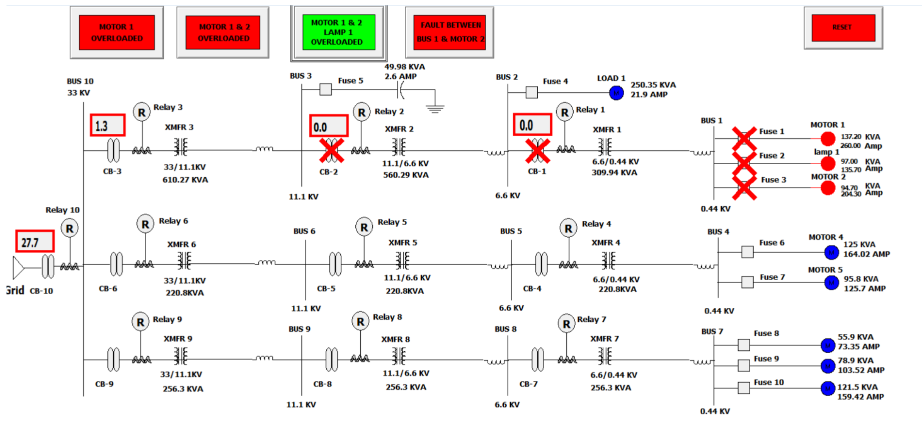


Figure 4.5: Mtr1, Mtr2 and Lamp1 are overloaded simultaneously

Case 4: When there is a short circuit between Bus1 and Motor 2:

When fault occurs between Bus 1 and Mtr2 than fuse3 trips instantly. Relay 1, Relay 2, Relay 3, and Relay 10 are utilised as backup relays. These relays each had their unique trip time, which was used to characterise them. This time was determined by the fault current measured at the relay's own CT secondary. As the fault current is very high, the time it takes for each CB to trip down gradually reduces. As can be seen from the fig. 4.6, if fault does not clear within the trip time of Relay 1, then CB-1 will function as a backup protection following Fuse 3, and then CB-2 will function after that, and so on.

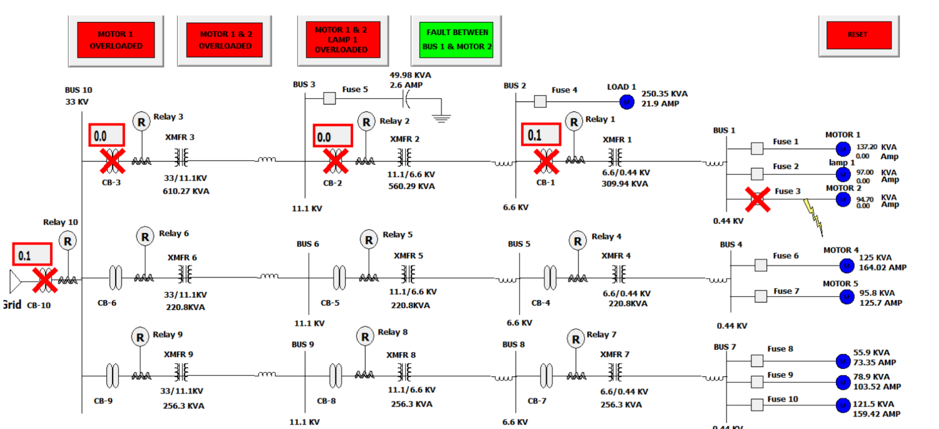


Figure 4.6: short circuit between Bus1 and Motor 2

CHAPTER 5

Suggested Model for Research

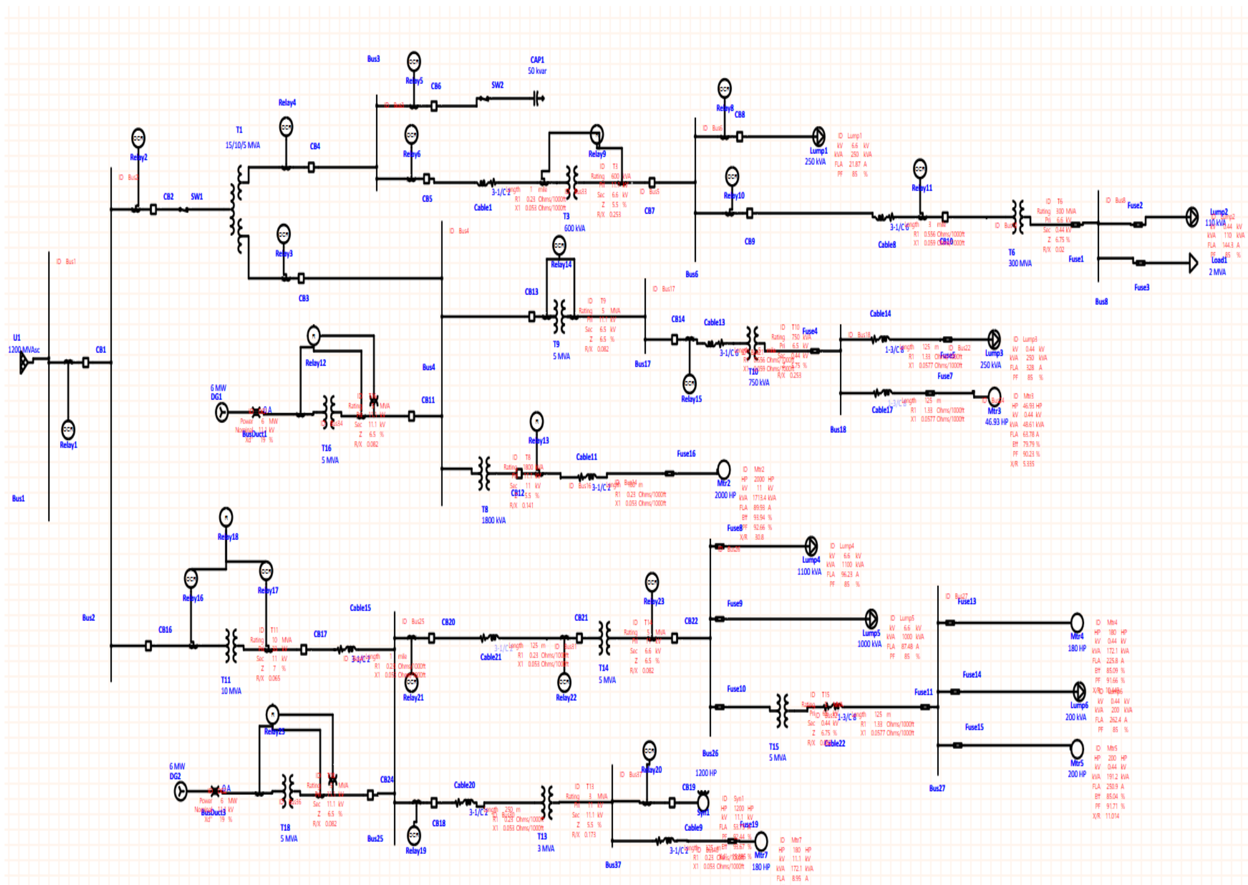


Figure 5.1: ETAP model for research

There are 26 buses, each with an impedance provided by a cable, transformer, or transmission line. Current transformers provide some resistance to transmission lines between two buses in practise. Each bus is linked to loads with varying duty cycles, induction motors, lump loads, synchronous motors, and a capacitor at the radial feeder's end to increase the system's power factor. There have been three power sources: one at the top, the Utility Grid, and the other two, generators, which all deliver electricity to various areas of the suggested model. The number of power system components employed in the proposed model is shown in the table 5.1. This proposed model has the same voltage rating as the power system, which is 33, 11.1, 6.6, 0.44 KV. Fuse protection is used at the extreme load end, while digital library relays safeguard the intermediary branches. These data are all taken from the ETAP collection and selected in accordance with ANSI/IEC standards.

Table 5.1: Elements used in suggested model.

No. of buses	No. of elements	No. of Machines
Swing = 1	Transformer = 9 (Two winding)	Synchronous Generator = 2
Voltage Control = 2	Transformer = 1 (Three winding)	Synchronous Motor = 1
Load = 23	Reactor = 0	Power Grid = 1
	Cables = 11	Induction Motor = 5
	Tie PD =3	Lumped Load= 6
Total = 26	Total = 24	Total = 15

The following is a list of the input data that will be set to the different parts of the power system by the proposed model. Every component of the power system, including their identifiers, the kind of connection use, and the impedance they provide, is broken out here.

Table 5.2: Suggested model element Impedance

POWER GRID INPUT DATA									
		% POSITIVE SEQ. IMPEDANCE				% ZERO SEQ. IMPEDANCE			
Power Grid	Connected Bus	Rating		100 MVA Base		Grounding	100 MVA Base		
ID	ID	MVAsc	kV	X/R	R,X	Type	X/ R	R0	X0
Utility	Bus38	1200.0	33.000	45	0.18514, 8.33128	Wye - Solid	45	0.110181	4.95812

Table 5.3: DGs Input Data

				Positive Seq. Impedance					
Synchronous Generator		Rating			% Xd"		Grounding	Zero Seq. Impedance	
ID	Type MVA	kV	RPM	X"/R	% R	Tol.	Type	Amp	X/R, % R0
Gen1	Turbo 7.059	11.10	1800	48.0	0.250	12.0	Wye	Solid	48.0, 0.250
Gen2	Turbo 7.059	11.10	1800	48.0	0.250	12.0	Wye	Solid	48.0, 0.250

				Positive Seq. Imp.						
Rating (Base)				Xd"		Grounding		Zero Seq. Imp.		
ID	kVA	kV	RPM	X"/R	% R	% X'	Conn.	Type	Amp	X/R, % R0
Syn 1	1033.4	11	1800	25.84	0.595	23.077	Wye	Open	25.84	0.595, 15.38

Table 5.4: Induction Machine and LUMP Data

Induction Machine		Rating (Base)	Positive Seq. Imp.			Grounding			Zero Seq. Imp.		
ID	kVA	kV	RPM	X"/R	% R	% X"	% X'	Conn.	Type, Amp	% R0	% X0
Mtr 2	1713.37	11.00	1800	30.80	0.500	15.38	23.08	Wye	Open, 30.80	15.38	

Mtr 5	175.33	0.46	1800	11.01	1.816	20.00	50.00	Wye	Resistor, 20.00	1.816	20.00
Mtr 4	172.10	0.46	1800	10.45	1.914	20.00	50.00	Wye	Resistor, 20.00	1.914	20.00
Mtr 3	42.72	0.415	1800	5.34	5.217	27.8	99.00	Wye	Open, 5.34	5.217	27.83

LUMP LOAD												
ID	kVA	kV	MTR	STAT	kW	KVAr	X"/R	X'/R	%R	%X"	%X'	Conn.
LUMP5	1000.0	6.600	60	40	558.0	220.5	6.67	6.67	2.307	15.38	23.08	Wye Open
LUMP3	250.0	0.415	76	24	180.5	59.3	2.38	2.38	10.049	23.92	9999.00	Wye Open
LUMP4	1100.0	6.600	60	40	613.8	242.6	6.67	6.67	2.307	15.38	23.08	Wye Open
LUMP6	200.0	0.415	80	20	147.2	62.7	2.38	2.38	7.757	18.46	46.15	Wye Solid
LUMP1	250.0	6.600	60	40	133.5	68.4	6.67	6.67	2.307	15.38	23.08	Wye Reactor
LUMP2	110.0	0.440	60	40	59.4	28.8	2.38	2.38	7.757	18.46	46.15	Wye Open

Table 5.5: System 2-Winding Transformer Input Data

	Transformer Rating					Adjusted	Phase Shift
ID	MVA	Prim. kV	Sec. kV	% Z	X/R	% Z	Type
T11	8.000	33.000	11.000	6.90	23.50	7.1000	Dyn
T14	4.000	11.000	6.800	6.30	12.14	6.5000	Dyn
T10	0.750	6.700	0.450	5.78	3.70	5.7750	Dyn
T9	0.500	10.900	6.700	4.80	12.14	7.0000	Dyn
T15	0.500	6.600	0.440	4.80	4.70	4.8000	Dyn
T3	0.600	11.000	6.650	11.00	3.96	11.0000	Dyn
T6	0.350	6.600	0.440	6.75	50.00	6.7500	Dyn
T8	1.800	11.000	11.000	5.50	7.10	5.5000	Dyn
T13	1.000	11.000	11.100	5.50	5.79	5.5000	YNd

Table 5.6: 3-Winding Transformer Input Data

	Rating			Impedance			Z Variation		Phase Shift
ID	Winding	MVA	kV	% Z	X/R	MVAb	% Tol.	+ 5%	Type

T1	Primary:	15.000	33.000	50.2	7.10				
					Zps	397.20	15.000	+ 5%	0
	Secondary	10.000	11.100	14.10	Zpt = 40		15	+ 5%	30.000
	Tertiary:	5.000	11.100	14.10	Zst = 38		15.000	+ 5%	0

5.1 Sequence of operation:

ETAP's Sequence of Operation of Events block deals with the operational time of each and every system element. Relay delay timing by internal characteristics, relay time dial, and circuit breaker delay are all examples of time operation. The entire operating time in milliseconds of each element (Relay, CB), with relay ID, fault current (KA), and what are the circumstances of relay tripping are also specified in this subject sequence of operation in the fig. 5.2. It says that a failure occurred between load-1 and Bus3. The operating sequence is as follows: first, fuse 3, then fuse 2, and last, relay 11. These three indications (crossed over CB & fuses) signify relay activity; not only this, but numerous additional relays functioned as well, although they were not under 3 sequence tripping.

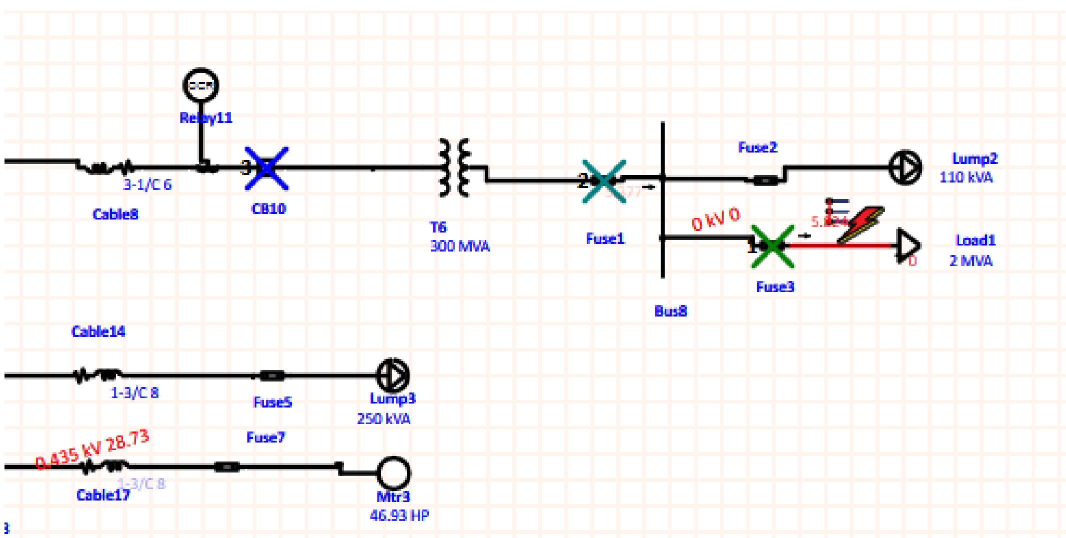
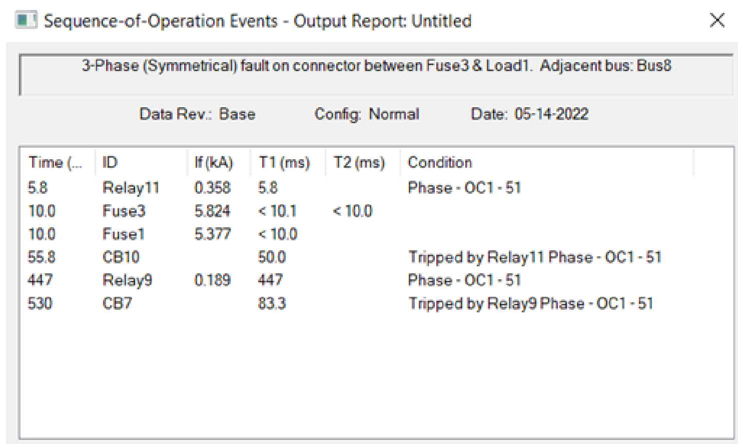


Figure 5.2: Sequence of Protection Devices when fault occurs between Bus3 and Load1

Other relays, like Relay-9, Relay-8, Relay-6, and Relay 4, also acted, but they were sluggish to react to the fault current, therefore no quick tripping occurred as can be seen in fig. 5.3. For a better order of operations, the impedance between the relay and the fault site should be calculated first, and then the relay setting determined, while the total line impedance plus the load impedance will inform us about the least overload current up to the load. So a relay may be changed for protection by adding some delay; it is true that no relay in a power system can perform flawlessly, but every time functioning can be enhanced.


Sequence-of-Operation Events - Output Report: Untitled

3-Phase (Symmetrical) fault on connector between Fuse3 & Load1. Adjacent bus: Bus8

Data Rev.: Base Config: Normal Date: 05-14-2022

Time (...	ID	If (kA)	T1 (ms)	T2 (ms)	Condition
5.8	Relay11	0.358	5.8		Phase - OC1 - 51
10.0	Fuse3	5.824	< 10.1	< 10.0	
10.0	Fuse1	5.377	< 10.0		
55.8	CB10		50.0		Tripped by Relay11 Phase - OC1 - 51
447	Relay9	0.189	447		Phase - OC1 - 51
530	CB7		83.3		Tripped by Relay9 Phase - OC1 - 51

Figure 5.3: Output report of sequence of operation for the considered case

The curve modification tool or the analysis tool may be used to adjust the relay/fuse timing curve. It is possible to deduce from the given fig. 5.3 that relay 11 functioned first, followed by fuses. Because the time delay of the circuit breaker is added to the entire working period, the timing is raised by 55.8, while fuses do not employ a circuit breaker, therefore their timing is 10ms. Both have a 10ms reaction time, however fuse 3 reacts faster than fuse 1, hence fuse 3 reacts first, followed by fuse 1. When the current setting is below the pre-defined current value, the relay's reaction time is extremely short.

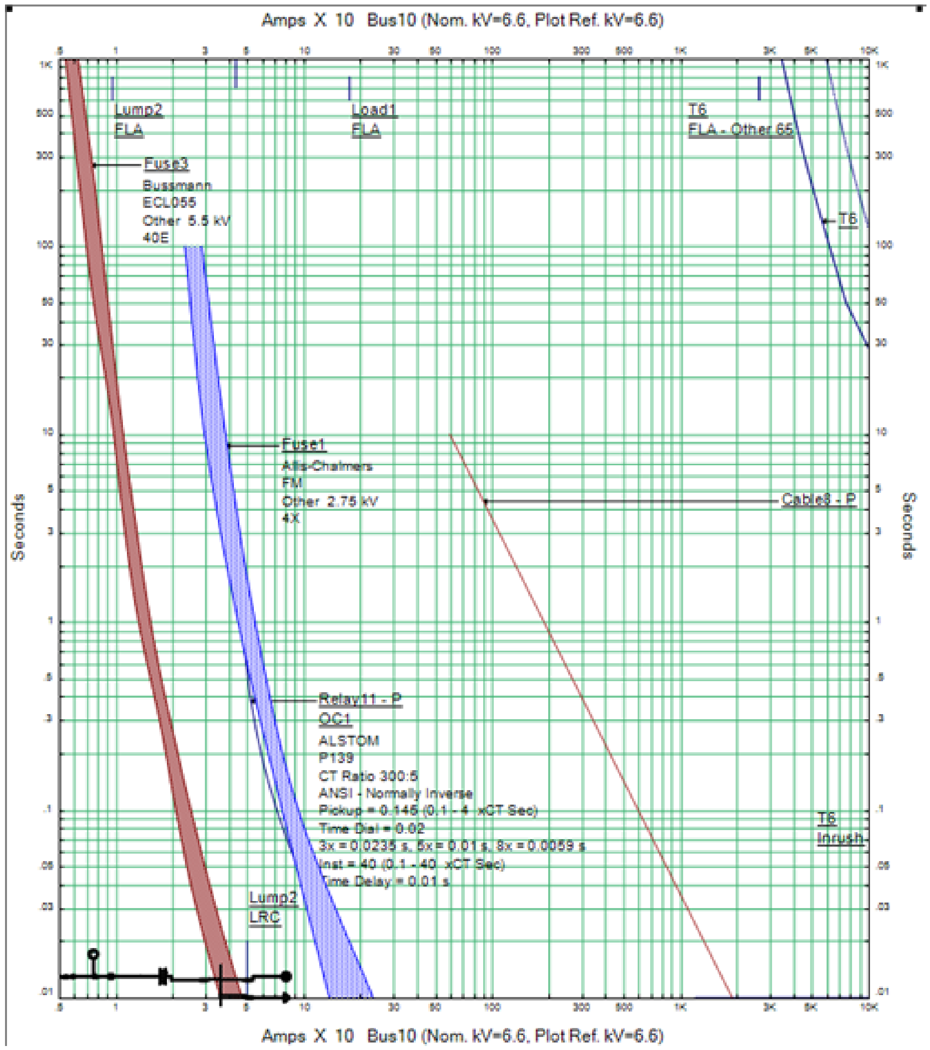


Figure 5.4: TCC curve of sequence of operation of relays

CHAPTER 6

RESULTS & CONCLUSION

In the ETAP programme, a radial distribution system model is created, and a load flow analysis is performed. Protection features are introduced to the system based on the findings of the model's load flow analysis. Short-circuit analysis is used to determine how much short-circuit current (kA) may flow over the system's bus. The short-circuit analysis results aid in the development of cooperation between the protective components. The ETAP programme is used to solve and optimise the complicated protection coordination amongst protection components. After the introduction of distributed generation, mis-coordination and maloperation of protective components were detected.

Radial feeder protection and coordination are investigated, with the following results: the relay employed and its setting for the proposed model, as well as the sequence of operation for up to three relay/fuses. The suggested model utilises the Driescher, Doman smith, Bussman, Allischalmess, ABB, GE Multilinn, ALSTOM, VAMP LTD, Copper, and Westinhhouse relays/fuses library. The manufacturing default value for each Relay/Fuse curve is stored in the library. This curve may also be customised by the user. Long time inverse, highly inverse, very inverse, IEC curve, ANSI curve, and other manufacturer-defined characteristics are employed.

6.1 Sequence of operation of Relays after fault (Relay Coordination):

The results of the radial feeder protection are shown in table 12 below. At various locations, the ETAP fault icon is used to apply faults, and the resulting data is analysed with the help of sequence of operation blocks. Although this study report only mentions the sequence of operations up to three times, other papers could utilise more. The operation sequence with defects such as line to line (L-L), line to ground (L-G), line to line to ground (LL-G), and triple line to ground (LLL-G) may be analysed, and the results will be the same as those presented in this work. A fault may be formed on the bus, at the loads, on the transmission line, or closer to the transformer (both main bus and load bus). The response time, the kind of fuse or relay that was operated upon, and the current that was detected by the relay are all included in the given sequence of action. This information may be obtained from table by initial screening relay from table 6.1, and it can be determined which of the circuit breaker IDs entered into the relay editor box will determine which relay is activated.

Table 6.1: sequence of operation (Time (ms), fuse/relay acted, fault current (kA))

Fault Location	Tripping cause	sequence of operation with time (Time(ms), fuse/relay acted, fault current(kA))		
		Seq.1	Seq.2	Seq.3
Nearer to Mtr5	Short circuit	10, Fuse-15, 8.632	12.1, Fuse -11, 8.632	21.2, Fuse -10, .575
Nearer mtr14	Short circuit	10, Fuse- 13, 8.632	12.1, Fuse -11, 8.632	21.2, Fuse -10, .575
Nearer lump6	Short circuit	10, Fuse-14, 8.632	12.1, Fuse -11,8.632	21.1, Fuse -10, .575
Bus27	Short circuit	12.1, Fuse - 11, 8.632	21.2, Fuse -10, 0.575	49.5, Relay-23, .575
Nearer to T15	Short circuit	10, Fuse -10, 2.1	12.1, Relay -23, 27	25.5, Relay -22, 1.696
Bus 26	Short circuit	12.1 Relay - 23, 2.74	25.5, Relay -22, 1.696	33, Relay -21, 1.696
Bus 25	Short circuit	23.2, OCR -24, 2.705	24.6, OCR -17, .902	24.6, Relay -1, .9
Synchronous 1	Short circuit	13.2,Relay-20, .731	14.1, Relay -19, .738	163, Relay-23, .738
Bus 25 - cab20	Short circuit	11, Relay -19, 2.705	23.2, Relay-23, 2.705	24.6, Relay-18, .902
Nearer to T11	Short circuit	15, Relay -1, 1.85	17.2, Relay-18	35, Relay-17, 1.838

Nearer motor 3	Short circuit	12.8, Fuse - 7, 1.599	20.6, Fuse -4, 1.599	22.8, Relay -15, .11
lump 3	Short circuit	11.8, Fuse - 5, 1.547	13.8, Fuse -4, 1.547	23.8, Relay -15, .106
bus 18	Short circuit	18.4, Fuse - 4, 1.791	20.2, Relay -15, .123	40.5, Relay -14, .123
Cable13 - T10	Short circuit	16.8, Relay - 15, .151	30.3, Relay -14, .151	32.2, Relay -12, .093
line 1 & sub 2	Short circuit	13.2, Relay - 8, .512	14.8, Relay -30, .512	16.7, Relay -31, .315
at bus Bus17	Short circuit	14.8, Relay -14 , .512	16.7, Relay -12, .315	20.0, Relay -3, .315
At T9	Short circuit	14.3, Relay - 14, 1.719	14.7, Relay -12, 1.613	15.3, Relay -3, .315
Nearer to motor 2	Short circuit	12, Relay -13, .861	24.6, Relay-12, .808	15.3, Relay -3, .315
Bus4	Short circuit	14.7, Relay -12, 1.628	15.1, Relay -3, .318	341 Relay -2, .107
Load 1	Short circuit	10, Fuse -3, 1.845	20.5, Fuse -1, 1.845	20.6, Relay -11, .123
Lump 2	Short circuit	9.9, Fuse -2, 1.845	20.5, Fuse -1, 1.845	20.6, Relay -11, .123
Bus 8	Short circuit	20.5, Fuse - 1, 1.845	20.5, Relay -11, .123	29, Relay -10, .123
Nearer to T6	Short circuit	16.8, Relay -11, .158	22.4, Relay -10, .158	32.2, Relay -9, .095
Lump 1	Short circuit	17.8, Relay - 8, .323	17.9, Relay -9, .195	19.5, Relay -6, .195
Bus 6	Short circuit	17.9, Relay - 9, .195	19.5, Relay -6, .195	20.8, Relay-4, .195
Nearer to CAP1	Short circuit	10, Relay -5, 1.235	1.9, Relay-4, 1.285	15.8, Relay-2, .431

Bus 3	Short circuit	13.9, Relay- 4, 1.285	15.8, Relay-2, .431	52, Relay -1, .431
Bus2 (Main Line)	Short circuit	11.6, Relay - 1, 21.414	16.5, Relay -2, .299	416, Relay-18, .101

Given that table 6.1 is for the series of operations utilising the star protection tab symbol up top, this indicates that a string of operations will be carried out without disrupting or dividing any area of the proposed model. Following the completion of sequence 1, sequence 2 will take place, and finally, sequence 3 will be triggered if the current value is greater than the value that was preset. The longer you set the timer on the relay, the longer it will take for it to react; hence, at nodes that have more than two branches, the primary branch of the source should have a high current setting. Not only does coordination rely on the current setting, the time dial, and the curve, but it also relies on the reaction of the circuit breaker.

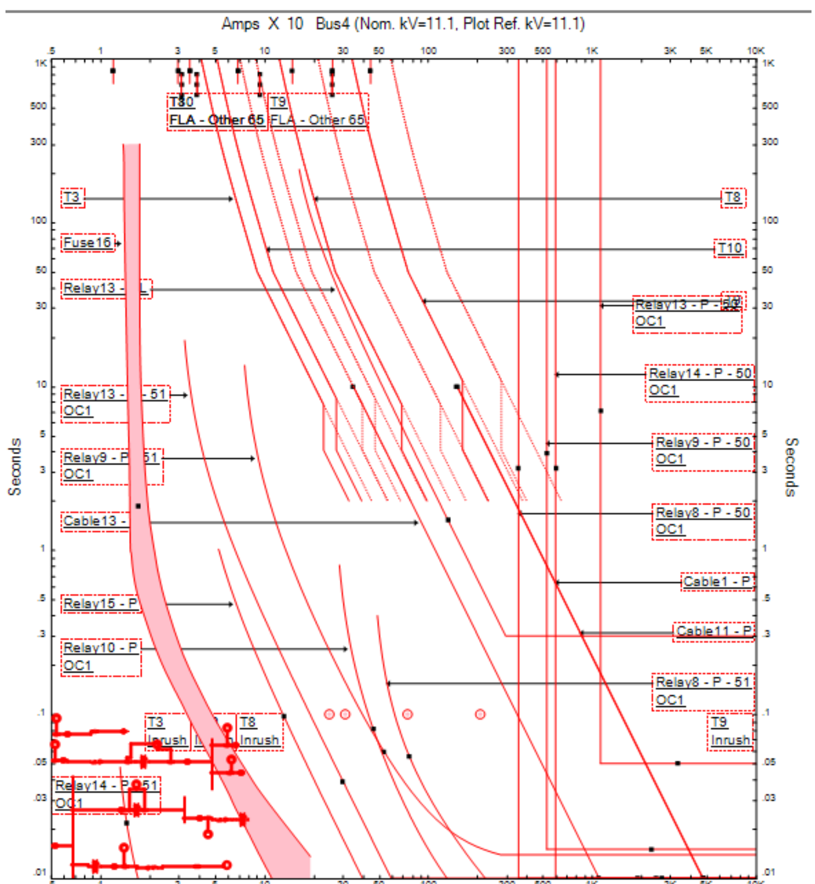


Figure 6.1: TCC for Proposed Model

6.2 CONCLUSION AND FUTURE SCOPE:

6.2.1 Conclusion:

The protection of radial feeders and their synchronisation is being examined; the results may be seen in the chapter that came before this one. For the sake of coordination, the tripping time should be set rather high. To defend this point of view, let's say the fault is just transitory; in such case, the high time may permit the system to continue running, and the recloser may be able to make use of its application. On the other hand, if the fault continues for a significant amount of time, sequence operation will take place, and backup safety will also perform its function in conjunction with the recloser.

By examining the findings presented so far, one may deduce that, when calculating the impedance between the site of the fault and the relay, time will be longer if the estimated impedance is large, and it will be shorter if the calculated impedance is low.

- Transmission lines that are suspended in open areas have the potential to be disrupted by a variety of anomalous situations, such as a fault or a lightning strike. In this situation, a numerical differential protection relay that has a very high degree of dependability is required in order to reduce the amount of power lost.
- When selecting a current and potential transformer, one should make sure that the device will not be harmed by excessive voltage and current, whether the fault state or the overload condition is present.
- Let's assume that there was a loss of power at some location for more than a few minutes. Whenever the board reenergises the feeder, there may be cold load pickup to relays due to strong inrush current caused by inductive loads. Relays should be able to identify this scenario.
- There need to be effective and appropriate coordination between the main protection and the backup protection, in addition to the relays that are sequenced to the source.
- Heavy motors and loads that are physically closer to the generation or utility grid demand a higher relay setting and longer dial time.
- Selectivity is an intrinsic property of any protection system that allows for a high rate of

tripping at each terminal, in addition to providing a high level of security and reliability.

- The use of a backup protection strategy for the generator requires a time buffer of 0.5 seconds in order to ensure its safety.
- The current flowing from a single line to the earth would be extraordinarily high if a generator were to be strongly grounded. This is the reason why generators are never completely grounded. Therefore, a single unity is grounded by a significant resistance, while the others are left unclosed.
- The voltage, current, burden, saturation, and amount of space that is occupied all have a role in the selection of fuses, circuit breakers, current transformers, and potential transformers, as well as relays.
- The main protection should eradicate both permanent and transient faults as quickly as possible, and it should also avoid giving any opportunity for the backup protection to be activated.

6.2.2 FUTURE SCOPE:

Although research has been done on coordination, this does not imply that it is flawless; in fact, there is no such thing as flawless coordination; rather, coordination may always be improved. The primary focus of this thesis is to examine, within the context of a radial feeders distribution network, how different kinds of relays and fuses are coordinated with one another. The circuit breaker, the time dial, and the relay itself all play a part in the coordination procedures that include time. Time plays a vital role in these operations. With the development of new technologies, the amount of time required to reply may decrease, rapid operations may become feasible, and the relay curve may become more crowded as a result of enhanced coordination.

- More exact and precise coordination may be accomplished thanks to an increase in the library's capacity for updating information. This is especially true in settings for the time dial, delay communication, and current setting, which are the three most important functions.
- Safety of the public and of equipments — Protecting the public and protecting equipment

is of the utmost importance. Even if electricity lines hang for whatever reason, there is a greater chance that the whole line is electrified, which is dangerous, particularly during the rainy season; however, with the use of the appropriate relay, these faults may be removed.

- Power quality-relays are carried out in compliance to the application, which means that although it will merely detect voltage, current, or its phases for the purposes of providing protection, it may be configured to monitor power quality as well.

If a failure occurs on a bus that has a smaller load or a heavier load, it is extremely difficult to coordinate whether the fault occurred on that vehicle or on another neighbouring bus. Therefore, with an improved ETAP library or by using some other particular relay, this coordination may become much simpler.

Appendix 1

ETAP- A Brief Introduction:

A transmission line, generating station, grid, distribution system, protection system, solar system, and other types of power system designs may all be designed, simulated, and automated with the help of this programme. Other types of power system designs include: There are several libraries from different manufacturers that adhere to ANSI, IEC, and IEEE standards that are already contained inside it. Users are able to construct their own unique electrical systems by making use of the editing tool, which ensures that all of the power system parts utilised in ETAP adhere to both national and international standards. This results in a single connected device that has applications integrated inside it. It functions as an application model for an exe file that is still being built. This programme is utilised by businesses all over the globe because of the numerous benefits it offers, including monitoring, intelligent solutions, optimization, and the potential to generate results in MS-Excel, Word, PDF, and a great many more formats. The following is a list of the tests and analyses, along with the essential characteristics that may be used on ETAP-

Reliability Assessment:

It addresses issues about the quality and availability of the electrical power system at each end of the service. The failure statistics for customers reflect the results when compared to the results of other parts of the electrical power system. The quiet features of this module include things like system dependability, customer-oriented indices, energy indices, sensitivity analysis, and single and double contingency planning.

Analysis of AC/DC short circuits and arc flashes:

This tool analyses AC and DC short circuits of different sorts (phase and line faults) according to the ANSI/IEEE C37 Standards, and it also coordinates preventive device use. The ETAP Arc Flash tool gives users the ability to find and assess high-risk flash arc locations in an electrical scheme. It also simulates a variety of strategies that electricians employ to reduce high-incidence energy. This module also requires significant calculations for one-phase and three-phase arc flash evaluations, as well as a vital arc flash monitoring system equipment, in order to read and comprehend the results of arc flash study.

Harmonics analysis:

The user is able to analyse and measure the system's harmonic voltage and current sources with the help of this tool. These measured values will assist the user in re-designing the circuit, and they may also provide the user design and testing options for nuisance trips and filters. These tests might be constructed using IEEE 519, ANSI/IEEE 399, IEEE 141, IEEE 519-2014- MV/HV/EHV, IEC 61000-3-6, or IEC 61000-3-14-LV. All of these standards can be found on the IEEE website. This module's primary functions include determining THD and IHD, as well as the telephone influence factor and harmonic current injection technique.

Load flow analysis:

Using this programme, you may analyse power flow, demand, power factor adjustment, and several reports of results. The operational state of the whole system in response to a certain load may be determined using load flow analysis. When attempting to repair non-linear algebraic equations, it is very necessary to have access to mathematical solutions that are not only rapid but also effective and exact. The output of this instrument addresses the node voltage, line losses, angle, and power in the system under consideration.

Star protection Coordination and Selectivity:

When the user employs this tool, they are able to do an analysis of the coordination and protection plan for the new power system operation or to renew an older system. Curves may be altered, analysed, and traced with the help of this programme, which is compatible with both AC and DC systems and provides access to a variety of manufacturer libraries. The system may be configured with a wide variety of faults, check relay timing, verify its status, and see the operating sequence. It is possible to create reports in a variety of forms, some of which are described in this appendix chapter.

Designing of panels and the planning of one-line diagrams:

It is simple to plan and build the panel, and there is only one line diagram to examine after spending some time with it. The graphical user interface of the board displays every icon and can analyse three-phase (three W and four W), one-phase (two W and three W), and one-phase (A, B, C, AB, AC, and BC) boards. It will automate tasks, display the results on the screen, and provide a warning if the system violates a rule.

Appendix 2

The following is a selection of the many writers' contributions to the field of relay coordination:

- A work by Param Mehta[16] et al. describes the usage of IEEE and IEC relay curve features in MATLAB/simulink to simulate overcurrent relays for radial feeders. In a similar fashion, the output of the Simulink block is checked, and the inverse characteristic graph of the IDMT is collected for a range of different time multiplier settings and plug multiplier values. In point of fact, a developer-friendly GUI software is designed to make it simple for users to operate the radial feeder system by putting relays at various parameters and checking the network's efficiency and efficiency for distinct fault places. This can be accomplished by putting the relays in the appropriate positions.
- Hima A. Patel and Vaibhov M. Sharma[07] et al has presented a study on relay coordination in which they employed an ETAP application on a big linked system. The paper was on relay coordination. The whole of the research report presents a short-circuit investigation as well as relay coordination of overcurrent relays of an industrial plant's radial power grid capability of 1218.5 MVAsc by employing stage modelling and hand calculation and comparing the results using various methodologies. The method of studying short circuits that is discussed in this article is the method that is often used in businesses in relation to Schneider Electric's ect 158. This research makes extensive use of manufacturing instructions and IEEE periodicals to inform its use of the relay cooperation approach.
- Ÿ GU Cailian and JI Jianwei[06] et al provided a study article on feeder protection in micro grid. In this paper, they have taken care of distributed generators linked system and its impact by utilising the programme PSCAD. The conventional power distributed system is converted from a single power power supply radial system into more than one power supply loop system. This transformation alters the trajectory of the power flow, which prevents the completion of the micro grid running in the grid-connecting mode as well as two types of operational mode of connectivity and isolated island switching. According to

the demand sensitivity of the buffer system, the existing differential protection system and the inverse time overcurrent protection system are developed, the simultaneous action defence approach is intended, and the simulation outcomes with the standard micro-grid are presented in the article. This is done in order to solve the problem of micro-grid relay safety.

- Poonyapa Sookrod and Paramet Wirasanti[14] et al presented a study work on relay coordination for radial system; DG may have a detrimental influence on the collaboration of overcurrent relays with regard to varied rates of short circuits. [Citation needed] Poonyapa Sookrod and Paramet Wirasanti[1]et al. Overcurrent relays are vital to guaranteeing a power station's efficiency since they prevent both the breakdown of the system and the unintended failure of a significant component of the scheme. The configurations of the relays need to be changed so that they are appropriate for the capabilities and location of the attached DG. In addition, the effects that the presence of DG has on present relays need to be investigated so that protective cooperation can be maintained. This article suggests using an overcurrent relay communication device as a solution to the problem of cooperative relay use.
- Amim Zamani, Amir Zamini[20] et al. address the issue of protection flashing in their article on the protection of radial distribution systems by implementing a simple approach for coordinating radial distribution system protective devices with various DGs. The proposed method takes use of numerically-based reclosers and directional components for radial feeder relays. Additionally, it solves the issues of security detection, false tripping, recloser fuse and fuse-fuse mismatch, and failure of self-reclosure. The PSCAD/EMTDC application programme, which provides precision comparable to that of ETAP, has been used to study this situation.
- Using ETAP software, K Anupreyaa[31] et al. describe the sequence of operations and relay characteristics required for protection in their power distribution system. Protection relay collaboration seeks to achieve selectivity without sacrificing vulnerability and fault elimination in an efficient manner. The coordination systems must provide quick, targeted, and safe contact method to avoid failed components of the power system, and relay monitoring plays a vital role in the design of the safeguard scheme.
- Venkatesh and Ranjan[29] establish the idea of distribution system configurations

using the load flow approach for radial distribution systems. In radial distribution system automation methods, including as defect detection, network reconfiguration, and system recovery, an efficient distribution load flow approach is essential. A dynamic topology algorithm based on a well-defined data structure is required to perform these complex tasks requiring frequent topology alterations in the Radial distribution system. The suggested load flow method is based on the generated data structure. This strategy is superior than many other ways for distributing the load.

- Divya S Nair[13] et al have submitted a research article on relay coordination and discrimination in the current situation with its solution. The selection of appropriate relay designs under various system conditions is critical to the early elimination of the faulty energy scheme section. It is important to note that for a power system, each relay is coordinated with the different kinds of its own, as well as with numerous characteristics curves.
- Acharya Sandesh[18] et al explain in their study how much coordination is required for radial feeder and parallel feeder with various locations in the radial feeder system and how soon its inspection must be worked out in order to ensure uninterrupted power delivery to the load. System integration and protection are critical to reducing the impact of a breakdown. The research focuses on models and evaluations of the current alignment of radial feeder networks' current relays. The time current aspects of ETAP application are being studied using coordinated overcurrent relays for radial feeder systems in this research report. In order to ensure that the relays are properly engaged, coordination between the relays and their related protection devices is focused. The major backup security of the relays is achieved by excellent coordination between the two relays in the shortest possible period. In essence, proper relay coordination eliminates the flaw and increases security.
- Every New Year, regardless of the new features of the power system, new sources are added. This report discusses the present context and the changes that have taken place since the previous study by Yeonho OK and Jaewon Lee[32] et al. Korean Electric Power Corporation's relay coordination system and the needed number of operations are discussed in this document, as are alternate systems in the event that the KEPCO system fails.
- J. A. Sa'ed and S. Favuzza[25] et al. disused paper on radial distribution system and influence on DG, they performed simulations using MATLAB and POWER WORLD

simulator. Although DG systems have many benefits, implementing them is fraught with challenges, and ensuring user privacy is a major one of those challenges in the implementation of DG systems. The addition of DG to the project leads to the redistribution of branch flows, which necessitates the modification of typical security notions. Protective device collaboration is highly dependent on how the supply strategy, the size of the DG, and its location are set up. Radial power network system mismatches and distributed generator capacity are both examined in this research. In order to determine the influence of linked DGs on the current fault state, the rate, quantity, and location of DGs are employed as factors. Local supply network security is maintained while the DG capability limit status is reported.

- Muhammad Yousaf[15] et al. use a straightforward approach in their study on system coordination with numerous DGs. Increased error present size and changes in energy supply instructions are two of the most prominent consequences of DGs on a typical distribution system Additionally, this article discusses the usage of relay-recloser cooperation in the event of a temporary or permanent problem. A recloser's directional properties may be used to aid in the recovery of recloser-fuse coordination for late-DG inclusion implications. Using a maximum voltage of 11 KV and a unidirectional power flow, this study proposes the introduction of upstream and downstream relay setup. Reclosers must be used in place of fuses if they are to be used for directional security, despite the fact that fuses do not have a specified purpose. It is unnecessary to assign ownership to the feeder relay since the fault flow through it is still one-way.

Appendix 3

Summary of Electrical Relays:

A non-directional overcurrent relay may comprise instantaneous, thermal overload inverse definite time overcurrent relay, and a great deal of other types of overcurrent relays. The operational quantities of these relays, such as individual phase, residual, and line negative sequence current, may also be used to further categorise them into different groups. These relays may be utilised for motor failure protection, feeder failure protection, and breaker failure protection depending on the form of the relay's time-current characteristic. There is just one quantity that may operate as an actuator, and that is current (current coil). There is no voltage coil.

A current-operated coil is required to be present in an overcurrent relay. When there is no defect in the line, also known as a healthy line, the magnetic field created by the relay coil is not strong enough to cause the relay to trip even if the set point is higher than the usual point. It is also possible to characterise this operation by stating that the restoring torque is greater than the deflecting torque. If a short circuit fault occurs, then the current will, of course, become large enough to cause damage to the system. If this current is greater than the current setting, then a strong magnetic field would be produced, which will cause the relay to operate, meaning that the relay's deflecting torque will be greater than its restoring torque. In this particular instance, the moving element begins to move when the current passes through its limitations; moreover, by tracing the curve, it responds and disconnects the curve.

According to fig. A 3.1, one can see that a relay is linked in series with the power line and the load. When the current in a circuit reaches a certain threshold, the moving contacts are replaced with the fixed contacts. This procedure is carried out using an electromagnetic coil, which is stimulated by a secondary circuit or another circuit that is linked to it. The torque is sent back into the system by the spring that is attached to the opposite end of the relay system.

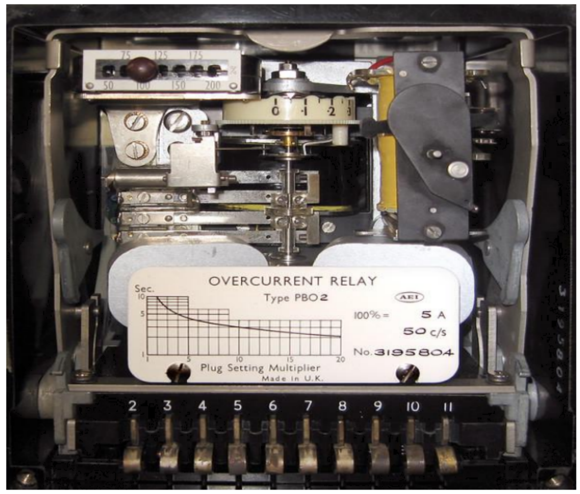


Figure A 3.1: Electromagnetic Relay

A.3.1 Characteristics of different types of Overcurrent Relays:

Using microprocessor-based varieties of relay, any curve may be built from scratch and altered to meet the specific requirements of the user. A certain amount of deliberate delay is necessary for the operation of the circuit breaker, and this delay may be obtained depending on the curve. There are many different kinds of curve characteristics, some of which are given below:

a. Inverse Definite Minimum Time Overcurrent Relay
b. Extremely Inverse Overcurrent Relay
c. Normal Inverse Overcurrent Relay
d. Instantaneous Over Current Relay
e. Definite Time Overcurrent Relay
f. Long Time Inverse Overcurrent Relay

A.3.1.1 Inverse Definite Minimum Time Overcurrent Relay: This kind of relay operates with time that has an inversely proportional equation to the fault current. Its design is comparable to that of a wattmeter or a reverse power relay. When the current through the relay is low, its operation time is quite high, but when the current through it is high, its operation time is very low. It is used often for the purpose of protecting distribution lines.

A.3.1.2 Extremely Inverse Relay: This relay has more inverse features than an inverse definite minimum time overcurrent (IDMT) relay. It is employed in situations when there is a decrease in fault current occurring, as well as fault distance from the relay that might be high. Due to the steep nature of its features, this relay performs very well in the event of a ground fault. This relay is well suited for protecting small alternators, transformers, heater feeds, and transformers alike.

A.3.1.3 Normal Inverse Time Overcurrent Relay: Overcurrent protection relay with normal inverse time operation Inverse time is an inherent property of all induction spinning devices. This relay has a greater degree of inversion than the long time inverse relay. The majority of applications for it may be found in fault-prone sectors and areas.

A.3.1.4 Instantaneous Overcurrent Relay: It has a relatively simple design. These relays have a minimum period of time to react, during which time the current is measured (10 to 20 times the typical current), and the circuit is made to open if the current exceeds the limit for that amount of time. It must be utilised at the farthest possible distance from the source; yet, it has a broad range of applications at put going feeder and backup protection.

A.3.1.5 Definite Time Overcurrent Relay: This relay utilises an intestinal delay relay if the relay current setting is violated or the line current exceeds the predetermined current (fault current at least same as relay current setting). This relay's easy-to-coordinate features include a constant acting time, an operating time that is not dependent on current (after the set point), and a constant operating time. This relay is not suitable for use at every point since it is not good for the power transmission line, and if a fault occurs closer to the relay, then a significant quantity of current will flow, which is not what one wants to happen. Due to the advantageous time delay features it has, its primary function is that of providing backup protection.

A.3.1.6 Longe Time Inverse Overcurrent Relay: This relay's primary use is for backup earth fault prevention in power system because of the long time delay it provides. When compared to the extreme inverse relay, this curve has a more linear appearance. It is used for the earth protection of power transformers and generators respectively.

The input current from the CTs is constantly being compared by the relays with the curve shown below; as soon as the current reaches the predetermined threshold, the trip signal is activated. These relay curve features may be applied in a number of different ways at a variety of places, depending on the nature of the load and the kind of protection, either main or backup.

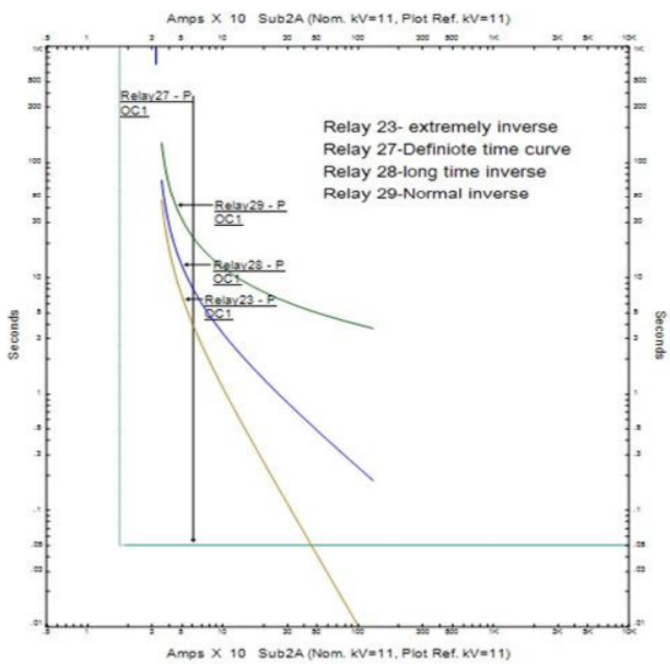


Figure A.3.2 : Time Current Characteristics of various types of relays

These relays adhere to a number of different standards depending on the end use, including ANSI C37.90, IEC 255-4, IS 3231-0, IEC60255-3, and IAC. These standards limit the reaction time of the relay to a fault situation; part of the curve data is addressed in appendix III. It is not required that, for a particular curve, it be identical in every way to another standard or manufacturer; in fact, there could be significant differences.

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Research Publications

1. Hitesh Agarwal, J. N. Rai, "Traffic Control System based on Density with Emergency Priority Mechanism" at the International Conference on Electronics and Renewable Systems (ICEARS 2022) presented the paper on 15th March 2022.
2. Hitesh Agarwal, J. N. Rai, "Protection Coordination of Distributed system with Distributed Generation" at International Conference on Intelligent Controller and Computing for Smart Power (IEEE Hyderabad section ICICCSP 2022), paper is accepted for presentation on 21st July 2022.

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