A Short Review on Fault Detection and Fault Classification in Transmission Lines

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Abstract: *Delivering consistent electric power to end users is a difficult task for power system operators (PSO). Although fault intrusion is unavoidable, it is crucial to accurately identify, categorize, and pinpoint the fault location. There has been a lot of research done on fault detection, classification, and location finding techniques in power transmission systems. An intelligent protection system that can accurately detect, categorize, and locate faults is currently being developed. In studies involving traditional fault protection strategies, improvements in signal processing methods, artificial intelligence (AI), and machine learning (ML) have helped researchers adopt a more thorough and focused approach.*
Keywords: Transmission lines, fault detection, fault classification, fault location, classification.

I. Introduction

Transmission lines in an electric power system move electric energy from one location to another. Alternating or direct current, or a system that combines the two, can be carried by them. Additionally, overhead or underground lines are both capable of transporting electric current. Transmission lines are distinguished from distribution lines primarily by operating at relatively high voltages, transmitting large amounts of power, and transmitting the power over long distances. Electricity is transferred from the generating substation to the various distribution units via a transmission line. From one end to the other, it transmits the voltage and current wave. A conductor with a uniform cross-section along the line makes up the transmission line.The conductors and the air are separated by an insulating or dielectric medium.

Figure 1 Transmission lines

The distance between the line and the ground is much greater for safety reasons. The conductors of the transmission line are supported by the electrical tower. Steel is used in the construction of towers to give conductors a high level of strength. High voltage direct current is used in the transmission line to transmit high voltage over long distances.

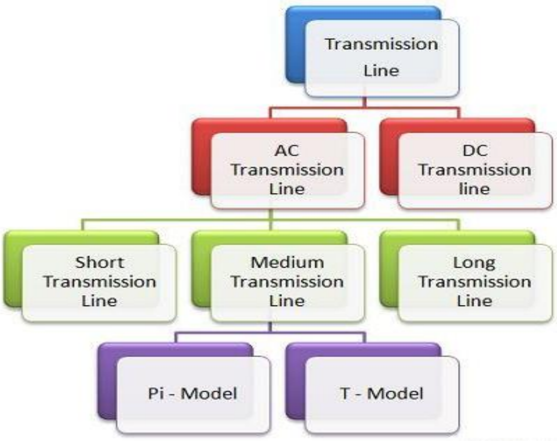

Figure 2 Transmission Line

While they are in use, electrical networks, machines, and equipment are frequently prone to different kinds of faults. When a fault arises, the machine's characteristic values (like impedance) may shift from their current values to different values until the fault is fixed. There are many potential faults that could occur in the power system network, such as lightning, wind, trees falling on power lines, equipment failure, etc.

Any abnormal system condition involving the electrical failure of components like transformers, generators, busbars, etc. is referred to as a fault in an electric power system. In addition to insulation failures and problems with the conducting path, the fault also involves conductor short-circuits and open-circuits. In a power system network, the electrical equipment operates at normal voltage and current ratings when it is safe to do so. Voltage and current values start to deviate from their nominal ranges when a fault occurs in a circuit or device. The faults in the power system result in high voltage surges, unbalanced phases, reversed power, and overcurrent and undervoltage.This causes the network's regular operation to be interrupted, as well as equipment failure, electrical fires, etc. Switchgear protection devices like circuit breakers and relays are typically used to protect power system networks in order to reduce the amount of service loss caused by electrical failures.

Shunt and series faults are two different types of faults. Series faults, also known as open conductors, occur when the series impedance of the lines is unbalanced. These faults are unbalanced because they interfere with the symmetry of one or two phases. Voltage and frequency rise along with a decrease in current in the faulted phases are the hallmarks of series faults. The main categories of shunt faults (short circuit faults) are symmetrical and unsymmetrical faults, as shown in Fig. 1: an imbalanced or asymmetric fault that doesn't affect all three phases equally. In addition, 5% of transmission faults are symmetric or balanced, which equally affects the three phases.

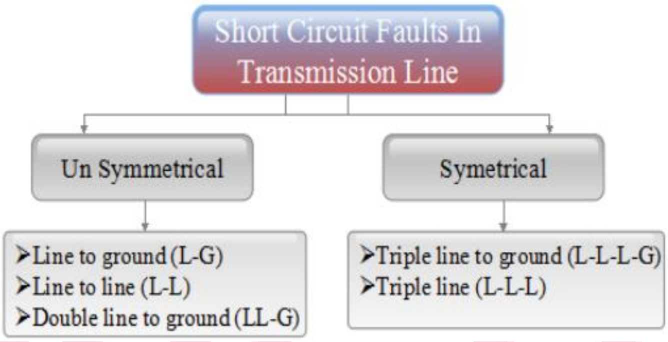

Figure 3 Classification of Short circuit Faults in Transmission line

The three stages of fault diagnosis in a transmission line protection scheme based on digital distance relaying are fault detection, fault classification, and fault location estimation. The fault detector unit first determines when a fault starts. In essence, it separates events with faults from those without. The fault classifier unit is turned on by the fault detector unit to categorize the fault type. After identifying the fault type, the fault locator unit calculates the impedance to determine how far away from the relay the fault is.The steady state and transient components of the measured voltage and current signals at the relay point in FACTS compensated high-voltage transmission lines are impacted when the fault loop contains TCSC/UPFC devices. Furthermore, in such compensated lines, two different locations (before and after the TCSC/UPFC) of the line may experience equal magnitude current from the same fault or from two different faults. Therefore, fault zone identification is extremely important for both protecting FACTS compensated transmission lines and fault detection.

Fig. 4 depicts a condensed framework for fault detection, classification, and location. Current and voltage signals are sampled in the initial step, and the sampled points are then sent to the feature extraction module. Then, this module extracts the features required by the fault locator, fault classifier, and fault detector. The fault classifier and fault locator, respectively, produce two outputs: the fault type and the fault location. While some works focus on just one or two of the three, others address all three.

It is very difficult to fit the raw signals into some sets of rules and criteria capable of intelligently interpreting the underlying messages brought by the signals, even though the current and voltage signals contain all the information within themselves.In situations like these, feature extracting techniques are useful because they carefully unearth relevant data and lessen the influence of variance in the system under study. Researchers may become more aware of the nature of the fault classification or location problems after using the appropriate feature extraction techniques, leading to more cogent and effective solutions. Additionally, a decreased data dimension can occasionally improve the performance of specific algorithms used in classifiers or locators, delivering more precise and reliable results as soon as possible.

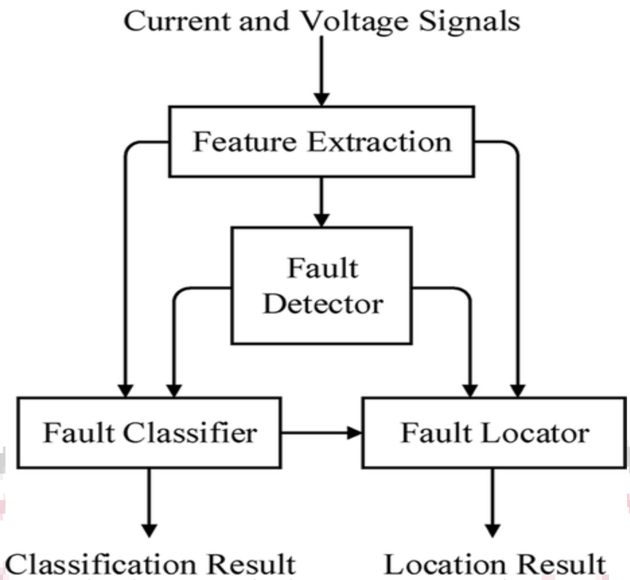

Figure 4 Simplified framework for fault detection, classification and location

A tree-like logic flow with multiple criteria is typically used if no machine learning or artificial intelligence-based algorithms are implemented. The majority of the authors compared four extracted features' values for three phases and the ground to pre-determined thresholds. The corresponding phase (or ground) is involved in the fault if any one of the values is greater than its threshold. Artificial neural networks (ANNs) are a group of non-linear statistical models and learning algorithms designed to mimic the behavior of connected neurons in biological neural systems. These systems have evolved and developed over a considerable amount of time. Various ANN models have been applied in a variety of fields, including the classification of faults in transmission lines and distribution systems.

In light of the fact that precise location of faults in transmission lines and distribution systems can significantly shorten the time to recovery, a sizable number of studies have concentrated on fault location. Impedance focused methods (phasor or time-domain based) and travelling wave based methods can be used to locate faults in transmission lines. Methods utilizing superimposed components and data on power quality may also be taken into consideration for distribution systems. Fault location techniques can also be divided into single-end, double-end, multi-end, and wide-area categories depending on the data source.

II. Literature review

(Yang et al., 2020)Power equipment and power line mileage both grow quickly with the quick development of the smart grid. The disparity between the quantity of maintenance workers and the quantity of maintenance equipment becomes more obvious. However, the traditional maintenance approach has the drawbacks of either performing too much or too little maintenance, which will increase the risk of power transmission system failure. In response to these problems, numerous researchers have worked hard to develop automatic power line inspection, and some cutting-edge techniques for power line inspection have been proposed to increase inspection effectiveness and quality,such as deep architecture, image processing, and unmanned aerial vehicle (UAV) technology. In order to offer a useful resource for researchers working on the smart grid, we analyzed and summarized the most recent methods for power line inspection in this article. First, a review of the typical power line inspection tasks is done. Second, this article examines the current inspection platforms.

(Samanta et al., 2021)This paper's goal is to review academic journals' articles on fuzzy-based intelligent relaying schemes. Individual problem statements have been discussed by researchers, and they have also suggested the appropriate solutions. Additionally, we have outlined the current state of the power and energy department's protection sector along with any outstanding issues. Finally, authors identified a few research gaps to fill in and suggest potential areas for future research.

(Stefanidou-Voziki et al., 2022)The development of smart grids from conventional power systems has altered how these systems are thought of and run. The distribution grid is the part of the grid that is changing the fastest, and the addition of new sensors and actuators has improved its observability and controllability. These have made it possible to develop processes that are more precise and automated, including some crucial ones like fault isolation, restoration, and detection techniques. Unconventional techniques in this direction, like artificial intelligence, have become more and more popular in recent years. This article reviews fault location and classification techniques for low-voltage distribution grids, a situation that has previously gone unstudied. The fault is classified by the different techniques used for fault location and classification.These techniques are described and analyzed, along with the key benefits and drawbacks of each category.

Modern techniques from each category are carefully compared, and research trends in both fields are also examined. Finally, the gaps in the research are noted.

(Prasad et al., 2018)The expansion of power systems and applications necessitates the development of more effective methods for classifying faults in power transmission systems in order to improve system performance and prevent catastrophic failures. The technical literature offers numerous methods for achieving this goal. The study reviews the key techniques that can be used to classify faults in power transmission systems by analyzing the technical literature.

(Hare et al., 2014)Given the growing environmental concerns, it is anticipated that clean energy will be a significant portion of both current and future microgrids. If preventive measures are not taken in a timely manner, the cascading effect of faults can cause severe failures and blackouts, which is a serious problem in power systems. Smart micro-grids are designed to recognize these crucial changes and enter island mode for continuous power generation and system stability as a recovery mechanism. However, due to the fact that their electrical energy infrastructure is also prone to faults and instabilities, real-time self-diagnosis algorithms are required. These algorithms can use data gathered from monitoring units to identify failure characteristics at an early stage of their evolution.The comprehensive review in this paper focuses on faults, fault diagnosis techniques, and interconnections in smart micro-grids with clean and conventional generation systems.

(Rogers et al., 2019)For more than 20 years, research has been ongoing in the field of fault detection and diagnosis (FDD) for air conditioning systems. However, the vast majority of techniques were created for commercial structures. Despite the fact that a lot of this work also applies to the residential market, it has its own set of problems and opportunities that should be taken into account in addition to those that apply to commercial HVAC systems and industrial refrigeration systems. Modern approaches to FDD for air conditioning systems are reviewed and evaluated in this paper. Opportunities for development exist in the area of applying these techniques to the residential market, including: (a) Considering the level of fault diagnosis that is most practical in the residential market.(b) Making the list of necessary sensors for FDD simpler. This study also examines the recently developed field of residential air conditioning system fault detection using data from cloud-based thermostats. Large-scale analyses of thermostat data have only recently begun to appear in publications, but experts anticipate significant growth in this area.

(Ferreira et al., 2016)Power system fault analysis and diagnosis is a significant issue with significant financial repercussions for operators, maintenance personnel, and the power sector as a whole. This has sparked research into the issue and the creation of fresh techniques and algorithms. In a large number of applications, intelligent systems have been suggested in the literature to address this issue. This survey provides an overview of the use of intelligent systems for fault diagnosis in electric power system transmission lines in the context of diagnosing faults in electric power systems.There are a ton of related works in the literature, with the most significant contributions being those that have been published in international journals. The works cited in the current survey are only those that have been published in regular journals and have a strong focus on the aforementioned subject. In order to identify the major trends and research areas pertaining to transmission line intelligent fault diagnosis systems, the classification of employed strategies and their relationships with classical techniques are presented and discussed.

(Adem, 2021)the techniques that can be used to locate, identify, and diagnose transmission line faults. Artificial neural networks, impedance measurement-based techniques, fuzzy expert methods, wavelet transforms, and other techniques have all been used to identify and categorize faults. In order to protect the equipment from electric faults, this paper reviews the different types of faults that could happen in an electric power system, the fault detection and location techniques that are available, and the protection devices that can be used in the power system. Future researchers gain insight for future works in this area from this paper's conclusion and recommendations.

(Biswas & Nayak, 2018)presents a thorough analysis of current advancements in TCSC/UPFC compensated high-voltage transmission line protection. Additionally presented for comparison are each method's relative benefits and drawbacks. Before going into detail, the effect of TCSC/UPFC on distance protection is assessed using data from a 400 kV two-bus test power system generated by EMTDC/PSCAD. Both academic researchers and practicing engineers can benefit from this study's insights into the protection of FACTS-compensated transmission lines and from its potential to advance the development of newer algorithms.

(Raza et al., 2020)This paper presents a comprehensive review of fault diagnosing techniques in the power transmission system. For analysis, voltage and current samples are frequently used. To provide a clearer and more thorough understanding of the concepts, three tasks/topics—fault detection, classification, and location—are presented separately. Discussions include feature extraction, transformations, and dimensionality reduction techniques. Artificial intelligence (AI) and signal processing techniques are heavily used in fault classification and location techniques. After discussing general concepts and methods, future developments are discussed.

(Ghaderi et al., 2017)One of the biggest problems with the power distribution network has been protecting against high impedance faults (HIF). HIF typically happens when conductors in a distribution network break and come into contact with the ground or lean and come into contact with a tree branch. Over-current relays are unable to detect this fault because the current magnitude is so close to the load current level. The purpose of this essay is to review the literature on the HIF phenomenon. The HIF detection methods are categorized, assessed, and contrasted in this work.

(Chen et al., 2016)In this study, a thorough analysis of the techniques for fault detection, classification, and location in transmission lines and distribution systems is presented. Despite the strong correlations between the three topics, the authors make an effort to discuss each one separately to help the reader understand the ideas more clearly and completely. The feature extraction process, without which the majority of methods may not be implemented properly, is also of paramount importance. On the basis of feature extraction, fault detection techniques are discussed. Following the presentation of the broad concepts and general ideas, representative works as well as recent advancements in the techniques are covered and discussed in detail.The information in this study could be useful as a thorough literature review or as practical technical advice.

(Bunnoon, 2013)proposes a power system fault detection method that is state-of-the-art. Several articles cover each implementation and technique from the most recent to the present (2013). Future development of the approach's advantage for the new detection is anticipated. There are many fascinating topics used to find power system faults. There are two types of interesting fault detection data in this study. This analysis of numerous papers will be used to advance research or discover a fresh technique for effective fault detection in the power system.
(Parihar & Warudkar, n.d.)The most important component of the electrical system is the transmission line. Transmission lines are a significant source of power. Over the course of the fashionable era, the need for power and its allegiance have grown exponentially. A cable's primary function is to transmit wattage from the supply space to the distribution network. The main objective on reducing power losses has matured as a result of the explosion between restricted production and an incredible claim. The main problem is a reactive power and voltage deviation that are significant within the long-range transmission line. Conjecture factors as well as physical losses to numerous technical losses are also a concern.In order to resolve a problem quickly and restore the power grid with the least amount of disruption, fault analysis may be a very important factor in power grid engineering.

(Mishra & Ray, 2018)Discusses various signal processing techniques, impedance-based measurement methods, methods based on the travelling wave phenomenon, methods based on artificial intelligence, and special techniques for locating, identifying, and classifying various transmission network faults. This survey's paper refers to all methodologies and approaches used up to August 2017. This concise and useful survey aids the researcher in understanding various approaches and procedures.

(Wong et al., 2021)This study of the various artificial intelligence (AI) techniques for the identification and categorization of faults on power transmission lines is systematic, thorough, and up to date. We examine the state-of-the-art of various intelligent approaches and even talk about the differences and effects of implementing intelligent methods in the protection scheme and the integrated protection scheme. Additionally, there has been an increase in demand for and interest in the use of AI approaches in drones to help with fault detection and classification. With a collection of references that were devoted to the attentive contribution, this thorough study can serve as a foundation for new researchers to evaluate the potential for various intelligent methods in detecting and classifying faults on power transmission lines.

III. Conclusion

While in use, electrical networks, machines, and equipment frequently experience a variety of faults. When a fault arises, the characteristic values of the machines (such as impedance) may switch from their current values to different values until the fault is fixed. Numerous faults, such as those caused by lighting, wind, trees falling on power lines, and equipment failure, may occur in the power system network. In this paper, a thorough review of fault localization, classification, and detection in transmission lines has been provided. Along with examples of works, a variety of methodologies and techniques are presented. An overview of feature extraction techniques is provided prior to the introduction of methods used in fault detection, classification, and location.

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