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Review Paper on Single and Three Phase Fault Identification System using Machine Learning

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ABSTRACT

The modern power system requires real- time monitoring and fast control to be protected from faults on transmission lines. The detection and classification of faulty conditions in power systems is a task of crucial importance for reliable operation. The traditional fault diagnosis methods rely on the manual feature extraction of engineers with prior knowledge that has been proposed by several researchers for fault detection and classification. It is highly necessary to identify faults in any analog circuit to ensure the circuit's reliability. Early diagnosis of faults in a circuit can help to maintain the system significantly by avoiding potentially harmful damage from the fault. Automatically and accurately identifying the incipient micro-fault in the power system, especially for fault orientations and severity degree, is still a significant challenge in the field of intelligent fault diagnosis. Intelligent fault diagnosis methods based on machine learning become a research hotspot in the fault diagnosis field. In this paper, various machine learning algorithms are discussed.

***Key Words*:** Single Phase, Three Phase, Fault Detection, Machine Learning

INTRODUCTION

An electric power system contains of generation, transmission and distribution of electric energy. Overhead transmission lines are the maximum advantageous approach for transportation of electrical energy from sources of generation to load centers to bring about electricity use and consumption. The quick development of electric power systems in the course of recent decades has brought about an extensive increment of the quantity of lines in operation and their aggregate length. These lines are uncovered to faults that are caused by short circuits, overload, tree branches, faulty equipments, lightning, human errors. In most cases, electrical faults manifest themselves as mechanical damage, which should be repaired earlier than returning the line to service. Any fault, if no longer detected and separated rapidly will in this manner, develop into a system wide unsettling influence causing blackouts and even ensuing power outages [1, 2].

When a fault occurs on a power system, economic losses may be decreased and the line service can be maintained if the location of the fault may be as it should be decided, specifically while generation, transmission and distribution happens over a longer distance, thereby enhancing the safety and quality of the power supply. Electric utility services would thus be able to be kept up if the detection, classification and location of the fault on a line can be precisely decided. These suitability factors and deductions make fault analyzers and their algorithms, a critical tool in keeping the competence of smart grids. Faults cause short to long term power outages for customers and can resultin extensive losses especially for the producing enterprise [3].

Faster detection, classification and location of these faults are important in preserving a reliable power system operation. Deregulation of the electricity market, financial and ecological prerequisites have pushed electrical utilities to operate transmission lines near their most extreme points of confinement. Smooth operation of electric power transmission lines is fundamental to convey negligibly interfered with control supply to buyers, who have turned out to be increasingly touchy to control blackouts with the development in overall innovation. This requires solid operation of power equipment and satisfaction of consumers. Engineers are therefore driven to design transmission networks that formulate power system protection schemes to reliably detect, classify and locate faults compromising the security of the system. There is probably fast viable repair and preservation procedures specifically prompt enhance the power accessibility to the customers which, therefore, improve the general effectiveness of the power systems. Those standards of availability, efficiency and high-quality have a growing significance these days because of the new marketing policies on account of deregulation and liberalization of electricity and electricity markets. Sparing time and exertion, expanding the power accessibility and maintaining a strategic distance from future mischances can be straightforwardly translated as a cost decrease or a benefit expanding [4].

Therefore, there is a necessity to improve accuracy of the existing fault analysis methods. The inflated growth of power systems each in size and complexness has caused the necessity for quick and reliable relays to safeguard significant hardware and to maintain system stability. The traditional shielding relays are either of static or electromagnetic kind. The electromagnetic relays have numerous disadvantages like high working time, excessive burden on instrument transformers, contact issues and so on. In the late 1950s solid state relays started out to seem. These had been designed with discrete electronic components consisting of operational amplifiers, transistors and diodes. Static relays are progressively employed in recent years owing to their intrinsic benefits of less maintenance, lower burden, high speed and compactness. Although with success used, the static relays be afflicted by a number of hazards, for example inadaptability, inflexibility to dynamical system conditions and complexness [5].

ELECTRICAL FAULTS

In electrical power systems consisting of generators, transformers, transmission lines and distribution circuits, most of the faults, about two-thirds, are liable to occur in the transmission lines. A fault in a circuit is any failure which interfaces with the normal flow of current. The faults occur in power system due to insulation failure of equipment's, flashover of lines initiated by a lightning stroke, due to permanent damage to conductors and towers or due to accidental faulty operations. The faults can be broadly classified into shunt faults(short circuits) and series faults(open conductors). The shunt fault involves short circuit between conductor and ground or short circuit between two or more conductors. The shunt faults are characterized by increase in current and fall in voltageand frequency. Shunt faults are classified as follows:

Single line to Ground fault (LG fault).
Line to Line fault (LL fault).
Double line to Ground fault (LLG fault).
Three phase fault.

The series fault may occur with one or more broken conductors which creates open circuits. It also happens in circuits controlled by fuses or circuit breakers which do not open all phases, i.e., one or two phases of the circuit may open and the other phases may be closed. The series faults are characterized by increase in voltage and frequency and fall in current in the faulted phase. The series faults may be classified as open conductor fault and two open conductor fault. In the faults mentioned above, three phase fault is a symmetrical fault and all other faults are unsymmetrical faults. The symmetrical fault conditions are analyzed on per phase using Thevenin's theorem or by using bus impedance matrix. The unsymmetrical faults are analyzed using symmetrical components. The relative frequency of occurrence of various types of faults in the power systems in the order of decreasing severity is as follows: Three phase faults-5% Double line to Ground fault-10% Line to Line fault-15% Single line to Ground fault-70% Adequate protection has to be afforded to the power system components by incorporating relays and circuit breakers, as the faults may cause interruption in power supply to the consumers; substantial decrease in voltage and frequency, decrease in stability of parallel operation, possibility of drop out of generators and separate generating stations operating in parallel and damage to equipment near the short-circuit points. Circuits should be switched out as warranted by the severity of faults.

Faults in Overhead Transmission Lines

When fault occur, the voltage of the phase on which fault has occur drops and it allows a flow of large current. If this large current left uninterrupted a major damage to the components may occur. The cause of faults is generally, short circuit, mistake in operation, error in equipment's, men error, overload on system oraging of the system.

Nature and Causes of Faults

Either insulation failure or failures of conducting path are the major causes for the occurrence of faults. In addition to this, faults are also caused due to over voltages which are occurring due to switching surges and lightening. Falling of conducting objects on overhead lines, encounter of flying birds, tree branches, direct lightening strokes, ice loading, creepers, storms etc. are the other reasons which can cause different types of faults in overhead lines. Moisture in the soil, heat of earth, ageing of cables may lead to the solid insulation failure in cables, transformers and generators. Types of faults:

- Symmetrical faults
- Unsymmetrical faults

Table 1: Types of faults

Types	Symbol	% of Appearance	Acuteness
Line to Ground	L-G	75-80%	Fall under the category of not so grave
Line to Line	L-L	10-15%	Sever compared to L-G but less than L-L-G
Double Line to Ground	L-L-G	3-10%	Graver
Three phase	3-ϕ	1-5%	Most grave

Line to Ground Fault

When any one of the three lines is in touch with the neutral or ground accidently this type of fault occurs. Hence it is named so. It is the most common type of fault as mentioned already. The possible cause for this fault to occur may be due to the wind flowing with high speed or may be some big object like tree has fallon it or due to the event of lightning.

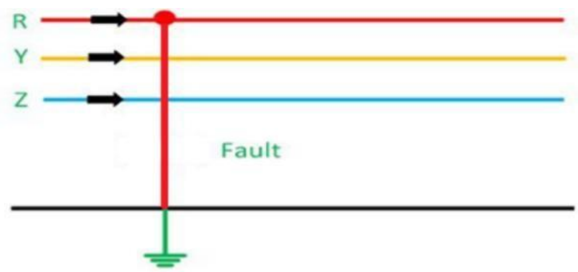

Figure 1: Single Line to Ground Fault

Line to Line Fault

Here two lines are in touch with each other accidently.It can be said that condition is of short circuit. Rest ofthe details is expressed clearly in figure 3.9.

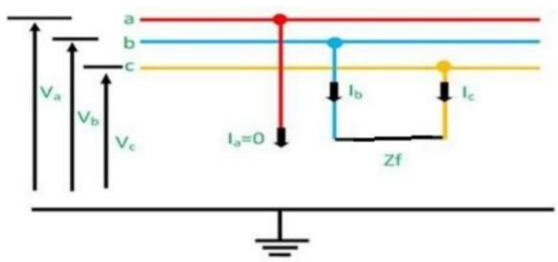

Figure 2: Line to Line Fault

Double Line to Ground Fault

As compared to the L-L fault, here the short circuit condition is between three elements, two of these elements are any two line from given three phases andthe third element is ground.

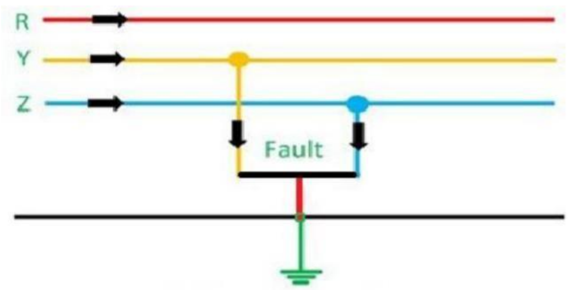

Figure 3: Double Line to Ground Fault

Three Phase to Ground Fault

The most grave but occurrence is most acute, is this fault where all the three phases are touching each otherand together in contact with the ground.

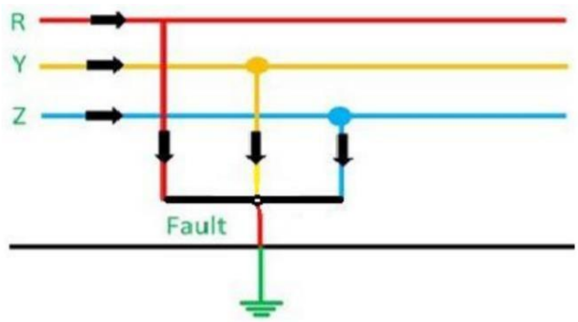

Figure 4: Three Phase Fault

LITERATURE REVIEW

Kunjin Chen et al. (April 2016 [1]), reviewed various methods of faults detection in the transmission and distribution networks in detail. It also shows analytical comparison of the conventional methods such as impedance based, travelling wave based with machine learning based fault location methods, out of which the later methods is more suitable for fault detection. Machine learning based fault location methods will be essential in the current as well as upcoming scenariosof continuing increasing computation and communication capabilities for a huge power system.

Avagadi Prasad et al. (January 2017 [2]), surveyed several methodologies to classify faults in transmission line. It also features recent methods to classify the faults. The content of the paper can be divided into sections. The first section reviewed the basics faults encountered in transmission line along with old techniques related to the former. The second section describes the recent techniques used for the classification of the faults in the transmission network. Hence, it could be said that the Flexible Alternating Current Transmission System (FACTS) devices must be used accordingly to eliminate various faults with the help of recent algorithms developed via advanced optimization techniques. Since, the efficiency of these techniques would be far better and suitable for the current scenario for the various faults.

Zimmerman et al. (2005, [3]), described several fault detection methods mainly based on impedance. Most of these are one and two ended. All the terms related to fault location and detection were also explained. Some of the impedance based methods presented here are simple reactance, Takagi, zero-sequence current with angle correction, and two-ended negative-sequence. Many of them were analyzed considering the conditions such as short fault window, non- homogeneous system, incorrect fault type selection, etc.

Song Guobing et al. (October 2009, [4]), developed a fault detection algorithm for parallel transmission line taking into account the accuracy it can have. The values of voltage and current after the event of fault atany one of the terminals i.e. fundamental components

are used. Here, partition of parallel transmission line is done into common and differential component net. The coefficient which disturbs the current is taken as the distance fault function in the later represented as the current at local terminal. Similarly, phase fault current is presented as that same as just mentioned in case thefault is asymmetrical in nature.

E.E. Ngu et al. (October 2011, [5]) demonstrated the combine use of impedance and travelling wave based methods for detecting location of faults in multi- terminal transmission lines. When the fault occurs in the system, it was checked if it is grounded or not. Here, comparison of ground mode wavelet coefficient magnitude is made. Then, faulted half of two terminals, multi-terminal or a section where fault occurs, was determined by impedance based methods. In ATP simulation, four and five terminal transmission lines were also examined using the above mention method under different fault conditions (fault resistances and fault inception angles).

Alkim Capar et al. (March 2015, [6]) tested a series compensated transmission line of 380 kV capacity to know the location of faults and resistance under fault condition. Particularly the impedance of MOV (Metal Oxide Varistor) is determined. An algorithm is developed to approximation of the fault location on series compensated line by calculating the values of current and voltage under fault. It calculates these values by two end measurement using line parameters.The algorithm developed is effective in approximating location faults under every condition.

Ying Hong Lin et al. (July 2000, [7]) described the fault locating method based on adaptive PMU on transmission lines. It accurately finds the location of the fault with the help of superimposed phasors of voltage and current. The transmission line considered is of 100km length and of 161kV capacity. It has presented a discrimination index for section under fault. It has also assumed tapped lines effects. It also depicts the source impedance equivalent value apart from the transmission network. The simulation is carried out using Alternative Transients Program (ATP) simulator, in which the given scheme shows 99.99% accuracy for finding location where faults occurs for different faults and its source impedance.

Debomita Ghosh et al. [8], modelled a Phasor Measurement Unit (PMU). It was designed in MATLAB/Simulink environment and applied to two bus transmission network. The article explains the importance of protection and control unit in the event of fault or major disturbance. A proper configuration of both the units normalizes the system by reducing the disturbances effects. It mainly requires a good communication network to transfer command signal in such events which depends on the sensor it uses, measurement units and the medium of transferring signals. It has described the new technologies in this field and discusses the advancement made in PMU.

Ozkan Altay et al. (2011, [9]), utilized one end recording for fault locating faults on transmission networks based on wavelet analysis. It does not involve the velocity of propagation. Under different fault conditions and parameters values the given power system was simulated and the results obtained supports the given scheme as its accuracy is suitable in locating faults of different types. To get the clearance of fault to be very précised rapid it can also be utilized fortravelling wave protection.

METHODOLOGY

Machine Learning is a subset of Artificial Intelligence concerned with “teaching” computers how to act without being explicitly programmed for every possible scenario. The central concept in Machine Learning is developing algorithms that can self-learn by training on a massive number of inputs. Machine learning algorithms are used in various applications, such as email filtering and computer vision, where it is difficult or infeasible to develop conventional algorithms to perform the needed tasks [4]. Machine learning enables the analysis of vast amounts of information. While it usually delivers faster, more precise results to identify profitable prospects or dangerous risks, it may also require additional time and assets to train it appropriately. Merging machine learning with AI and perceptive technologies can makeit even more effective in processing vast volumes of information. Machine learning is closely associated with computational statistics, which focuses on making predictions using computers. Machine learning approaches are conventionally divided into three broad categories, namely Supervised Learning, Unsupervised Learning & Semi-supervised Learning, depending on the nature of the "signal" or "feedback" available to thelearning system.

Supervised Learning

A model is trained through a process of learning in which predictions must be made and corrected if those predictions are wrong. The training process continues until a desired degree of accuracy is reached on the training data. Input data is called training data and has a known spam / not-spam label or result at one time.

Unsupervised Learning

By deducting the structures present in the input data, a model is prepared. This may be for general rules to be extracted. It may be through a mathematical process that redundancy can be systematically reduced, orsimilar data can be organized. There is no labeling of input data, and there is no known result.

Semi-Supervised Learning

Semi-supervised learning fell between unsupervised learning (without any labeled training data) and supervised learning (with completely labeled training data). There is a desired problem of prediction, but the model needs to learn the structures and make predictions to organize the data. Input data is a combination of instances that are marked and unlabeled.

Fuzzy Logic

FL is particularly good at handling uncertainty, vagueness and imprecision. This is especially useful where a problem can be described linguistically (using words) or, as with neural networks, where there is data and one is looking for relationships or patterns within that data. It is an approach to uncertainty that combines real values [0…1] and logic operations. FL is based on the ideas of fuzzy set theory and fuzzy set membership often found in natural (e.g., spoken) language. FL uses imprecision to provide robust solutions to problems. FL relies on the concept of a fuzzy set. The notation for fuzzy sets: for the member x, of a discrete set with membership μ, is μ/x. In other words, x is a member ofthe set to degree μ. Discrete sets are defined as:

$$A = \mu_1 / x_1 + \mu_2 / x_2 + \mu_3 / x_3 ....\mu_n / x_n \quad ....(1)$$

FL systems are universal function approximates. In general, the goal of the FL system is to yield a set of outputs for given inputs in a nonlinear system without using any mathematical model. Fuzzy model is a collection of IF – THEN rules with vague predicates that use a fuzzy reasoning such as Sugeno and Mamdani models. Sugeno type systems can be used to model any inference system in which the output membership functions are either linear or constant whereas Mamdani type produces either linear or nonlinear output. FL controller contains four main parts, two of which perform transformations. The four parts are

- Fuzzifier (transformation 1)
- Knowledge base
- Inference engine (fuzzy reasoning, decision-making logic)
- Defuzzifier (transformation 2)
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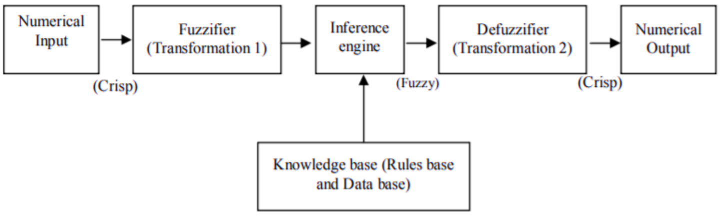

Figure 5: Schematic of FL system

Fault Detection using Fuzzy System

The general process performed in a fuzzy logic approach is shown in Figure 2.
The S1, S2 and S3 in Figure 2 are inputs to the fuzzy system, the calculation of these input variables using currents at one end of the system are given below. Theratios P1, P2 and P3 are calculated using post-fault currents, as follows:

P1 max{abs(Ia)} / max{abs(Ib)} (2)
P2 = max{abs(Ib)}/max{abs(Ic)} (3)
P3 max{abs(Ic)}/max{abs(Ia)} (4)

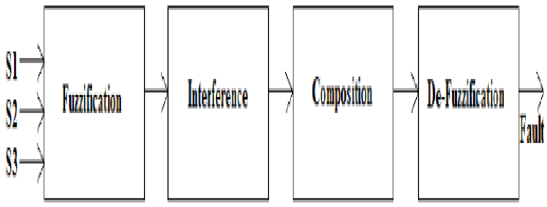

Figure 6: Fuzzy system

Next, the values of S1, S2 and S3 are found out asfollows:

$$P_1(n) = \frac{P_1}{\max(P_1, P_2, P_3)} \quad (5)$$

$$P_2(n) = \frac{P_2}{\max(P_1, P_2, P_3)} \quad (6)$$

$$P_3(n) = \frac{P_3}{\max(P_1, P_2, P_3)} \quad (7)$$

Lastly, the differences of these $P_1(n)$, $P_2(n)$ and $P_3(n)$ are calculated as follows:

$S_1 = P_1(n) - P_2(n)$,
$S_2 = P_2(n) - P_3(n)$,
$S_3 = P_3(n) - P_1(n)$

CONCLUSIONS

Protective relaying system is a versatile tool for protection of electric power systems. Because of the drastic changes occurring in power systems, the necessity for providing better protective relaying systems for transmission lines is essential. This work gives brief overview on different existing techniques for fault analysis and apart from the existing methodologies a novel fault detection scheme is presented in this work. It uses post fault current samples of all the phases.

As discussed already a power system can be encountered with the faults named as AG, BG, CG, AB, BC, CA, ABG, BCG, CAG, ABC and ABCG phase fault. Hence it should be equipped suitably to tackle these faults in the most appropriate manner.

Tackling these faults means to classify and finding outits location and graveness. In past on occurrence of fault, current is measured from either ends of the line which were then used in the algorithm to classify them. It could be the raise in magnitude of current magnitude as the data in algorithm. Since each fault react differently i.e. different characteristics of current whenit occurs.

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