Principle of
Power System Protection

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ABSTRACT

Power system protection and asset operation have drawn the attention of researchers for several decades; but they still suffer from undetermined and grueling technical issues. The situation has been recently exacerbated in the wake of the ever- changing terrain of power systems driven by the growing query and volatility posterior to the vast renewable energy integration, more frequent natural extreme events due to climate changes, adding vicious cyberattacks, and more constrained transmission systems as the result of weight growth and limited investments. On the contrary side, the proliferation of advanced measuring bias analogous as phasor dimension units, arising electric andnon-electric sensors, and Internet of Thing(IoT)- enabled data gathering platforms continually expand/ nourish the databases; they hence offer unknown openings to take the advantage of data- driven ways. Machine knowledge(ML) as a top class of artificial intelligence is the perfect match affect to this need and has lately abandoned multitudinous researchers ' interests to attack the problems banning their exact/ detailed models. This paper aims to give an overview on operations of ML ways in power system protection and asset operation. This paper elaborates on issues pertaining to(1) coterminous generators,(2) power manufactories,(3) transmission lines, and(4) special and system integrity protection schemes. In addition to the openings offered by the ML ways, this paper discourses on the walls and challenges to the wide spread operation of ML ways in real world practice.

Section 1 Introduction

Power systems protection is a critical aspect of electrical engineering that focuses on safe guarding electrical equipment, labor force, and the power grid from faults, failures, and abnormal operating conditions. This comprehensive companion aims to give masterminds with precious perceptivity into crucial principles, ways, and stylish practices in power systems protection.

Before probing into protection strategies, it's essential to have a solid understanding of how power systems operate and the colorful types of faults that can do. This includes studying system factors, similar as generators, transformers, transmission lines, circuit combers, relays, and defensive devices. Familiarity with fault types like short circuits, open circuits, ground faults, and flash over voltages is pivotal as a foundation. Effective power systems protection requires proper collaboration among defensive devices. Master minds must understand the conception of selectivity to ensure that only the device closest to a fault operates, minimizing dislocation to the rest of the system. Proper collaboration involves opting applicable current settings, time detainments, and collaboration angles for relays and circuit combers. Relays are an integral part of power systems protection, serving as the first line of defense against electrical faults. Master minds should have a thorough knowledge of different relay types, including overcurrent relays, differential relays, distance relays, and directional relays. Understanding their operating principles, features, and limitations aids in choosing the most suitable relays for specific operations.

Coordinating defensive devices within a system is critical to maintaining stability and precluding slinging failures during faults. Master minds must precisely dissect and design protection schemes that consider factors similar as fault impedance, fault currents, relay response characteristics, and collaboration perimeters.

Advanced ways like time grading and impedance grading can be employed to achieve optimal collaboration. Performing fault analysis and system modeling helps masterminds gain perceptivity into power inflow, fault currents, voltage biographies, and system stability. Master minds must be complete in using software tools like ETAP, PSCAD, and DSA Tools to directly pretend fault scripts and assess the performance of protection schemes. Detailed knowledge of system modeling ways enables masterminds to make informed opinions regarding relay settings and collaboration.

Section 2 Power System Protection

This chapter defines the power system faults, the part of defensive relaying, and the introductory generalities of relaying. The discussion is a rather general overview. More specific issues are bandied in several excellent handbooks.

2.1 Power System Faults

Power systems are erected to allow continuous generation, transmission, and consuming of energy. nearly of the power system operation is rested on a three-phase system that operates in a balanced mode, constantly described with a set of symmetrical phasors of currents and voltages being equal in magnitude and having the phase shifts between phases equal to 120 $_o$. The voltages and current bear conferring to Kirchhoff's laws of the electrical circuits stating that the sum of all currents entering and leaving a network knot is equal to zero, and the sum of all voltage drops and gains in a given circle is also equal to zero. In addition, the voltage and currents produced electric power that integrated over a period of time yield energy. For the three- phase systems, a type of delineations for the delivered, consumed, or transmitted power may be established as follows immediate, average, active, reactive, and complex. The power system consists of factors that are put together with a thing of matching each other concerning the power conditions, dielectric insulation situations, galvanic sequestration, and number of other design pretensions. A summary of the most common fault types for the power system is given in Table 1.

As similar, the system is able of sustaining a variety of environmental and operating impacts that act normal operating conditions. The abnormal operating conditions that the system may experience are rare but do be. They include lightning striking the transmission lines during severe rainfall storms, inordinate lading and environmental conditions, deterioration or breakdown of the outfit sequestration, and intrusions by humans and/ or creatures. As a result, power systems may experience occasional faults. The faults may be defined as events that have contributed to a violation of the design limits for the power system factors regarding sequestration, galvanic insulation, voltage and current position, power standing, and other similar conditions. The faults do aimlessly and may be associated with any element of the power system. As a result, the power element gests an exceptional stress, and unless disconnected Orde- amped, the element may be damaged beyond form. Generally, the advanced the duration of a fault, the larger is the damage. The fault conditions may affect the overall power system operation since the criticized element needs to be removed, which in turn may contribute to violation of the stability and/ or loading limits. Last, but not least, the faults may present a life trouble to humans and brutes since the damage caused by the faults may reduce safety limits differently satisfied for normal operating conditions. Protective relaying was introduced in practice as early as the first power systems were constructed to make sure that faults are detected and damaged factors are taken out of service snappily.

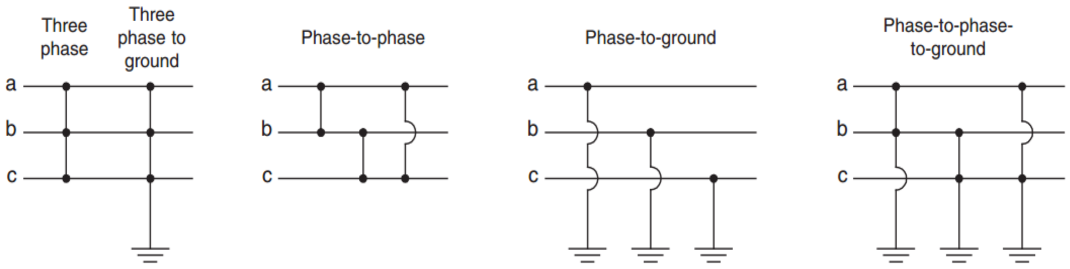


Figure 1 Types of most common transmission lines

To grease graphic representation of different types of faults, circuit plates shown in Figure 1 are used. The illustration is related to the faults on transmission lines and covers eleven types of utmost common transmission line ground and/ or phase faults. To grease the donation, multiple fault types are shown on the same illustration. The rest of the discussion in this section describes the introductory power system factors and how different power system factors are used to grease perpetration of the protection conception. The introductory conditions for the protection system result are outlined pointing out the most critical perpetration criteria.

Table 1 Fault types and description

Fault types	**Description**
Transient Fault	fault that only occurs for a short period time
Persistent Fault	fault that's present anyhow of the disposition of the source
Active Fault	when the current inflow between two phase conductors or phase and ground conductor
Passive Fault	a condition rather than an factual fault
Overloading	condition when current several times larger than the nominal current
Overvoltage	a condition in which the operating voltage rises above the nominal or the rated voltage of the system
Power Swing	the quantum of power generation and consumption at any point in time is equal
Bolted Fault	A bolted Fault is a short circuit fault between all the phase conductors and the earth conductor as if connected by a metal bar
Overcurrent	increasing current occurs due to a short circuit or corona discharge between live conductors
Incipient Fault	type of active fault starts with a low magnitude and gradationally increases with time into a solid fault
Under voltage	In under voltage fault, the voltage decreases below the operating range
Unbalance Fault	occurs when there's a fault in one or two of the three phases
Reverse Power	in case the generator output falls which may be due to the high transport not supplying enough torque
Ground or Earth Fault	occurs when a reenergized or live conductor comes into contact with the ground or earth conductor
Arc Fault	is an important electrical discharge between two or further than two conductors
Open Circuit Fault	occurs due to failure in one or further than one phase conductor
Short Circuit Fault	occurs when two or further than two phase conductor comes into contact with each other
Asymmetrical Fault	type of fault that causes an imbalance in the power system
Symmetrical Fault	occurs when all three phases of a power system are involved in the fault

2.2 Power System Components

The most introductory power system factors are generator, manufactories, transmission lines, busses, and loads. They allow for power to be generated(word), converted from one voltage position to another(trans.), transmitted from one position to another(transmission lines), distributed among a number of transmission lines and power trans.(busses), and used by consumers(loads). In the course of doing this, the power system factors are being switched or connected in a variety of different configurations using circuit breaker and associated switches (The circuit breaker are suitable of interposing the flux of power at a high energy position and, hence, may also be used to disconnect the system factors on an emergency base, analogous as in the case when the element gests a fault(Florsheim,). Because the power systems are erected to cover a large geographical area, the power system factors are scattered across the area and connected with transmission lines. The grouping of the factors associated with generation, switching, transformation, or consumption are called power shops(generation and transformation), substations(transformation and switching), and weight centers(switching, transformation, and consumption). In turn, the combined monitoring, control, protection, and communication gear is also located at the mentioned installations. To grease the description of power systems, a graphical representation of the power system factors as shown in Figure 2 is used. Analogous representation is called a one- line illustration. It's reducing the donation complexity of the three- phase connections into a single- line connection. This is sufficiently detailed when the normal system operation is considered since the results of voltages and currents are symmetrical and one- line representations act truly nearly the single- phase system representation used to gain the result. The result for the criticized systems requires more detailed three- phase representation, but the one- line illustration is still sufficient to bat the introductory relaying generalities. In that case, a detailed representation of the faults shown in Figure1 isn't used, but a single symbol representing all fault types is used rather.

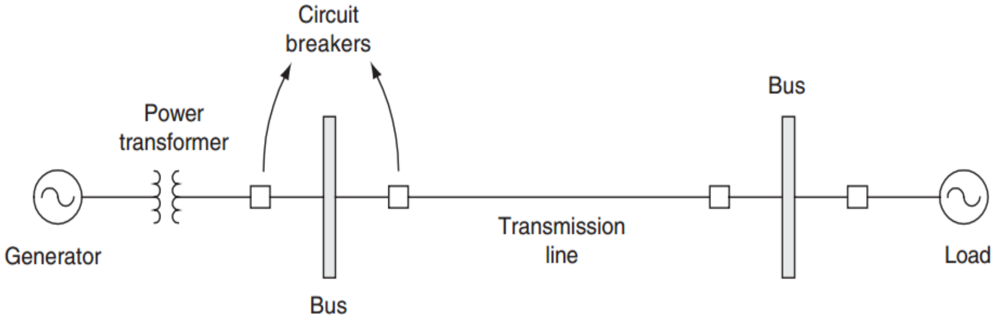


Figure 2 One-Line Representation of the Power System Components and Connection

The coming position of detail is the representation of the points where the factors combine, shown in Figure 2 as busses. A good illustration of such a point is a substation where a number of lines may come together, and a metamorphosis of the voltage position may also take place. Figure 3 shows a one- line representation of a substation. Substations come in a variety of configurations, and the one named in Figure 3 is called a breaker- and-a-half. This configuration is used in high- voltage substations containing a number of transmission lines and mills as well as different voltage situations and associated busses. This representation also includes circuit breaker and busses as the top means of switching and/ or connecting the power system factors in a substation. The defensive relaying part is to dissociate the factors located or terminated in the substation when a fault occurs. In the case shown in Figure 3, the transmission line is connected to the rest of the system through two breaker marked up as " L, " the machine is girdled with several breaker connected to the machine and marked up as " B, " and the power motor is connected between the two voltage position busses with four breaker marked up as "T. " In the common relaying language, all the breaker associated with a given relaying function are appertained to as a bay, hence, the language exists of “ protection kudos ” for a transmission line, a machine, and a motor. It may be observed in the high voltage substation illustration, given in Figure 3, that each breaker serves at least two protection kudos. In Figure 3, each breaker box designated as “L” or “T” also acts as the breaker designated with “B. ” This property will be used latterly when introducing the conception of lapping protection zones.

2.3 Relay Connections and Zones of Protection

Devices known as protective relays are linked to instrument transformers in order to receive input signals and perform cct. Breakers to provide opening or closing control commands. Relays are occasionally linked to communication lines in order to exchange data with other relays. Electronic relays are always powered, and this power is typically supplied by a link to the station's DC battery. Relays are always linked to an additional monitoring and control system to facilitate coordination with other comparable systems and driver supervision. Relays are found in substations and control houses almost always in high-voltage power systems. the link between the cct and instrument transformer. The substation switchyard's breakers are wired using conventional conduit.starting at the switchyard of the substation and ending at the control house. The whole relaying challenge is built around the generality of relaying zones in order to produce effective protective results. Breakers demanded to disconnect the element from the rest of the system, and the zone is established to contain the power system element that has to be defended as well as the CCT. Figure 4 depicts a typical distribution of protective relaying zones for the electricity system depicted in Figure 2. To ensure that the breakers connected to each electrical system part can operate several times, the zones are first named. At least two protective purposes may be served by each circuit breaker. This allows the surrounding components to be separated in the event that one or both bones are questioned.

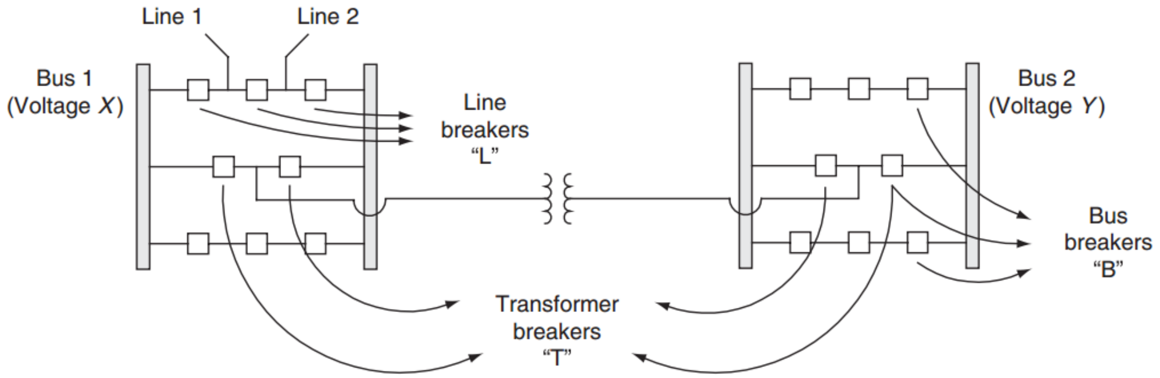


Figure 3 Breaker-and-a-Half Substation Connection

Simultaneously, as few breakers as possible are needed to link the variables. Ensuring that every circuit breaker has a minimum of two protective zones surrounding it is crucial to ensure that no portion of the electrical system remains exposed. This completes the brief connection between the circuit breaker and the busses or the circuit breaker and the breaker. Only when instrument mills are positioned on both sides of the breaker, as is the case with so-called dead-tank breakers that have current-trans installed in the breaker bushings, is an imbrication of this kind conceivable. Defining a backup content is another crucial zone concept. When separate transmission line portions are protected by distinct zones of protection, this is perfect for transmission line protection. Figure 5 indicates how zones are named in case 3 zones of protection used by each relay. The zones of protection are named by determine the settings of the relay reach and the time associated with relay operation. Each zone of protection is set to cover specific length of the transmission line, which is nominated the relay reach. Typical selection of the zones in the transmission line protection is to cover (80 to 90) in zone1, (120–130) inzone2 and (240 – 250) zone 3.

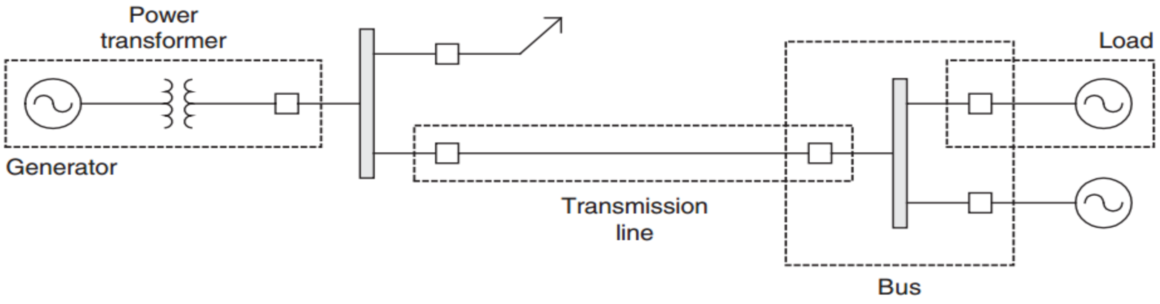


Figure 4 Allocation of Zones of Protection for Different Power System Components

Locating a relay at a specific line terminal and figuring out the length that corresponds to the relay content as a chance of the line length between the relay terminal and conterminous relay stations is how this protection is named. When doing this, the relay's outstation is the morning point for the named direction down the transmission line. It's assumed that the transmission line that starts at the relay position and ends at the coming terminal is 100 measures long. The transmission line as a whole and the fresh 20 bases of line that form from the conterminous terminal are covered by the number 120. The times of operation associated with zones are different zone 1 operation is immediate, zone 2 is delayed to allow zone 1 relays to operate first, and zone 3 times authorize the match relays near to the fault to apply first in either the zone 1 or zone 2. The relays closest to the problem are allowed to control first when using this time-step technique, which is named for distinct zones of protection.. However, the relays located at the remote stations, that “ see ” the same fault in zone 2, If they fail to operate. still, relays located if zone 2 relay operation fails. Further down from the criticized line will operate coming with the zone 3 settings. The advantage of this approach is a spare content of each line section. They are also covered with multiple relay zones of the relay located on the conterminous lines, icing that the criticized element will be eventually removed indeed if the relay nearest to the fault fails. The disadvantage is that each time a backup relay operates, a larger section of the system is removed from service because the relays operating in zone 2(sometimes) or zone 3(always) are connected to the cct breaker that are control from the ends of the transmission line going the fault. In addition, the time to remove criticized sections from service increases as the zone Content responsible for the relay action increases due to the time detainments associated with the zone 2 and zone 3 settings. The power system factors are generally important advanced than the situations used at the input of a relay. To accommodate the demanded transformation, instrument manufactories with different rates are used. Next, a brief discussion of the options and characteristics of utmost typical instrument trans. types isgiven.

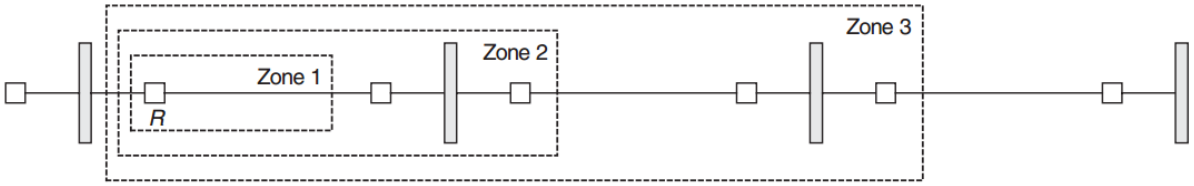


Figure 5 Selection of the Overlapping Zones for Transmission Line Protection

Section 3 Relaying Systems, Principles, and Criteria of Operation

This section describes rudiments of a relaying system and defines the introductory conception of a relaying scheme. In addition, the introductory principles of defensive relaying operation are bandied. Further detailed conversations of each of the relaying results using the mentioned principles aimed at guarding different power system factors are outlined in posterior sections.

3.1 Components of a Relaying System

Each relaying system consists, as a minimum, of an instrument transformer, relay, and a circuit breaker. A typical connection for protection of high- voltage transmission lines using distance relays is shown in Figure 6. In the case of Figure 6, since the relay measures the impedance (which is commensurable to distance), both current and voltage instrument mills are used. The relay is used to cover the transmission line, and it's connected to a circuit breaker at one end of the line. The other end of the line has another relay guarding the same line by operating the breaker at that end. In a case of a fault, both relays need to operate, causing the corresponding breaker to open and performing in the transmission line being removed from service. The part of instrument mills is to give galvanic insulation and metamorphosis of the signal energy situations between the relay connected to the secondary side and the voltages and currents connected to the primary side. The original current and voltage signal situations endured at the outstations of the power system factors are generally much advanced than the situations used at the input of a relay. To accommodate the demanded metamorphosis, instrument mills with different rates are used.

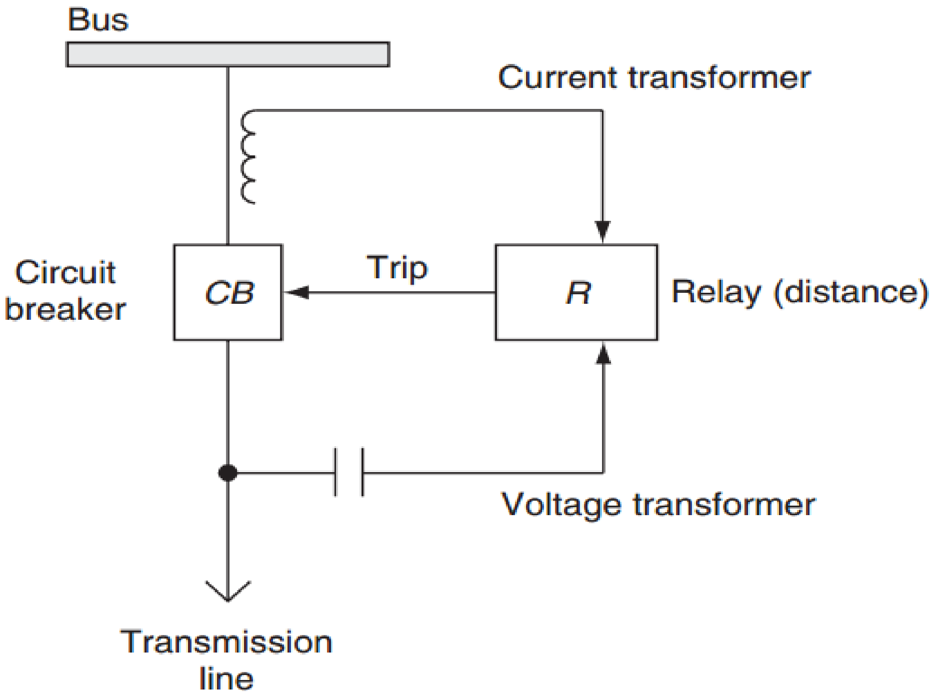


Figure 6 Protective Relaying System Consisting of Instrument Transformers, a Relay, and a Breaker

Current Transformer

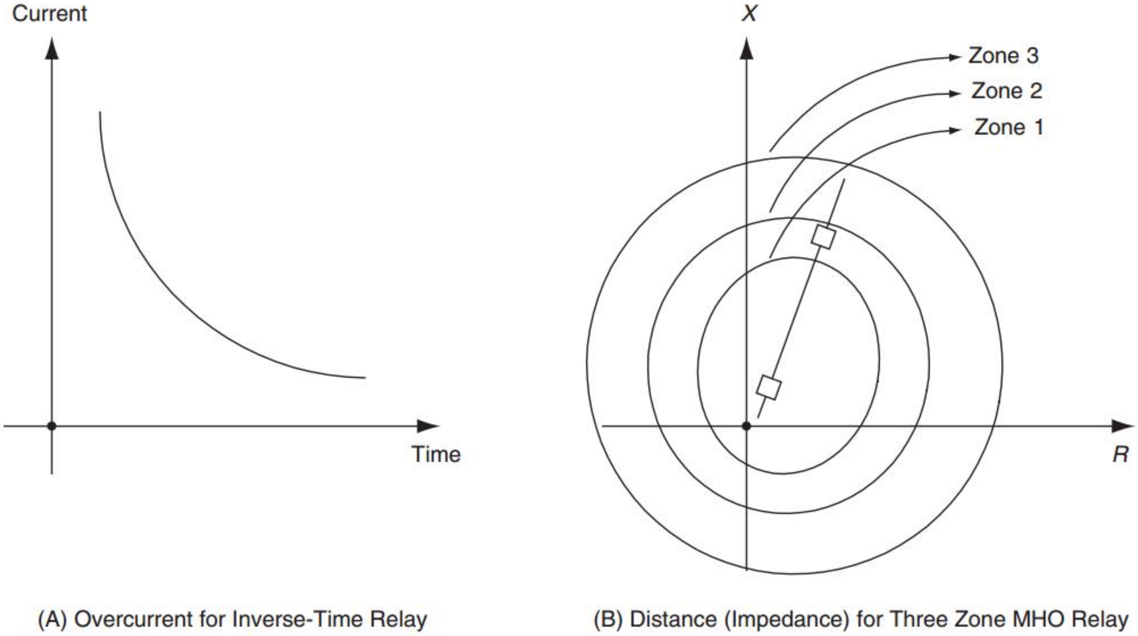
Current trans. (*CTs) is* used to reduce the current situations from thousands of amperes down to a standard affair of either 5 A or 1 A for normal operation. During faults, the current situations at the transformer outstations can go up several orders of magnitude. Utmost of the current mills in use moment are simple magnetically coupled iron- core mills. They're input/ affair bias operating with a hysteresis of the glamorous circuit and, as similar, are prone to achromatism. The selection of instrument mills is critical for icing a correct defensive relaying operation. They need to be sized meetly to help saturation. However, If there's no saturation. Instrument mills will operate in a direct region, and their introductory function may be represented via a simple turn’s rate. Indeed, though this is an ideal situation, it can be assumed to be true for calculating simple relaying interfacing conditions. If a remnant captivation is present in an instrument transformer core, also the hysteresis may affect the time demanded to souse coming time the transformer gets exposed to inordinate fault signals. The current mills come as free- standing results or as a part of the circuit breaker or power transformer design. If they come preinstalled with the power system outfit, they're located in the bushings of that piece of outfit.

Voltage Transformer

Voltage transformers come in two introductory results implicit transformer (PT) with iron core construction and capacitor coupling voltage transformers (CVTs) that use a capacitor coupling principle to lower the voltage position first and also use the iron- core transformer to get farther reduction in voltage. Both transformer types are generally free- standing. PTs are used constantly to measure voltages at substation busses, whereas CVTs may be used for the same dimension purpose on individual transmission lines. Since the voltage situations in the power system range well beyond kilovolt values, the transformers are used to bring the voltages down to a respectable position used by defensive relays. They come in standard results regarding the secondary voltage, generally 69.3 V or 120 V, depending if either the line- to- ground or line- to- line volume is measured independently. In an ideal case, both types of instrument transformers are assumed to be operating as voltage separations, and the transformation is commensurable to their turn’s rate. In practice, both designs may witness specific diversions from the ideal case. In PTs, this may manifest as a nonlinear behavior caused by the goods of the hysteresis. In CVTs, the abnormalities include colorful ringing goods

Relays

Another element shown in Figure 6 is the relay itself. Relays are regulators that measure input amounts and compare them to thresholds, generally called relay settings, which in turn define operating characteristics. The relay characteristics may be relatively different depending on the relaying volume used and the relaying principle employed. Many different operating characteristics of colorful relays are shown in Figure 7. The first one is for the relay operating using an overcurrent principle with an inverse time- detention applied for different situations of input current. The alternate bone is used by transmission line relays that operate using an impedance (distance) principle with the time- step zone perpetration. Farther discussion of the specific relaying principles will be given latterly. In general, the relay action is grounded on a comparison between the measured volume and the operating specific. Once the characteristic thresholds settings) are exceeded, the relay assumes that this is caused by the faults affecting the measuring volume, and it issues a command to operate associated circuit breaker (s). This action is generally nominated as a relay tripping, meaning opening a circuit breaker. The relays may come in different designs and perpetration technologies. The number of different designs at the early days when the relaying was constructed was rather small, and the main technology was the electromechanical bone. Moment's design options are important wider with a number of different relay perpetration approaches being possible. This is all due to a great inflexibility of the microprocessor- grounded technology nearly simply used to make relays moment. Since the microprocessor-grounded relays use veritably low- position voltage signal at inputs to the signal dimension circuitry, all these relays have supplementary transformers at the front-end to scale down the input signal situations indeed further from what's available at the secondary of an instrument transformer. To accommodate specific requirements and give different situations of the relay input amounts, some of the relay designs come with multiple connections of the supplementary transformers called gates. Opting applicable valve determines a specific turn's rate for the supplementary transformer that allows more precise selection of the specific position of the relay input signal. Besides the voltage and/ or current signals as inputs and trip signals as labors, the relays have a number of input/ affair connections aimed at other functions collaboration with other relays, communication with relays and drivers, and monitoring. For an electronic relay, a connection to the power force also exists.



(A) Overcurrent for Inverse-Time Relay

(B) Distance (Impedance) for Three Zone MHO Relay

Figure 7 Typical Relay-Operating Characteristic

Circuit Breaker

The last element in the introductory relaying system is the circuit breaker. The breaker allows interruption of the current inflow, which is demanded if the fault is detected and a tripping command is issued by the relay. Circuit breaker operate grounded on different principles associated with physical means of interposing the inflow of power. As a result, vacuum, air- blast, and oil painting- field breaker is generally used depending on the voltage position and needed speed of operation. All breaker tries to descry the zero crossing of the current and intrude the inflow at that time since the energy position to be intruded is at a minimum. The breaker frequently does not succeed in making the interruption during the first attempt and, as a result, several cycles of the abecedarian frequency current signal may be demanded to fully intrude the current inflow. This affects the speed of the breaker operation. The fastest breaker used at the high- voltage situations are one cycle combers, whereas a typical breaker used at the lower voltage situations may take (20 to 50) cycles to open. Cct breaker is initiated by the relays to dissociate the power system element in the case a fault is present on the element. In the case of the transmission line faults, numerous faults are temporary in nature. To distinguish between endless and temporary faults on transmission lines, the conception of breaker auto reclosing is used. It assumes that once the breaker is tripped (opened) by the relay, it'll stay open for a while, and also, it'll automatically reclose. This action allows the relays to corroborate if the fault is still present and, if so, to trip the breaker again. In the case the fault has wilt, the relays will not act, and the transmission line will remain in work. The auto reclosing function may be enforced relatively else depending on the particular requirements. The main options are to have a single or multiple reclosing attempts and to operate either a single pole or all three poles of the breaker. Cct. breaker is also relatively frequently equipped with supplementary relays called breaker failure (BF) relays. If the breaker fails to open when called upon, the BF relay will initiate operation of other circuit breaker that will dissociate the blamed element, relatively frequently at the expenditure of decoupling some fresh healthy factors. This may be observed in Figure 3 once a transmission line relay operates the two breakers in the transmission line bay and one of the breakers fails to operate, the BF relay will dissociate all the breaker on the machine side where the failed breaker is connected, making sure the blamed line is disconnected from the machine.

3.2 Basic Relaying Principles

When considering protection of the most common power system factors, videlicet generator, power transformers, transmission lines, busses, and motors, only a many introductory relaying principles are used. They include overcurrent, distance, directional, and discrimination. In the case of transmission line relaying, communication channels may also be used to give exchange of information between relays located at two ends of the line. The following discussion is aimed at explaining the general parcels of the below- mentioned relaying principles. Numerous other relaying principles are also in use moment. The details may be set up in a number of excellent references on the subject. Overcurrent protection is grounded on a veritably simple premise that in utmost cases of a fault, the position of fault current dramatically increases from the pre fault value. However, as soon if one establishes a threshold well above the nominal cargocurrent.as the current exceeds the threshold, it may be assumed that a fault has passed and a trip signal may be issued. The relay grounded on this principle is called an immediate overcurrent relay, and it's in wide use for protection of radial low- voltage distribution lines, ground protection of high-voltage trans. lines, and protector of machines (motors and gen.). The main issue in applying this relaying principle is to understand the behavior of the fault current well, in particular when compared to the variation in the cargo current caused by significant changes in the connected cargo. A typical illustration where it may come delicate to distinguish the fault situations from the normal operating situations is the overcurrent protection of distribution lines with heavy oscillations of the cargo. To accommodate the mentioned difficulty, a variety of overcurrent protection operations are developed using the introductory principle as described preliminarily combined with a time detention. One approach is to give a fixed time detention, and in some cases, the time detention is commensurable to the current position. One possible relationship is an inverse bone where the time detention is small for high currents and long for lower bones.

The illustration shown before in Figure 7 describes an inverse time characteristic, which may also be a veritably or extremely inverse type. Farther variations of the overcurrent relay are associated with the use of the directional element, which is bandied latterly. The issues of coordinating overcurrent relays and guarding colorful parts of a distribution line are also bandied latterly. Distance relaying belongs to the principle of rate comparison. The rate is between the voltage and current, which in turn produces impedance. The impedance is commensurable to the distance in transmission lines, hence the ‘‘distance relaying’’ designation for the principle. This principle is primarily used for protection of high- voltage transmission lines. In this case, the overcurrent principle cannot fluently manage with the change in the direction of the inflow of power, contemporaneous with variations in the position of the current inflow, which is common in the transmission but not so common in the radial distribution lines. Computing the impedance in a 3-phase system is a bit included because each type of fault produces a different impedance statement. Because of these differences the settings of a distance relay need to be named to distinguish between the ground and phase faults. In addition, fault resistance may produce problems for distance measures because the value of the fault resistance may be delicate to prognosticate. It is specially challenging for distance relays to survey correct fault impedance when a current in- feed from the other end of the line makes an unknown voltage drop on the fault resistance. This may contribute to incorrect calculation of the impedance, called apparent impedance, ‘‘seen’’ by the relay located at one end of the line and using the current and voltage dimension just from that end. Once the impedance is reckoned, it is compared to the settings that define the operating characteristic of a relay. Grounded on the comparison, a decision is made if a fault has passed and, if so, in what zone. As mentioned before, the impedance relay may be set to fete multiple zones of protection. Due to variety of operation reasons, the operating

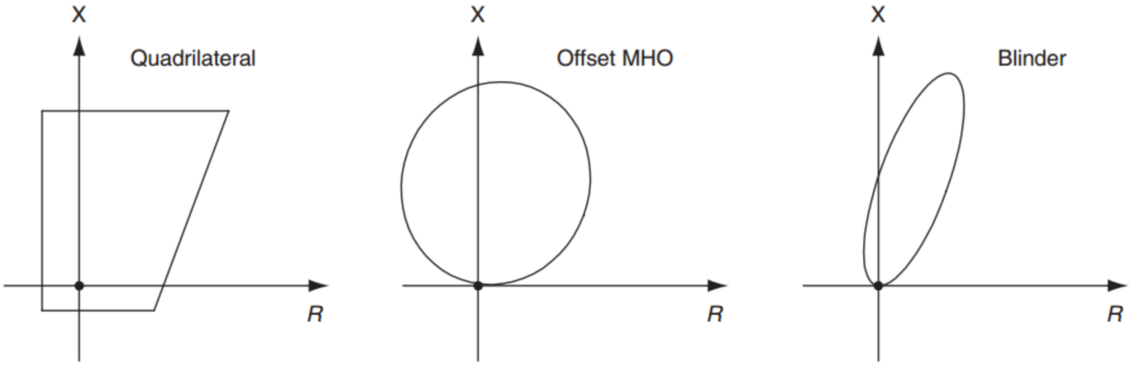


Figure 8 Operating Characteristics of a Distance Relay

Characteristics of a distance relay may have different model, the four-sided and MHO being the most usual. The different operating characteristic shapes are shown in Figure 8. The characteristics mandate relay performance for specific operation conditions, similar as the changes in the lading situations, different values of fault resistance, goods of power swings, presence of collective coupling, and reversals of fault direction. Distance relays may be used to cover a transmission line by taking the input measures from only one end of the line. Another approach is to connect two distance relays to perform the relaying as a system by swapping the data between the relays from two ends through a communication link. In this case, it's important to decide what information gets changed and how is it used. The sense that describes the approach is called a relaying scheme. Most common relaying schemes are grounded on the signals transferred by the relay from one end causing either blocking and freeing or easing and accelerating of the trip from the relay at the other end. In all of the mentioned operations, directionality of a distance relay is an important point. It'll be bandied in further detail latterly on. As an illustration of the relaying scheme operation, Figure 9 shows relaying zones used for perpetration of a blocking scheme. The zones for each relay are forward overreaching FO) and backward rear (BR). The FO setting is named so that the relay can “see” the faults being in a forward direction, looking from the relay position toward the conterminous line terminal and beyond. The BR setting is named so that the relay can “see” the faults being in the backward direction, causing a reversal of the power inflow. If the relay R1 (at position A) has “seen” the fault (at position X1) in zone FO behind the relay R2 deposited at the other end (at position B) of the line, the relay is obstructed by relay R2 from processing. Relay R2 has “seen” the fault at position X1 in a BR zone and, hence, can “tell” the relay R1 not to trip by transferring a blocking signal. Should a fault do in between the two relays (position X2), the blocking signal isn't transferred, and both relays operate presently since both relays “see” the fault in zone FO and neither in zone BR. A relaying conception extensively used for protection of busses, creators, power mills, and transmission lines is the current differential. It assumes that the currents entering and leaving the power system element are measured and compared to each other. If the input and affair currents are the same, also it means that the defended element is “healthy,” and no relaying action is taken. If the current comparison indicates that there's a compliance, which means that a difference is caused by a fault, the relay action is called upon. The difference has to be importance enough to be attributed to a fault since some normal operating situation and inaccuracy in the instrument trans. may also show a difference that isn't attributed to a fault.

Further discussion about the criteria for establishing the type and position of the difference that are typical for a fault event are presented at an after time when this relaying principle is bandied in further detail. In the case of a differential protection of transmission lines, the measured amounts need to be transferred over a communication channel to cipher the difference. Since the speed and trust ability of communication channels may play a part in the overall performance of the conception, slightly different gospel is established regarding the type of measures taken and the comparison criteria for the transmission lines versus other, more original, operations. Directionality of a relay operation is relatively important in numerous operations. It's established grounded on the angle of the denounce current with the respect to the line voltage. It can be founded for current only or for impedance. In the ultimate case, the directionality is detected by looking at the angle between the reference voltages and denounce current. In the impedance aero plane, the directionality is detected by the quadrant where the impedance falls. Whether the calculated fault impedance is in a forward (first- quadrant) or rear (third- quadrant) zone determines the directions of the fault. Generally, the zone associated with the rear direction is called a rear zone and is numbered in a sequence after the forward zones are numbered first. The directionality may also be grounded on the power computation, which in turn determines the direction of the power inflow to/ from a given power system element. Besides being used for perpetration of the transmission line relaying schemes, directionality is relatively important when applying overcurrent principle and is frequently used when enforcing colorful approaches to base protection.

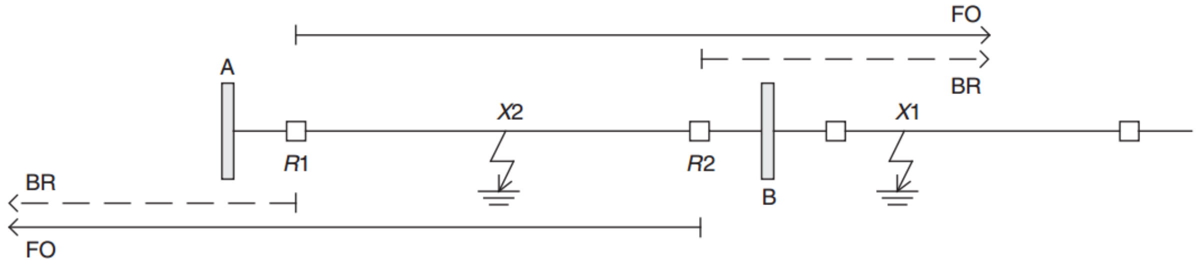


Figure 9 The Blocking Principle of Relaying with Fault Directionality Discrimination

3.3 Criteria for Operation

A number of different criteria for operation may be established, but the three most common bones are speed, responsibility/ security, and selectivity (WD G5, 1997a, b). All the criteria need to be combined in a sound engineering result to produce the desirable performance, but for the sake of clarity, each of the criteria is now bandied independently.

Speed

The speed of operation is the most critical defensive relay operating criterion. The relays have to be presto enough to allow clearing of a fault in the minimal time demanded to insure dependable and safe power system operation. The minimal operating time of a relay is achieved when the relay operates without any purposeful time detention settings. Such an illustration is the time of operation of a distance relay in a direct (immediate) trip in Zone 1. The operating time may vary from the theoretical minimum possible to the time that a practical result of a relaying algorithm may take to produce a decision. The operating time is dependent on the algorithm and technology used to apply the relay design. Because the relays respond to the fault transients, the relay operating time may vary slightly for the same relay if subordinated to the transients coming from different types of faults. The minimal respectable operating time is frequently established to make sure that the relay will operate presto enough to meet other time critical criteria. For the transmission line protection illustration, the overall time budget for clearing faults in a system is expressed grounded on the number of cycles of the abecedarian frequency voltage and current signals. This time is reckoned from the worst- case fault type persisting and potentially causing an insecurity in the overall power system. To help the insecurity from being, the fault needs to be cleared well before this critical time is reached, hence the description of the minimal fault concurrence time. The relay operating time is only a portion of this time- budget allocation. The rest is affiliated to the operation of circuit breaker and a possible multiple reclosing action that needs to be taken. The consideration also includes the breaker failure action taken in the case a breaker fails to open and other breaker get involved in clearing the fault. The relay operating time is an enough critical criterion indeed though it's allocated a veritably small portion of the mentioned fault- clearing time- budget criteria. As an illustration, the anticipated average operating time of transmission line relays in zone 1 is around one to two abecedarian frequency cycles, where one cycle duration is16.666 ms.

Dependability/ security

Security Another important operating criterion for defensive relays is responsibility/ security. It's frequently mentioned as a brace since responsibility and security are named in a trade- off mode. Responsibility is defined as the relay capability to respond to a fault by feting it each time it occurs. Security is defined as capability of a relay not to act if a disturbance isn't a fault. In nearly all the relay approaches used moment, the relays are named with a bias toward responsibility or security in such a way that one affects the other. A further reliable approach will beget the relays to over trip, the term used to designate that the relay will operate whenever there's a fault but at the expenditure of conceivably tripping indeed for non-fault events. The security emphasis will beget relays not to trip for no fault conditions but at a threat of not operating rightly when the fault occurs. The mentioned trade- off when opting the relaying approach is made by choosing different types of relaying schemes and related settings to support one or the other aspect of the relay operation. Selectivity

Selectivity

One criterion frequently used to describe how dependable a relaying scheme is relating to the relay capability to separate between a varieties of operating options it's designed for. This criterion is called relay selectivity. It may be attributed to the relay delicacy, relay settings, or, in some cases, the measuring capabilities of the relay. In all cases, it designates how well the relay has honored the fault conditions that it's designed or set to operate for. An illustration of the selectivity problem is an Incapability of a relay to rightly decide if it should operate in zone 1 or zone 2 for a fault that occurs in the region near to the set point between the zones. In this case, the relay operation may be nominated as "overreaching" or "under reaching" depending if the relay has mistaken that the fault was inside of the named zone while it was actually outside and vice versa

Section 4 Protection of Transmission Lines

The protection of transmission lines varies in the principle used and the perpetration approaches taken, depending on the voltage position. The main principles and associated perpetration issues are bandied for the following most frequent transmission line defensive relaying cases overcurrent protection of distribution radial affluent, distance protection of transmission lines and associated relaying schemes, and differential protection of transmission lines.

4.1 Overcurrent Protection of Distribution Feeders

Protection of distribution Feeder is most adequately fulfilled using the overcurrent relaying principle. In a radial configuration of the confluent, shown in Figure 10, the fault current distribution is similar that the fault currents are the loftiest for the faults closest to the source and the current decays as the fault gets further down from the source. This property allows the use of the fault current bulks as the main criterion for the relaying action. The overcurrent relaying principle is combined with the inverse- time operating characteristic, as shown in Figure 11, and this represents the relaying result for radial distribution affluent in utmost cases. The inverse- time property designates the relationship between the current magnitude and the relay operating time (the advanced the fault current magnitude, the shorter the relay operation time). Farther discussion is related to the setting procedures for the overcurrent relays with inverse- time characteristics. To embark on determination of relay settings, the following data have to be made available for an overcurrent relay either through a computation or through simple selection of design options time dial, valve (pick- up setting), and operating characteristic type; current transformer rate for each relay position; and extreme (minimal and maximum) short circuit values for fault currents. The mentioned data applied to the relaying system shown in Figure 10 are handed in Table 2. The values are determined only for relays R2 and R3 as an illustration. Analogous approaches will yield corresponding values for relay R1. The coming step is to establish the criteria for setting collaboration. The criteria named as exemplifications for relays R3 and R2 shown in Figure 10 are as these rules state

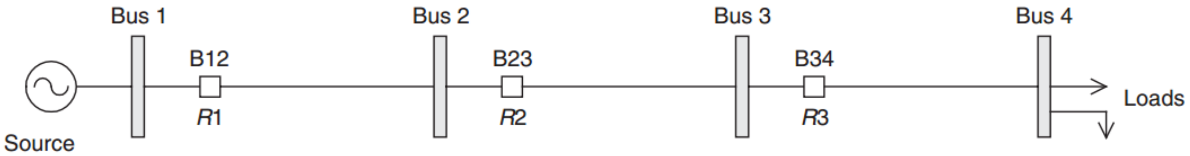


Figure 10 Protection of a Radial Distribution Feeder

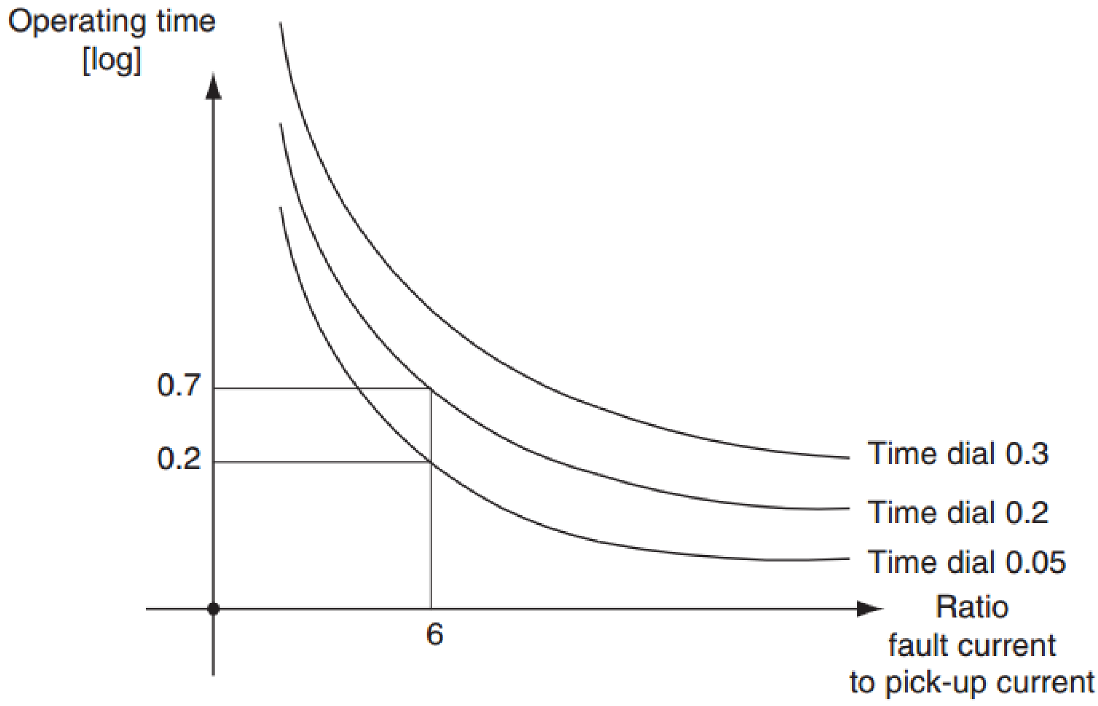


Figure 11 Inverse-Time Operating Characteristic of an Overcurrent Relay

Table 2 Data Needed for Setting Determination for the Case in Figure 10

	Bus/relay	
Max and min fault current [A]	*R2*	*R3*
Max fault current	306	200
Min fault current	250	156
CT ratio	50:5	50:5
Pick-up setting	5	5
Time-dial setting	0.2	0.05

1. R2 must pick up for a value exceeding one- third of the minimal fault current (rule of thumb) seen by relay R3(assuming this value will no way be below the maximum load current)

2. R2 must pick up for the maximum fault current seen by R3 but no sooner than0.5 sec(rule of thumb) after R3 should have picked up for that current.

Grounded on the mentioned criteria and data handed in Table, the following are the setting computation way. Step 1 Settings for Relay R3 the relay has to operate for all currents above 156A. For trust ability, one- third of the minimal fault current is named. This yields a primary fault current of156/3 ¼ 52A. Grounded on this, a CT rate of50/5 ¼ 10 is named. This yields a secondary current of52/10 ¼5.2A. To match this, the relay valve (pick- up value) is named to be5.0A. To ensure the fastest tripping for faults downstream from relay R3, the time dial of0.05 is named (see Figure 11). Step 2 Settings for Relay R2 Selection of CT rate and relay valve the relay R2 must act as a backup for relay R3, and, hence, it has to operate for the lowest fault current seen by relay R3, which is 156A. Thus, the selection of the CT rate and relay valve is the same for relay R2 as it was for relay R3. Time dial selection Grounded on the rule 2, relay R2 acting as a backup for relay R3 has to operate0.5 sec after relay R3 should have operated. This means that relay R2 has to have a detention of0.5 sec for the loftiest fault current seen by relay R3 to meet the over mentioned criteria. Let us assume that the loftiest fault current seen by relay R3 is at position next to breaker B34 looking downstream from breaker B34, and this current is equal to 306 A. In that case, the primary denounce current is equal to306/10 ¼30.6 A. The named relay valve setting will produce a pick-up current of30.6/ 5 ¼6.12 A. From Figure 9.11, the time detention corresponding to this pick- up value is0.2 sec. Hence, if relay R3 fails to operate, the relay R2 will operate as a backup with a time detention of0.2 sec þ0.5 sec ¼0.7 sec. According to Figure11, the time detention of 0.7 sec requires the selection of time dial of 0.2. It also becomes egregious that selection of a lower current for computation of the time detention of relay R3 won't allow the criteria in rule 2 to be met. The overcurrent relaying of distribution affluent is a veritably dependable relaying principle as long as the time collaboration can be achieved for the named situations of fault current as well as the given circuit breaker operating times and instrument transformer rates. The problems start being if the confluent lading changes significantly during a given period of time and/ or the position of fault currents are rather small. This may affect a proper selection of settings that will accommodate a wide- range change in the cargo and fault currents. Some other, less likely, marvels that may affect the relaying performance are as follows current transformer achromatism, selection of shy supplementary transformer gates, and large variation in the circuit breaker opening times

4.2 Distance Protection of Transmission Lines

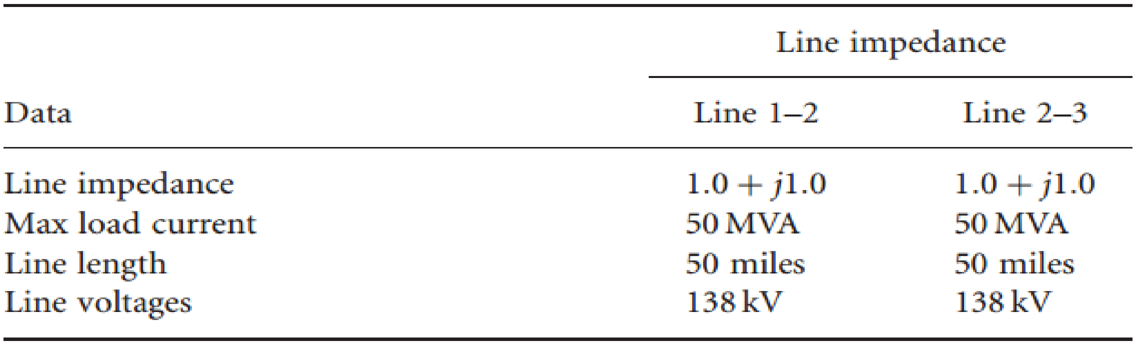
As explained before, the distance protection principle is grounded on computation of the impedance “seen” by the relay. This impedance is defined as the apparent impedance of the defended line calculated using the voltages and currents measured at the relaying point. Once the impedance is calculated, it is compared to the relay operating characteristic. If linked as falling into one of the zones, the impedance is considered as corresponding to a fault; as a result, the relay issues a trip. The conception of the impedance being commensurable to the length of the transmission line and the idea of using the relay settings to correspond to the line length lead to the cause for calling this relaying precept distance relaying. To illustrate the process of opting distance relay settings, a simple network configuration, with data given in Table 3, is considered in Figure 12. Table 3 also contains fresh information about the instrument transformer rates. The setting selection and collaboration for the illustration given in Figure 12 can be formulated as follows.

Step 1: Determination of Maximum Load Current and Selection of CT and CVT Ratios:

From the data given in Table 3, the maximum load current is

Computed as:

Table 3 Data Needed for Calculation of Settings for a Distance Relay



	Line impedance	
Data	Line 1–2	Line 2–3
Line impedance	$1.0 + j1.0$	$1.0 + j1.0$
Max load current	50 MVA	50 MVA
Line length	50 miles	50 miles
Line voltages	138 kV	138 kV

$$\frac{50(10^6)}{(\sqrt{3})(138)(10^3)} = 418.4\ \text{A}$$

The CT rate is400/5 = 80, which produces about 5 A in the secondary winding. If one assumes that the CVT secondary phase- to- ground voltage needs to be close to 69 V, also calculating the factual primary voltage and opting the rate to produce the secondary voltage close to 69 V allows one to calculate the CVT rate. The primary phase- to- ground voltage is equal to

$$138\sqrt{3}(10,000) \doteq 79.67(10,000)\ \text{V}.$$

If we allow the secondary voltage to be69.3 V, also the CVT rate can be named as

$$79.67(10,000)/69.3 = 1150/1.$$

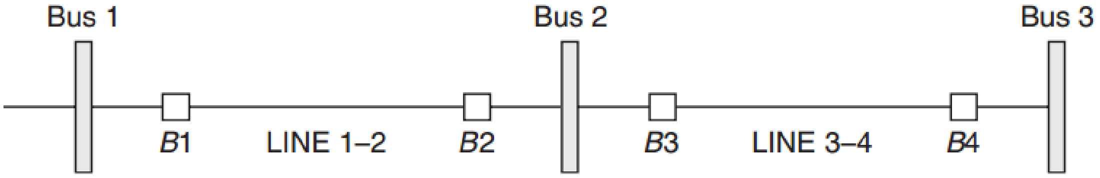


Figure 12 A Sample System for Distance Relaying Application

Step 2: Determination of the Secondary Impedance “Seen” by the Relay

The CT and CVT ratios are used to compute the impedance as follows:

$$\frac{V_p/1150}{I_p/80} = \frac{V_p}{I_p}(0.07) = Z_{\text{line}}(0.07).$$

Thus, the secondary impedance “see” by the relay is for both lines equal to 0:07 þ j0:07.

Step 3 calculation of Apparent Impedance

Apparent impedance is the impedance of the relay seen under specific lading conditions. If we elect the power factor of0.8 lagging for the named CT and CVT rates as well as the named fault current, the apparent impedance is equal to:

$$Z_{\text{load}} = \frac{69.3}{418.4\left(\frac{5}{400}\right)}(0.8 + j0.6) = 10.6 + 8.0.$$

Step 4: Selection of Zone Settings

Eventually, the zone settings can now be named by multiplying each zone's impedance by a safety factor. This factor is arbitrarily determined to be0.8 for zone 1 and1.2 for zone 2. As a result, the following settings for zone 1 and zone 2, independently, are calculated as:

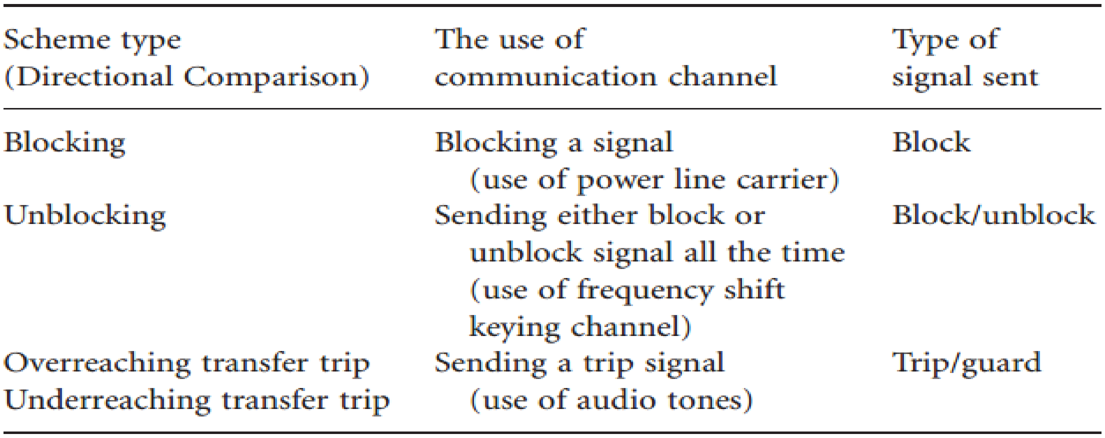
$$\text{Zone 1} \quad 0.8(0.007 + j0.7) = (0.056 + 0.56)\Omega$$
$$\text{Zone 2} \quad 1.2(0.007 + j0.7) = (0.084 + 0.84)\Omega.$$

Distance relaying of transmission lines isn't free from essential limitations and operation inscrutability. The most applicable essential limitation is the influence of the current in- feed from the other end as described before. The other resource of possible error is the fault resistance, which cannot be survey online. Thus, it has to be assumed at the time of the relay setting calculation, when a value different from what's actually present during the fault may be picked up. The anticipated value of the fault resistance is named arbitrarily and may be a cause for a gross error when calculating the impedance for a ground fault. Yet another source of error is the collective coupling between conterminous transmission line and phases, which still, can negatively affect relay operation if not taken insignificant. Adequately into account when calculating the fault impedance. The distance relaying becomes particularly delicate and occasionally unreliable if applied to some special protection case, similar as multi terminal lines, lines with series compensation, veritably short lines, and resembling lines. In all of the cases, opting relay settings is relatively involved and prone to crimes due to some arbitrary hypotheticals about the value of the fault impedance

4.3 Directional Relaying Schemes for High-Voltage Transmission Lines

Due to the essential failing of distance relays not being suitable to fete the effect of the current in- feed from the other end of the line and because of this conceivably leading to a wrong decision, the conception of a relaying scheme is developed. The conception assumes that the relays at the two ends of a transmission line will coordinate their conduct by swapping the information that they descry for the same fault. To be suitable to perform the collaboration, the relays have to use a communication channel to change the information. In an earlier discussion, illustrated in Figure 9, one of the principles for scheme protection of transmission lines was explained. A further comprehensive summary is given now. The choices among introductory relaying scheme principles are told by two factors the approach in using the communication channels and the type of information transferred over the channel. Regarding the approach for using the channels, one option is for the channels to be active during a fault, which means transferring the information all the time and making sure that the communication didn't fail.

Table 4 Summary of Basic Characteristics of Most Common Relaying Schemes



Scheme type (Directional Comparison)	The use of communication channel	Type of signal sent
Blocking	Blocking a signal (use of power line carrier)	Block
Unblocking	Sending either block or unblock signal all the time (use of frequency shift keying channel)	Block/unblock
Overreaching transfer trip Underreaching transfer trip	Sending a trip signal (use of audio tones)	Trip/guard

The other option is for the communication channels to be actuated only when a command is to be transmitted and not being actuated during other intervals or cases related to the fault. Regarding the type of information transferred, the channels are used for issuing either a blocking or a tripping signal. In the process a blocking signal is sending out, the relay from one end, after performing a decision about a fault, send an obstructing signal to the other relay. If a trip signal is used, the relay that first detects the fault sends a signal to the other end. This will make the other relay perform a trip action incontinently after it has detected a fault as well. Fresh consideration in opting the scheme relates to the type of sensors used in the relays for making the opinions about the actuality of a fault and the position of the fault with the respect to the zones. Special choices in setting up the zones are done for each scheme operation. Typical choices for the sensor types are overcurrent and/ or directional, with the zone I and/ or zone II settings being involved in the decision timber. A summary of the below considerations is given in Table 4. As with any other relaying approach, the scheme executions also have different performance criteria established. If one takes the responsibility/ security criterion (WG D5, 1997; WG, 1981) as the guiding factor in making the opinions, also the property of the colorful relaying scheme results can be classified as follows:

1. Blocking freeing the blocking result tends to give advanced responsibility than security. Failure to establish a blocking signal from a remote end can affect in overt ripping for external faults. The freeing result offers a good concession of both high responsibility (channel not needed to trip) and high security (blocking is nonstop).

2. Transfer trip (overreaching/ under reaching) the transfer trip outcome offers promote security than responsibility. A failure to admit the channel signal results in a failure to trip for internal faults. The transfer trip systems bear redundant sense for internal- trip operation at an original terminal when the remote terminal breaker is open or for a “weak infeed” when the fault donation is too low to shoot a trip signal. This is not a problem with blocking and freeing systems. The options for

scheme protection perpetration are important more involved than what has been bandied then.

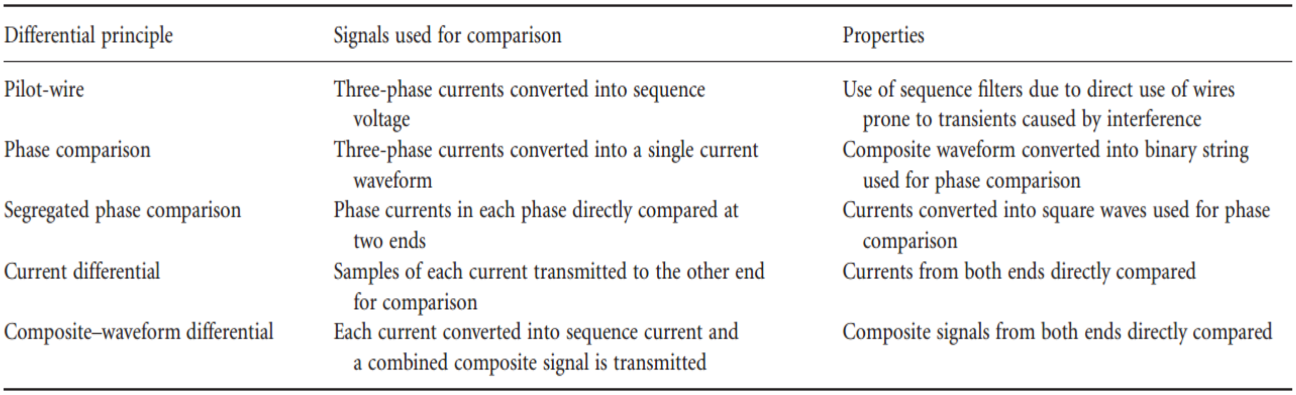
4.4 Differential Relaying of High-Voltage Transmission Lines

In the cases when the over- mentioned relaying schemes are not sufficiently effective, a differential scheme may be used to cover high voltage (HV) transmission lines. In this type of relaying, the measures from two (or multiple) ends of a transmission line are compared. Transmitting the dimension from one end to the other enables the comparison. The decision to trip is made once the comparison indicates a significant difference between the measures taken at the transmission line end (s). The main reason for introducing differential relaying is the capability to give 100 protection of transmission lines; at the same time, the influence of the rest of the system is minimum. The scheme has primarily been used for high- voltage transmission lines that have a strategic significance or have some delicate operation conditions similar as series compensation or multi terminal configuration. The use of a communication system is demanded for perpetration of this approach. This may be considered a disadvantage due to the increased cost and possibility for the channel conking. The bracket of the being approaches can be grounded on two main design parcels the type of the communication media used and the type of the measures compared. The communication media most generally used are metallic line, also known as airman- line; leased telephone lines; microwave oven radio; and fiber-optical lines. The measures generally used for the scheme are compound values attained by combining several signal measures at a given end and sample- by-sample values of the phase currents. A summary of the most common approaches for the differential relaying principle for transmission lines is given in Table 4. In the history, the most common approach was to use metallic line to compare the sequence values. The sequence values are a particular representation of the three- phase original values attained through a symmetrical element metamorphosis. Due to a number of practical problems caused by the ground implicit rise and limited length of the physical line endured with the metallic line use, these schemes have been substituted by other approaches where different media similar as fiber- optic or microwave oven links are used. Most lately, as the wideband communication channels have come more affordable, the differential schemes are being enforced using either devoted fiber- optical lines or a high- speed leased wideband communication system.

Section 5 Protection of Power Transformers

For power transformers, the current differential relaying principle is the most common bone used. In addition, other types of protection are enforced, similar as an unforeseen pressure relay on the units with large conditions. As much as the current differential relaying has been a important approach in the history, it has some essential limitations that pose difficulties for special operations or practical design considerations. Farther discussion concentrates on the mentioned limitations and their impact on the current discrimination approaches. The other relaying principles applied for guarding power transformers aren't bandied then.

Table 5 Summary of Most Common Differential Relaying Principles



Differential principle	Signals used for comparison	Properties
Pilot-wire	Three-phase currents converted into sequence voltage	Use of sequence filters due to direct use of wires prone to transients caused by interference
Phase comparison	Three-phase currents converted into a single current waveform	Composite waveform converted into binary string used for phase comparison
Segregated phase comparison	Phase currents in each phase directly compared at two ends	Currents converted into square waves used for phase comparison
Current differential	Samples of each current transmitted to the other end for comparison	Currents from both ends directly compared
Composite–waveform differential	Each current converted into sequence current and a combined composite signal is transmitted	Composite signals from both ends directly compared

5.1 Operating Conditions: Misleading Behavior of Differential Current

Power transformers are energy storehouse devices that experience transient behavior of the terminal conditions when the stored energy is suddenly changed. Similar conditions may be seen during transformer energization, energization of a resemblant transformer, junking of a near external fault, and an unforeseen increase in the terminal voltage. The following is a discussion of the mentioned marvels and the impact they've on the terminal currents. Amping a transformer causes a flash behavior of the currents at the transformer primary due to so- called magnetizing flux current. As a voltage is applied on a disburdened transformer, the nonlinear nature of the bewitching inductance of the transformer causes the bewitching current to experience an original value as high as 8 – 30 times the full- cargo current, which may appear to the differential scheme as a difference caused by a fault. An illustration of the harmonious flux surge shape for the bewitching current is given in Figure 13. Fortunately, the inrush current has a rich harmonious content, which can be used as the base for distinguishing between the high currents caused by a fault and the bones caused by the flux. Since the bewitching flux is a function of both the previous history of remnant captivation as well as the type of the transformer connection, opting the scheme for feting proper situations of the harmonics needs to be carried out precisely. Analogous flash behavior of the primary current is seen in a transformer connected in resemblant to a motor that's being reenergized. The change in the bewitching current is affecting the primary current of the resemblant transformer due to a flux created on the transformer being amped. This miracle is called sympathetic flux. Unforeseen junking of an external fault and an unforeseen increase in the transformer voltage also beget the flux miracle, again well honored by a circumstance of particular harmonics in the primary current.

5.2 Implementation Impacts Causing Misleading Behavior of Differential Current

The current differential bear for power transformer operations may be affected by practical perpetration constraints.

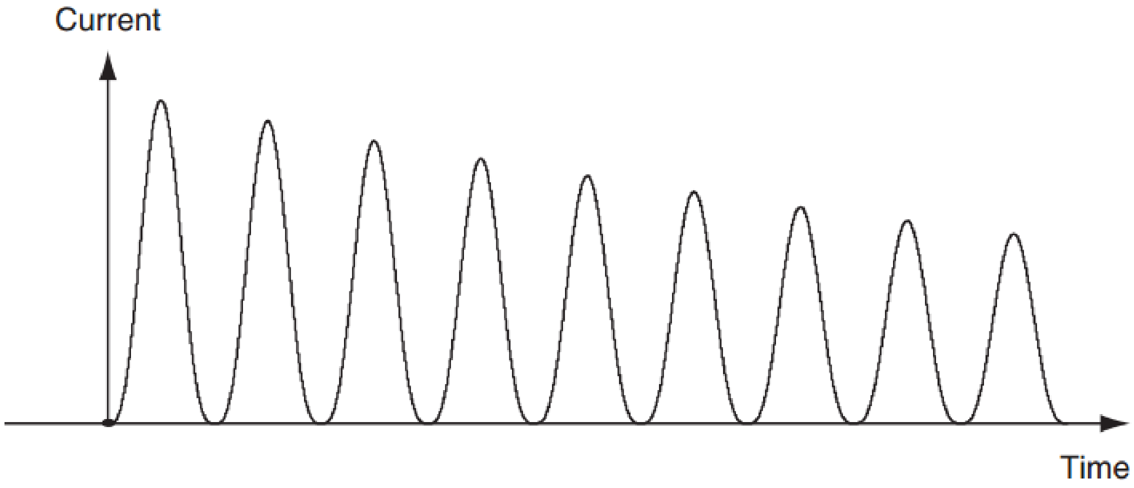


Figure 13 Magnetizing Inrush Affecting Primary Current

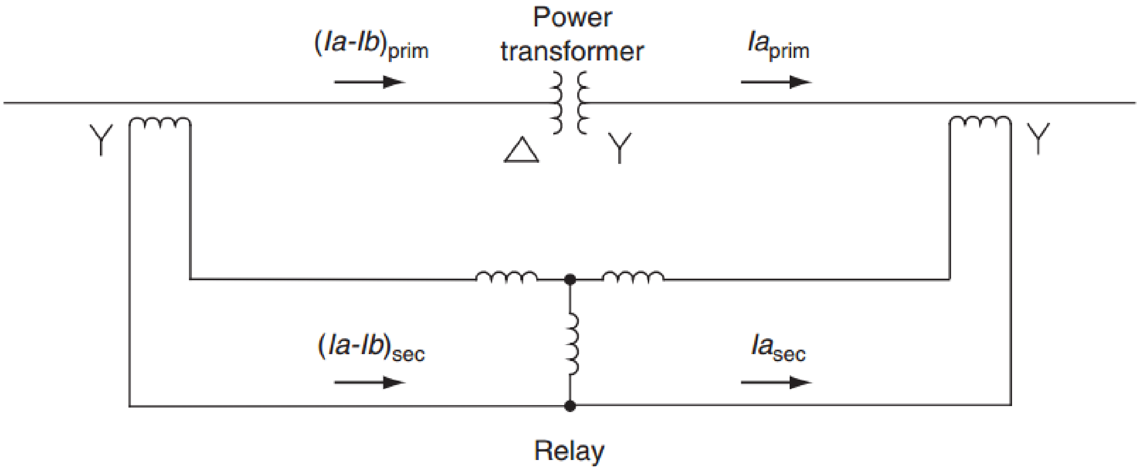


Figure 14 Phase Mismatch

One of the common problems is to have a mismatch between rates of the instrument transformers located at the two power transformer outstations. This is called a rate mismatch, and it is corrected by opting applicable gates on the supplementary mills located at the inputs of the transformer differential relay. Yet another handicap may be a phase mismatch, where the instrument transformer connection may beget a phase shift between the two currents seen at the transformer outstations. This is because the connection of the power transformer may introduce a phase shift, and if the instrument transformer doesn't correct for this, a phase mismatch will do at the outstations of the instrument transformer. The phase mismatch is illustrated in Figure 14, where the currents in the relaying circuit aren't rightly named. The mismatch can be avoided if the instrument transformer at the Y side of the power transformer is of a D type. Besides the mentioned constraints, other constraints include the mismatch due to a changing valve position on the cargo valve changer as well as the mismatch caused by the crimes in current transformers located at two outstations.

5.3 Current Differential Relaying solutions

The straightforward result for differential relaying is to take a difference of currents I1 and I2 at two ends and compare it to a threshold IT as shown in equation:

$$|(I_1 - I_2)| \geq I_T.$$

This result will have a problem to accommodate an error due to a mismatch bandied before. Hence, a different equation may be used to make sure that a advanced error is allowed for advanced current level

$$|(I_1 - I_2)| \geq \frac{|(I_1 - I_2)|}{2}.$$

Eventually, to distinguish the case of the flux condition mentioned before, a harmonious restraint scheme is used as represented by equation:

$$|(I_1 - I_2)| \geq k \cdot \frac{|(I_1 - I_2)|}{2}.$$

This type of operating characteristic will fete that the current difference is caused by an event that isn't an internal fault, and it'll block the relay from operating. The criterion for feting a non-fault event is the presence of a particular harmonious content in the differential current. This knowledge is used to restrain the relay operation by relating the factor k to the presence of the harmonious content, hence the “harmonious restraint” language.

Section 6 Protection of Synchronous Generators

Synchronous generators are generally used in high- voltage power systems to induce electric power. They're also defended using the current discrimination relaying principle. In addition, the gen. bears a number of other special operating conditions to be met. This bullet to the use of a debt of other relaying precept. This section reviews some introductory conditions for gen. protection and discusses the introductory relaying principles used.

6.1 Requirements for Synchronous Generator Protection

Generators need to be defended from the internal faults as well as the abnormal operating conditions. Since generators correspond of two corridors, videlicet the stator and the rotor, protection of both is needed. The stator is defended from both phase and ground faults, while the rotor is defended against ground faults and loss of field excitation. Due to the particular conditions needed for the coetaneous machine to operate, a number of operating conditions that represent either a power system disturbance or functional hazard need to be avoided. The conditions associated with network disturbances are overvoltage or undervoltage, unstable currents, network frequency divagation, and sub synchronous oscillations. The conditions of dangerous operation are loss of high transport more known as generator motoring), unintentional energization causing a no synchronized connection, load, out of- step or loss of coincidence, and operation at unhallowed frequentness.

6.2 Protection Principles Used for Synchronous Generators

The current differential protection principle is most generally used to cover against phase faults on the stator, which are the most common faults. Other conditions bear other principles to be used. The losing of field and the ground protection of the rotor are proportionately composite and rely on the type of the grounding and current seeing arrangement applied. This subject is well beyond the introductory considerations and is treated in a variety of technical literature. Protection from the abnormal generator operating condition requires the use of relaying principles grounded on discovery of the changes in voltage, current, power, or frequency. A rear power relay is used to cover against loss of a high transport known as generator motoring, which is a dangerous condition since it can beget damage of the turbine and turbine blades. In addition, coetaneous generators shouldn't be subordinated to an overvoltage. With normal operation near the knee of the iron achromatism wind, small overvoltage's affect in inordinate flux consistence and abnormal flux patterns, which can beget expansive structural damage in the machine. A relaying principle grounded on the rate between voltage and frequency, called a volt- per- hertz principle, is used to descry this condition. An unintentional connection of the generator to the power system not meeting the synchronization conditions can also beget damage. The overcurrent relaying principle in combination with the rear power principle are used to descry similar conditions. The load conditions as well as over and under- frequency operations can beget damage from overheating, and thermal relays in combination with frequency relays are used. Under voltage and overvoltage protections are used for detecting loss of coincidence and overvoltage conditions.

Section 7 Bus Protection

Guarding substation busses is a veritably important task because operation of the entire substation depends on vacuity of the busses. The bus faults are rare, but in the open- air substations, they sometimes be. They've to be cleared veritably presto due to high- fault current inflow that can damage the bus. This section briefly discusses the conditions and introductory principles used for bus protection.

7.1 Requirements for Bus Protection

High- voltage substations generally have at least two busses one at one voltage position and the other at a different voltage position with power transformer (s) connecting them. In high- voltage substations, the breaker- and-a-half arrangement, shown before in Figure 3, is used to give a spare bus connection at each voltage position. In addition, in some substation arrangements, there's a provision for separating one portion of the bus from another, allowing for independent operation of the two parts. All of those configurations are important when defining the bus protection conditions. The first and foremost demand for machine protection is the speed of relay operation. There are several important reasons for that all relate to the fact that the fault currents are enough grandly. First, the current transformers used to measure the currents may get impregnated; hence, a fast operation will allow for the relaying decision to be made before this happens. Next, due to the high currents, the outfit damage caused by a sustained fault may be enough severe. Hence, the need to negotiate an insulation of the blamed bus from the rest of the system in the shortest time possible is consummate. Last, but not least, due to the colorful possibilities in reconfiguring busses, it's veritably important that the bus protection scheme is developed and enforced in a flexible way. It needs to allow for colorful corridor of the bus to be insulated for conservation purposes related to the breaker on the connected lines, and yet the protection for the rest of the bus needs to stay complete.,

7.2 Protection Principles Used for Bus Protection

The most usual bus protection law is the current differential approach. All connections to the bus are covered through current transformers to descry current imbalance. However, the balance between If an internal bus fault occurs. Incoming and gregarious currents is drastically disturbed, and that becomes a criterion for tripping the bus breakers and segregating the bus from the rest of the system. This relaying principle would be veritably simple to apply if there were no problems with CT achromatism. Because of high- fault currents, one of the CTs may see extraordinarily high currents during a close in external fault. This may beget the CT to souse, making it veritably delicate to distinguish if the CT was impregnated due to high currents from an internal or external fault. However, the achromatism may not be an issue, and the If air- gap or air core CTs are used. Current differential relaying is fluently applied. This result is more expensive and is used far less constantly than the result using standard iron- core CTs. To manage with the CT achromatism, two types of relaying results are most generally used. The first one is a Multi restraint current differential, and the other one is a high- impedance voltage differential. The Multi restraint current differential scheme provides the restraint winding connection to each circuit that's a major source of the fault current. These schemes are designed to restrain rightly for heavy faults just outside the differential zone, with maximum neutralize current, as long as the CTs don't souse for the maximum symmetrical current. These schemes are more delicate to apply and bear use of supplementary CTs to match the current transformer rates. The high-impedance voltage differential law uses a possessions that CTs, when loaded with high impedance, will be powered to get the error differential current, and, this current won't flow through the relay operating coil. This principle translates the current differential perceptivity problem is to the voltage differential perceptivity problem for distinguishing the close- in faults from the bus faults. The voltage differential scheme is easier to apply since the worst-case voltage for external faults can be determined important more precisely knowing the open voltage of the CT.

Section 8 Protection of Induction Motors

Induction motors are a veritably common type of load. The main behavioral patterns of the induction motor are representative of the patterns of numerous loads; their operation depends on the conditions of the network that's supplying the power as well as the loading conditions. This section gives a brief discussion on the most important relaying conditions as well as the most common relaying principles that apply to the induction motor protection.

8.1 Requirements for Induction Motor Protection

The conditions may be divided in three orders guarding the motor from faults, avoiding thermal damage, and sustaining abnormal operating conditions. The protection from faults has to descry both phase and ground faults. The thermal damage may come from a load or locked rotor and has to be detected by relating the rise in the temperature to the circumstance of the inordinate currents. The abnormal operating conditions that need to be detected are unstable operation, under voltage or overvoltage, reversed phases, high speed reclosing, unusual ambient temperature, voltage and deficient starting sequence. The protection principle used has to separate the causes of problems that may affect in a damage to the motor. Once the causes are detected and linked to implicit problems, the motor needs to be snappily dissociated to avoid any damage.

8.2 Protection Principles Used for Induction Motor Protection

The most common relaying principles used for induction motor protection are the overcurrent protection and thermal protection. The overcurrent protection needs to be duly set to separate between colorful changes in the currents caused either by faults or inordinate starting conditions. A variety of current- grounded principles can be used to apply different protection tasks that fit the motor design parcels. Both the phase and ground overcurrent’s, as well as the differential current relays, are generally used for detecting the phase and ground faults. The thermal relays are available in several forms a ‘‘replica’’ type, where the motor- heating characteristics are approached nearly with a bimetallic element behavior; resistance temperature sensors bedded in the motor winding; and relays that process on a combination of current and temperature varies.

Conclusion

The aim of power system protection is to insulate a defective section of electrical power system from rest of the live system so that the rest portion can serve satisfactorily without any severe damage due to fault current. Actually cct. breaker isolates the defective system from rest of the healthy system and these cct. breakers automatically open during fault condition due to its trip signal which comes from protection relay. The main gospel about protection is that no protection of power system can help the inflow of fault current through the system, it only can help the durability of flowing of fault current in snappily dissociate the short circuit path from the system. For providing this quick disposition the protection relays should have concerning functional conditions.

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