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Review on Directional Protection for Long Transmission Line

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Abstract- This abstract illustrates distance protection scheme for high voltage power transmission line by using Principal Component Analysis (PCA) and Ensemble Decision Tree (EDT) methods. Discrimination between internal, external fault and power swing condition is a very interesting task in transmission line distance protection scheme due to large power system parameter variations and their complex structure. Therefore, instead of impedance or amplitude of current or voltage based approach this work used directional comparison based modified permissive overreach transfer trip (POTT) based approach that uses waveform of local end three phase voltages and currents and remote ends tripping signal which uses minimal bandwidth communication channel, and then PCA is used to reduce the dimensions of these voltages and currents samples that is utilized to train and test different EDTs for detection of internal, external faults and power swings, and it also provide EDT based backup protection in case of a communication failure that uses only local ends voltages and currents for protection. The power transmission line is modelled in PSCAD/EMTDC software to obtain the relaying under different operating conditions. The proposed algorithm will be evaluated in MATLAB under different operating conditions during Power Transfer and the tested data will be simulated in PSCAD/EMTDC by varying inception angle, fault location, fault resistances, power angle and fault types.

Indexed Terms- Principal Component Analysis (PCA), Ensemble Decision Tree (EDT), permissive overreach transfer trip (POTT).

I. INTRODUCTION

As the length of electrical power transmission line is generally long enough and it runs through open atmosphere, the probability of occurring fault in electrical power transmission line is much higher than that of electrical power transformers and alternators. That is why a transmission line requires much more protective schemes than a transformer and an alternator. The protection should be fast and reliable. Proper continuous monitoring of power transmission line can provide early warning of electrical failure and can prevent catastrophic losses. It can minimize damages and enhance the reliability of power supply. Accordingly, high expectations are imposed on power transmission line protective relays. Expectations from protective relays include simplicity, selectivity, sensitivity, security (no false tripping) and speed of operation (short fault clearing time) [1], [2]. Distance protection scheme is generally used as the primary protection of high voltage transmission line, where the value of measured impedance is less than the reach impedance indicates an internal fault. But the directional comparison using permissive overreach transfer trip using low bandwidth communication scheme provides better protection than distance protection. Transmission lines extend in large area. So, the probability of faults is much higher than other power system elements. Normally overcurrent relay is used for its protection in case of distribution lines fed from one side. But with time the power system is getting complex with addition of generation units and needs readjustment when system changes. In case of multiple overcurrent relays proper coordination is needed, but it makes the overcurrent relay located at one end slower. There is a delay of 0.1 to 1 sec in the operation of overcurrent relays which makes the power system susceptible to failure and lose stability [1]. Distance relays are used in transmission lines to overcome this problem. But distance relays mal-operates due to high fault resistance and arc faults and misjudges the zone of operation. Also, underreach and overreach of distance are common problems encountered in distance relays. Moreover, because of static and dynamic encroachment (power swings) the impedance falls in the zone of protection relays and the relay mal-operates [1] [3] [7] [8].

Although the differential relay has simple and explicit principle for fault detection, inherent selectivity and suitable sensitivity it suffers from four basic problem. The first one is the line charging current due to distributed shunt capacitance. The second one is the current transformer inaccuracy and the saturation of the core due to the dc offset current. The third one is the approximate delay equalization between local and remote end and the fourth one is the reliability of a communication link [2] [9] [10]. Also, it is encounter that in all fault types in transmission line 80% faults are single line to ground faults, 10% faults are two phases to ground fault, 2% faults are three phase faults and only 8% faults are isolated two-phase faults. So, 90-92% of the fault comes under ground fault this thesis presents an algorithm for ground fault detection [11] [12].

This research uses an intelligent scheme to overcome these shortcomings of distance relays and proposes a more secure and dependable protection system. The following subsection describe this in details:

1.1 Power transmission line

Transmission lines are a vital part of the electrical distribution system, as they provide the path to transfer power between generation and load. Transmission lines operate at voltage levels from 69kV to 765kV, and are ideally tightly interconnected for reliable operation.

Figure 1.1 shows the basic single line diagram of the model to be study. That has three generators, nine buses, three loads and six transmission line. Where Relay-9 and relay-6 are located at bus-9 and bus-6 for the protection of transmission line between bus-9 and bus-6.

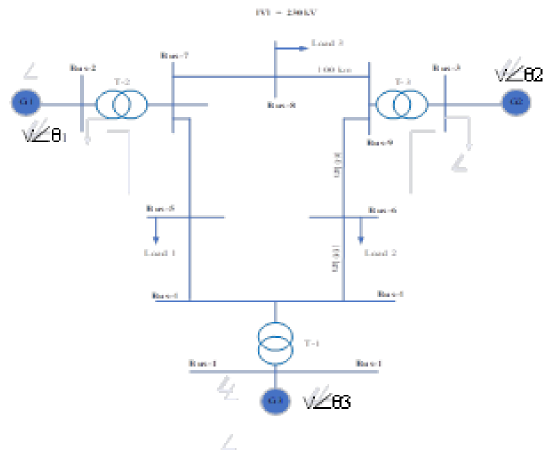

Figure.1. 230kV Single line model to be study

1.2 Operating conditions on power transmission line protection:

In this section different operating conditions of the power transmission line protection will be discussed briefly. This operating condition can be categorized in the following ways:

Normal operating mode is the one when source supplies the power to the load without interruption. It can be said that the power system is in the healthy condition. In this case rated or less than rated current flows in the transmission line, that means load could varies.

External fault is the one which occur outside of the protection zone of the relay. It could be LG, LL, LLG, LLL or LLLG fault. In this case huge amount of current above rated current flows in the power system. Internal fault is the one when transmission line gets braked and falls in ground or whenever arc induces between two phases of the line. The types of internal fault are LG, LL, LLG, LLL, LLLG and TT fault. In this case huge amount of current above rated current flows in the power system.

Power swings are oscillations in active and reactive power caused by load variation, clearing of faults and generator disconnection [3].

1.3 Transmission line protection relay

Basically, there exist three types of protection relay for protection of transmission line. The first relay type to be considered for transmission protection is the directional overcurrent relay. This is the same overcurrent relay, except it has been improved by the addition of a directional element. This added feature makes the directional overcurrent relay applicable to certain types of transmission protection problems in meshed networks. The second relay type to be discussed is the distance relay. This relay is immune to some of the inadequacies of the overcurrent relay, and variations of distance measuring devices are widely used for transmission protection. Third, pilot relays will be discussed and the advantages of this important class of equipment will be explored. Pilot relays add a very important and effective feature to the protective system-communication. Pilot relays at one terminal of a protected element have the advantage of being able to communicate with devices at other terminals [1].

1.3.1 Overcurrent relay

Depending upon the time of operation the overcurrent relays are categorised as follows:

- Instantaneous overcurrent relay: This is a type of overcurrent relay where intentional time delay is not provided. It works well where impedance from source to the relay terminal is small in compared with the line impedance to be protected [1].

- Inverse time-current relay (definite time): It is the one where operating time gets reduced when actuating quantity gets increase in magnitude. It is more inverse near pickup value of actuating quantity and less inverse as it increases [1] [4].

- Inverse definite minimum time (IDMT) overcurrent relay: It is one in which the operating time is approximately inversely proportional to the fault current near pick up value and becomes substantially constant slightly above the pickup value of the relay [1] [5].

- Very inverse relay: It is one in which the saturation of the core occurs at a later stage, the characteristic assumes the shape as shown in Figure 1.2 and is known as very inverse characteristic. The time-current characteristic is inverse over a greater range and after saturation tends to definite time [1] [4] [6].

- Extremely inverse relay: It is the one in which the saturation occurs at a still later stage than curve of very inverse in Figure 1.2. The equation describing the curve of extremely inverse in the figure is approximately of the form $I^2t = K$, where $I$is the operating current and t is the operating time [1] [4].

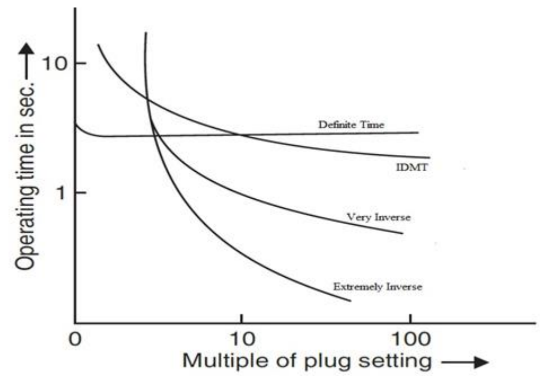

Figure.1. Overcurrent relay characteristic curve

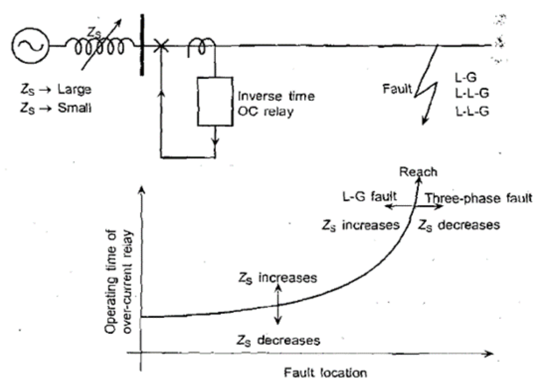

Figure.2. Fault current and reach as a function of fault types and source impedance

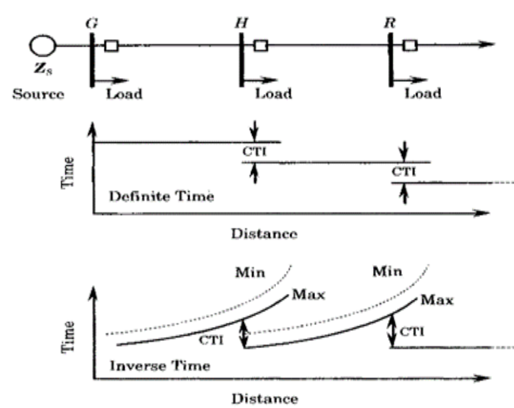

Figure.3. Coordination of overcurrent relays

1.3.2 Distance relay

Whenever over-current relaying is found slow or is not selective distance protection should be used. Since the fault currents depend upon the generating capacity and system configuration, the distance relays are preferred to the overcurrent relays. Consider Figure1.5 which consist of two-line section AB and CD; it is desired to provide distance protection scheme.

The protection scheme is divided in three zones. Say for relay at A, the three zones are Z_{1a}, Z_{2a} and Z_{3a}. Z_{1a} corresponds to approximately 80% length of the line AB and is a high-speed zone. No intentional time lag is provided for this zone. The ordinate shown corresponding to Z1a gives the operating time in case the fault takes place in this zone. It is to be noted here that the first zone is extended only up to 80% and not 100% length of the line as the relay impedance measurement will not be very accurate towards the end of the line especially when the current is offset [1].

Second zone Z_{2a} for relay at A covers remaining 20% length of the line AB and 20% of the adjoining line. In case of a fault in this section relay at A will operate when the time elapsed corresponding to the ordinate Z_{2a}.The main idea of the second zone is to provide protection for the remaining 20% section of the line AB. In case of an arcing fault in section AB which adds to the impedance of the line as seen by the relay at A, the adjustment is such that the relay at A will see that impedance in second zone and will operate. This is why the second zone is extended into the adjoining line. The operating time of the second zone is normally about 0.2 to 0.5 second [1].

The third zone unit at A provides back up protection for faults in the line CD, i.e., if there is a fault in the line CD and if for some reason the relay at C fails to operate then relay at A will provide back-up protection. The delay time for the third zone is usually 0.4 to 1.00 sec [1].

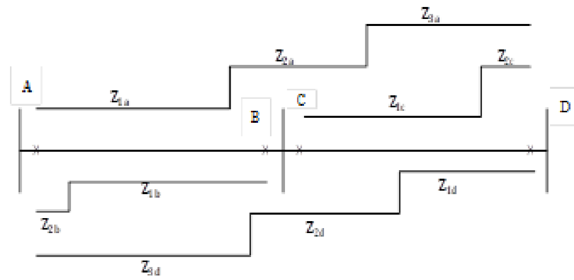

Figure.4. 3-zone protection

In case the feeder is being fed from both the ends and say the fault takes place in the second zone of line AB (20% of the line AB), the relay at B will operate instantaneously (because it lies in the first zone of BA) whereas the fault lies in the second zone of the relay at A. This is undesirable from stability point of view from stability point of view and it is desirable to avoid this delay. This is made possible when the relay at B gives an inter-trip signal to the relay at A in order to trip the breaker quickly rather waiting for zone-2 tripping.

There exist four types of distance relays as follows:

- Impedance relay: It has already been discussed that an impedance relay responds to the impedances seen by the relay. If the impedance seen by the relay is less than its setting the relay operates. The impedance relays are non-directional relays and, therefore, need a directional relay with them. The characteristic of the impedance relays with a directional unit for 3-zone protection is shown in Figure1.6 (a). While designing the relays; it is usual to make maximum torque angle τ smaller than the impedance angle θ of the line so that the effect of the arc resistance is reduced. The contact circuit for a 3-zone impedance protection is shown in Figure1.6 (b). The parallel lines in Figure1.6 represent the contacts of the various units, D-directional unit, Z_1, Z_2, Z_3 the 3-zone units, and T_2, T_3 the timing units. T_2 and T_3 are operating times for zone 2 and 3 respectively. Since Z_3 unit starts when the fault lies in any of the three zones 1, 2 or 3 as the impedance of the fault will be less than Z_3, Z_3 is the starting unit and therefore, the time unit is placed in series with Z_3 unit. Now for a fault in zone 1, all the three units will start but since the operating time of unit 1 is smallest, this will operate and the faulty section will be isolated from the source. In case the fault is in second zone, the units Z_2 and Z_3 will start but Z_2 will operate in time T_2 and isolate the faulty section from the source [1].

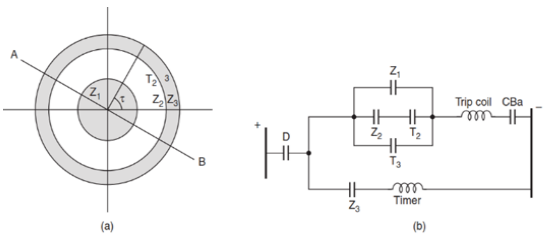

Figure.5. (a) characteristic (b) contact circuit for 3-zone impedance relay

- Reactance relay: A reactance relay responds only to the reactance component of the impedance. A reactance relay is a non-directional relay and the directional unit of the type used along with the impedance relay cannot be used for the several reasons. A mho relay is used as the starting relay along with the reactance relay in Figure 1.7 (a) shows the characteristics of the reactance relay for 3-zone protection. The mho unit prevents the operation of the reactance units under load conditions. Also, it gives protection for the 3rd zone of the scheme. The contact arrangement for 3-zone protection using reactance relays is given in Figure 1.7 (b). The operation is explained as follows: The contact circuit is connected between the d.c. supply terminals [1]. In case the fault takes place in the first zone, all the three units X_1, X_2 and S start. Since the operation of X_1 takes the least time, contact X_1 is closed. CB_a, the auxiliary contact of the circuit breaker, is a normally closed contact; therefore, trip coil gets energized which in turn operates the circuit breaker, thus isolating the faulty section of the line from the source. Similarly, the operation of the contact circuit can be explained if the fault is in zone 2 or 3.

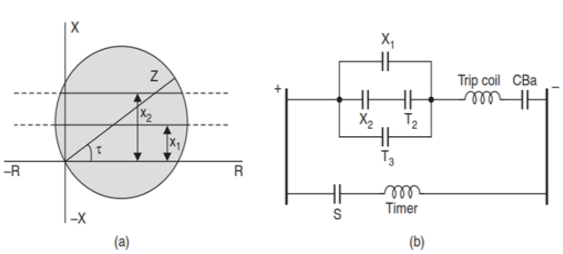

Figure.6. (a) characteristic (b) contact circuit for 3-zone reactance relay

- Mho relay: Mho relay, inherently being a directional relay, does not need additional unit for the purpose. Figure 1.8(a) shows the characteristics for 3-zone protection. The contact arrangement is shown in Figure 1.8(b). The operation of this circuit is similar to the circuit for reactance relays [1] [7].

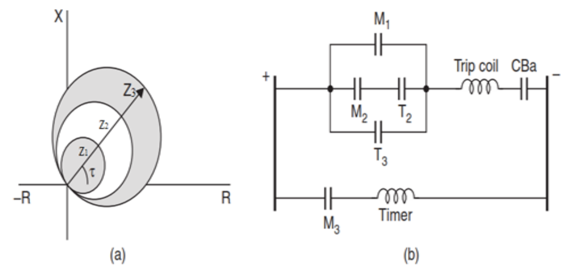

Figure.7. (a) characteristic (b) contact circuit for 3-zone mho relay

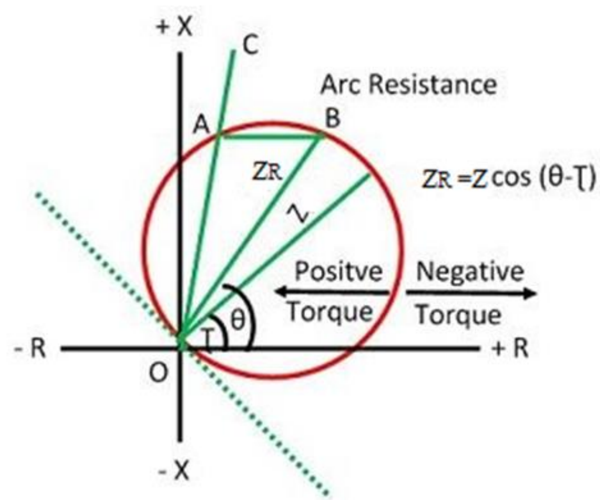

Figure.8. operating characteristics for single zone Mho relay

The operating characteristic of the mho relay is shown in the Figure1.9. The diameter of the circle is practically independent of V and I, except at a very low magnitude of the voltage and current when the spring effect is considered, which causes the diameter to decrease. The diameter of the circle is expressed by the equation as $Z= K_1 / K_2$= ohmic setting of the relay. The relay operates when the impedance seen by the relay within the circle. The operating characteristic showed that circle passes through the origin, which makes the relay naturally directional. The relay because of its naturally directional characteristic requires only one pair of contacts which makes it fast tripping for fault clearance and reduces the VA burdens on the current transformer. The impedance angle of the protected line is normally 60º and 70º which is shown by line OC in the figure [1]. The arc resistance *R* is represented by the length AB, which is horizontal to OC from the extremity of the chord *Z*. By making the τ equal to, or little less lagging than θ, the circle is made to fit around the faulty area so that the relay is insensitive to power swings and therefore particularly applicable to the protection of long or heavily loaded lines.

- Quadrilateral relay:

This form of polygonal impedance characteristic is shown in Figure 1.10. The characteristic is provided with forward reach and resistive reach settings that are independently adjustable. It therefore provides better resistive coverage than any mho-type characteristic for short lines. This is especially true for earth fault impedance measurement, where the arc resistances and fault resistance to earth contribute to the highest values of fault resistance. To avoid excessive errors in the zone reach accuracy, it is common to impose a maximum resistive reach in terms of the zone impedance reach. Recommendations in this respect can usually be found in the appropriate relay manuals [7] [8].

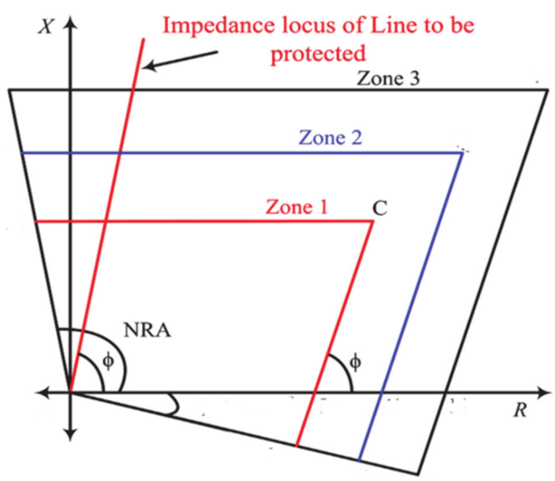

Figure.9. Quadrilateral characteristic for 3-zone protection

Quadrilateral elements with plain reactance reach lines can introduce reach error problems for resistive earth faults where the angle of total fault current differs from the angle of the current measured by the relay. This will be the case where the local and remote source voltage vectors are phase shifted with respect to each other due to pre-fault power flow. This can be overcome by selecting an alternative to use of a phase current for polarisation of the reactance reach line. Polygonal impedance characteristics are highly flexible in terms of fault impedance coverage for both phase and earth faults. For this reason, most digital and numerical distance relays now offer this form of characteristic. A further factor is that the additional cost implications of implementing this characteristic using discrete component electromechanical or early static relay technology do not arise [8].

- Effect of type of fault in calculation of fault impedances:

The impedance as seen by the relay will depend upon the type of fault, e.g., if it is a 3-phase fault, the impedance seen by the relay will correspond to the positive sequence impedance of the system and if it is a line-to-ground fault, the impedance seen will correspond to the sum of positive, negative and zero sequence impedances [1]. Thus, actually speaking, a different setting is required for each type of fault. In order that the relay has the same sensitivity for all types of faults it is required that the relay connections should be such that they measure the common impedance in all types of faults, i.e., the positive sequence impedance.

- Impedance calculation for earth faults:

Let the fault be on phase a. Since it is a line-to-ground fault, the impedance as seen by the relay will be $(Z_1+ Z_2+ Z_0)$. The voltage up to the relay point will be

$$V_r = I_{a2}Z_2 + I_{a2}Z_2 + I_{a0}Z_0 \qquad (1)$$

Also $I_a = I_{a1} + I_{a2} + I_{a0}$ and $I_a + I_b + I_c = 3I_{a0} = I_{res}$(say) where I_a, I_b and I_c are currents during the fault at the relay point and I_{res} is the residual current, V_r is the phase voltage at the relay point [1].

For a transmission line $Z_1= Z_2$; normally the zero-sequence impedance of the line is greater than positive sequence impedance. Let $Z_0= KZ_1$. Here K > 1.

$$V_r = I_{a2}Z_2 + I_{a1}Z_1 + I_{a0}KZ_1 \quad (2)$$
$$V_r = Z_1\{I_{a1} + I_{a2} + I_{a0} + (K-1)I_{a0}\} \quad (3)$$
$$V_r = Z_1\{I_a + (K-1)I_{a0}\} \quad (4)$$
$$V_r = Z_1\{I_a + (K-1)I_{res}/3\} \quad (5)$$
$$\frac{V_r}{I_a} = Z_1 + \frac{(K-1)}{3}\frac{I_{res}}{I_a} \quad (6)$$
$$Z_1 = \frac{V_r}{I_a + \frac{1}{3}(K-1)I_{res}} \quad (7)$$

From this it is clear that for the relay to respond only to positive sequence impedance the current fed to the relay is $I_a + \frac{1}{3}(K-1)I_{res}$.

Impedance calculation for phase faults (three phases, LL and LLG):

In this case the relay current and voltages are shown below, and impedance calculation is performed

Relay	Current (I_r)	Voltage (V_r)
Phase a	$I_a - I_b$	$V_a - V_b = V_{ab}$
Phase b	$I_b - I_c$	$V_b - V_c = V_{bc}$
Phase c	$I_c - I_a$	$V_c - V_a = V_{ca}$

$$V_{r1} = V_{f1} + I_{a1}Z_1 \quad (8)$$
$$V_{r2} = V_{f2} + I_{a2}Z_2 \quad (9)$$

$V_{f1} = V_{f2}$ for any type of phase faults and $Z_1 = Z_2$ for transmission line.

$$V_{r1} - V_{r2} = (I_{a1} - I_{a2})Z_1 \quad (10)$$
$$Z_1 = \frac{V_{r1} - V_{r2}}{(I_{a1} - I_{a2})} \quad (11)$$

Now using symmetrical component

$$V_b = \lambda^2 V_{a1} + \lambda V_{a2} + V_{a0} \quad (12)$$
$$V_c = \lambda V_{a1} + \lambda^2 V_{a2} + V_{a0} \quad (13)$$
$$V_b - V_c = (\lambda^2 - \lambda)V_{a1} + (\lambda - \lambda^2)V_{a2} \quad (14)$$

Now at the relay location $V_{a1} = V_{r1}$ and $V_{a2} = V_{r2}$.

This shows that when the relay is fed with the quantities as given above, the relay looks into only the positive sequence impedance [1].

1.3.3 Pilot protection

In this type of protection scheme information of one end of the transmission line is sent to the other end for the relaying purpose [1] [2] [9], that means it relies on the communication medium

- Wire pilot.
- Carrier current pilot.
- Microwave pilot
- Fiber-Optic Pilot Systems
- PMU (Phasor Measurement Unit) based Differential protection

The first one is in the form of a two-wire line, such as a telephone line. The second one for the protective relaying is one in which low voltage high frequency (30 KHz to 200 KHz) currents are transmitted along the conductor of the line

(line to be protected) at one end and received at the other end, the earth or ground wire generally acting as the return conductor. A microwave pilot is an ultra-high frequency radio system operating above 900 MHz In the last method data are sent through high-speed communication medium it also has synchronized clock. The reasons for not using the current differential relay for transmission line protection are: Cost of pilot wires. The large voltage drops in the pilot wires requiring better insulation. The pilot currents and voltages would be excessive for pilot circuits rented from a telephone company. The likelihood of improper operation owing to C.T. inaccuracies under heavy loading.

1.3.4 Digital protection

The transients consist of a large number of harmonic currents and voltages besides the d.c. component. For protective relaying purposes, since it is the fundamental component of current and voltage that is required, which should be extracted from the transients. Earlier analog filters were used which have an inherent large time delay. Digital filters play an important role in extracting the fundamental components from the transient in about half a cycle. For this reason, the digital protection relaying schemes have been developed which are fast in operation and have a higher index of reliability [8].

With the advent of microprocessors, minicomputers and now PC, protective relaying schemes have been developed using on line these devices. The use of these devices has resulted in several advantages such as low burden, faster in operation, low maintenance and not affected by external causes such as vibrations or mechanical shocks [8]. The other advantages are:

- Flexibility: With the same hardware or slight modifications in the hardware, a variety of protection functions viz. various distance relay characteristics (ohm, mho, quadrilateral, parabolic etc.) can be obtained with suitable changes in the software.
- Lower Cost: With advancement in technology and higher level of competition in the manufacture of hardware and software, will bring down the cost of these protective schemes.
- Self-Checking Capability: With the proper software control, most of the hardware faults can be diagnosed and properly checked.
- Digital Communication: The microprocessor-based relay furnishes easy interface with digital communication equipment.

1.3.5 Directional relay based on POTT scheme

A distance relay is not able to provide non-delayed tripping over 100% of the line length unless it is linked with the relay on the other end of the line through a communication channel. The key feature of this channel that distinguishes distance relays as a preferred choice for HV grids is its very low bandwidth requirement. A variety of pilot schemes are already deployed to reach fast and selective distance relaying. Among them, permissive overreach transfer trip

$$V_b - V_c = (\lambda^2 - \lambda)(V_{r1} - V_{r2}) \quad 15$$

similarly,

$$I_b - I_c = (\lambda^2 - \lambda)(I_{a1} - I_{a2}) \quad 16$$

$$\frac{V_b - V_c}{I_b - I_c} = \frac{V_{r1} - V_{r2}}{I_{a1} - I_{a2}} = Z_1 \quad 17$$

(POTT) is a relatively inexpensive, yet competent one, and is widely practiced in industrial applications.

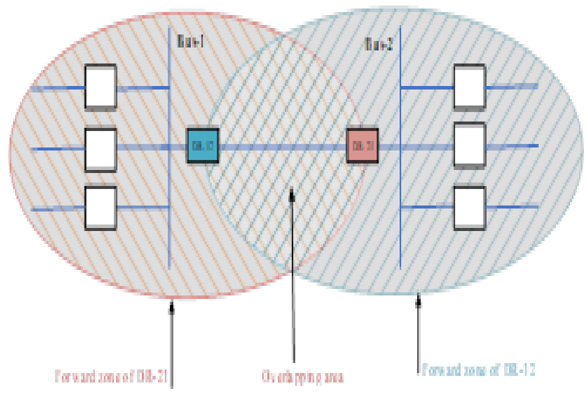

Figure.11. Directional comparison scheme for transmission line non-delayed tripping

Figure.11. illustrates an overview of the conventional POTT logic for line 12 of the test system. DR21 is the distance relay located next to bus 2 and protects line 12. If the impedance measured by DR21 falls within the reach of its directional over-reaching zone, there is a fault either on line 12, or on bus 1, or on the lines connected to the left of bus 1. The setting of this over-reaching zone is about 150% of the line length. On the other hand, if the impedance measured by DR12 drops below its directional over-reaching zone setting, there exists a fault on line 12 or on bus 2 or on the lines connected to the right of bus 2. The only overlap between the DR12 and DR21 zones is line 12. As a result, once DR21 detects a fault within its over-reaching zone, it sends a trip signal to DR12. DR12 trips line 12 if a trip signal sent by DR21 is accompanied by the detection of a fault within its own over-reaching zone. DR21 also operates based on the same logic. The communication channel over which the data are exchanged requires minimal bandwidth, since each relay transmits only a trip/no-trip signal.

II. TRANSMISSION LINE PROTECTION

This section discusses the new waveform based directional protection of transmission line. First different phase voltages and currents will be generated for the different operating conditions, then this protection algorithm needs to perform PCA for feature selection to achieve the best fault zone detection accuracy using EDT classifier [12], and also the detection of fault zones in case of backup protection. The flow of operating signals (phase voltages and currents) as mentioned below provides the clearest picture of the work:

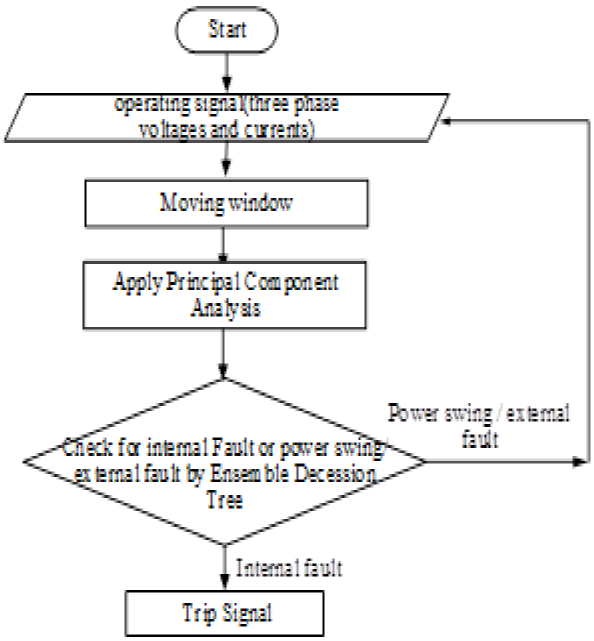

Figure.12. Basic flow diagram for transmission line protection

2.1 Relaying signals for Distance protection:

In this section voltages and currents of all the three phases gets achieved by connecting potential and current transformer (CT) at the local and remote end of the transmission line that means at relay-9 and relay-6 on line96. To do that PT and CT ratios are selected properly. And then these three phase voltages and currents are used by the protection algorithm to identify the internal fault zone and fault locations. Figure 4.2 shows the forward and backward fault zone for the relay-9 and relay-6 at bus-9 and bus-6 and then it trips the transmission line breakers when both the directional relay measures forward fault. Forward zone is considered 150% of the transmission line to be protected.

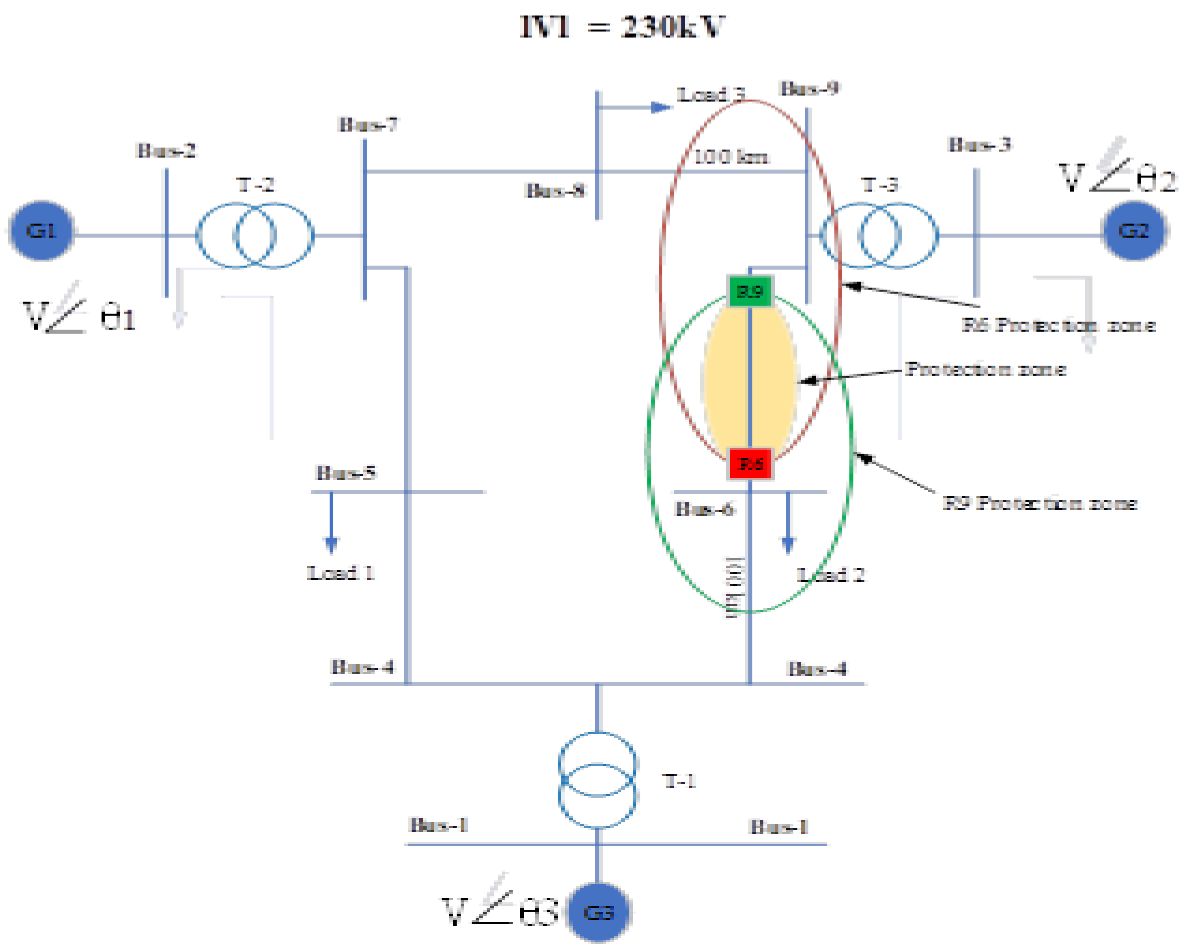

Figure.13. Single line diagram of a model for directional protection of transmission line

III. PRINCIPAL COMPONENT ANALYSIS

Here the basic application of principal component analysis is to reduce the dimension of the input vector that goes to the EDT for classification purpose so that the classification accuracy of the EDT increases.

PCA finds a new set of dimensions such that all the dimensions are orthogonal and ranked according to the variance of data among them [38]. It means more important principle axis occurs first.

PCA works as follows:

- It first calculates the covariance matrix of 'n' dimensional input data sets.
- Calculate Eigen vectors and corresponding Eigen values.
- Arrange the Eigen vectors according to their Eigen values in decreasing order.
- Select first 'm' Eigen vectors and that will be the new 'm' dimensions.
- Transform the original n-dimensional data points into 'm' dimensions

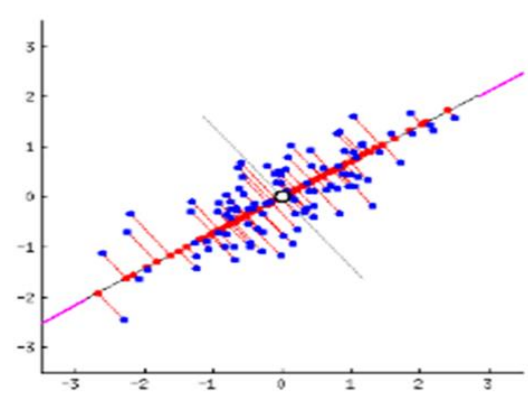

Figure.14. Mapping of data from 2- dimensional to 1-dimensional in the red line axis

IV. ENSEMBLE LEARNING

Ensemble techniques combine individual models together to improve the stability and predictive power of the model [13].

- This technique permits higher predictive performance.
- It combines multiple machines learning models into one predictive model.
- Ideaology behind Ensemble learning: -
- Certain models do well in modelling one aspect of the data, while others do well in modelling another
- Learn several simple models and combine their output to produce the final decision
- The combine strength of the model's offsets individual model variance and biases

This provides composite prediction where the final accuracy is better than the accuracy of individual models

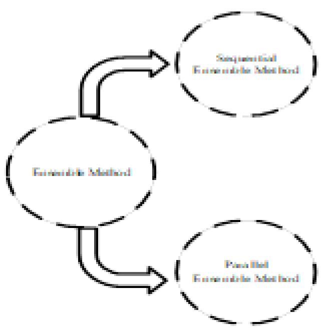

Figure.15. Ensemble Learning Method

Sequential Ensemble Method:

- Base learners are generated consecutively.
- Basic motivation is to use the dependence between the base learners.
- The overall performance of a model can be boosted.

Parallel Ensemble Method:

- Applied wherever the base learners are generated in parallel.
- Basic motivation is to use the independence between the base learners.

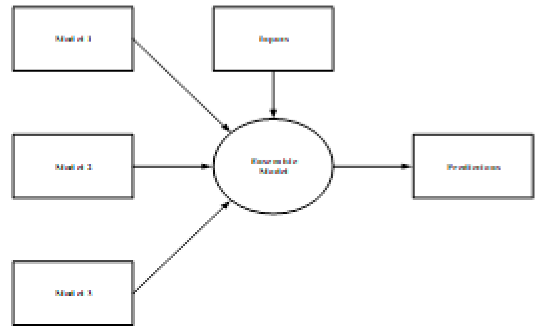

Figure.15. Ensemble Learning: Working

- Ensemble Learning: Significance

Ensemble models is the application of multiple models to obtain better performance than from a single model.

- Robustness: - Ensemble models incorporate the prediction from all the base leaners.

- Accuracy: - Ensemble models deliver accurate prediction and have improved performance.

4.1 Bagging

Bagging or bootstrap aggregation reduces variance of an estimate by taking mean of multiple estimates.

$$f(x) = {}^{1}/_{M} \sum_{m=1}^{M} f_m(x) \qquad (25)$$

Step 1: - Create randomly sampled datasets of the original training data (bootstrapping).
Step 2: - Build and fit several classifiers to each of these diverse copies.
Step 3: - Take the average of all the predictions to make a final overall prediction.

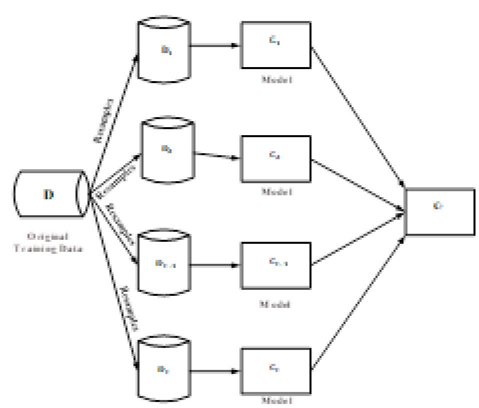

Figure.16. Block Diagram of bagging and bootstrap aggregation

- Random Forest:

Random forest is a good example of ensemble machine learning method.

- Random forest technique combines various decision trees to produce a more generalized model.
- Random forests are utilized to produce de-correlated decision trees.
- Random forest creates random subsets of the features.

Smaller trees are built using these subsets, creating tree diversity.

4.2 Boosting

Boosting is based on the idea of a weighted learning, where each instance in a training set gets a nonnegative weight. The higher the weight is, the higher is the importance of an instance. As a result of weight assignment during training, the training set becomes a weighted training set. Boosting starts from all weights equal. From this set, boosting generates the first hypothesis (classification result), h1 that classifies some instances correctly and some of them incorrectly. As we would like the next hypothesis to do better on the misclassified instances, the weights of misclassified instances increase while those of correctly classified decrease1. From this new weighted training set, a new hypothesis, h2, is generated and so on until we have generated M hypotheses, where M is pre-defined. After that, all hypotheses are combined with a weighted majority vote, where each hypothesis is weighted according to how well it performed on the training set.

- Boosting Algorithm:-

Step 1: Train a classifier H1 that best classifier the data with respect to accuracy.
Step 2: Identify the regions where H1 produces errors, add weights to them, and produces a H2 classifier.
Step 3: Aggregate those samples for which H1 gives a different result from H2 and produces H3 classifier.
Step 4: Repeat step 2 for a new classifier.

- AdaBoost: -

Boosting is a technique of changing weak learners into strong learners. Each new tree is a fit on a modified version of the original dataset.

- AdaBoost is the first boosting algorithm to be adapted in solving practices.
- It helps mixing multiple weak classifiers into one strong classifier.

Step 1: - Initially each data point is weighted equally with weight. $W_i = 1/n$. Where n is the number of samples.
Step 2: - A classifier 'H_1' is picked up that best classifiers the data with minimal error rate.
Step 3: - The weighting factor α is dependent on errors (ε_t) caused by the H1 classifier.

$$\alpha^t = \frac{1}{2} ln \frac{1-\varepsilon_t}{\epsilon_t} \quad (26)$$

Step 4: - Weight after time t is given as:

$$\frac{W_i^{t+1}}{z} e^{-\alpha t.h1(x).y(x)} \quad (27)$$

Where z is the normalizing factor, h1(x). y(x) is sign.

CONCLUSION AND SCOPE OF FUTURE WORK

In future implementation of this algorithm will be performed in real time using Machine Learning tools. And also, to enhance the speed of operation and selectivity of the relay, the less data length for the processing and good feature selection would be require for the EDT or other machine learning tools to classify more accurately.

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