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Application of using fault detection techniques in different components in power systems

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A B S T R A C T

Throughout the years, Fault detection has been one of the most frequently discussed topics in the scientific community at present. Consequently, it has been extensively studied and focused on in recent years. This scientific paper presents some of this research, what they have reached, and the methods used for their studies. The literature review provides that these problems are not covered yet. It needs more works to develop fault detection techniques for better performance.

Introduction

There are many electric energy sources, including clean ones, such as converting solar energy and wind energy into electric energy, including polluting the environment, such as producing them from fossil fuels[1]–[3]. Then, the electrical energy is transferred from its production to the consumption areas through a transmission system. However, faults can occur at any step due to the complexity of modern systems [4]–[6]. This research will present some previous research on Fault detection, how to reduce and modify it. what this research has reached, as shown in Figure 1, Figure 2, and Figure 3.

Despite the importance of the topic, in which many studies and research have been published, the reference research is very few. This shortage pushed us in this direction. This research will be one of a series focuses on this matter.

The last review paper in this topic was published in February 2021 by Magnus F. Asmussen. He talked about how to detect faults and the methods to solve it for fluid power pitch. The writer used 48 research as reference to his review paper[7].

Prashant Kumar in late 2020 published state-of-the-art paper. It was very specific discussing fault detection in induction motors. The author used 110 reference and conclude that we need more research using artificial intelligence (AI). It was the most cited paper in this field with 21 citations at the date we published[8].

Anam Abid in November published review and survey on fault detection techniques. Discussed types of faults and how to deal with everyone with best way. The author was very brief and collected many researches which is general in the field of fault detection[9].

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Methodology

In our review, more than 25 research was collected from 2004 to 2021. The research is general about the faults in several topics in power system and every component. The researches have been collected from some web sites as Google scholar and Elsevier.
The researches have been sorted by their published year and has been mentioned in the summary and by their diagnosis technique (SVM, ES, ANN, etc.). The component has the faults has been mentioned too.

Results and Discussion

As shown in Figure 1, 2 and 3 There are many techniques and other methods that take a great deal of research, such as spectral density, graphical, MATLAB, mathematical morphology and data mining. This opens the way to expand the scope of research in artificial intelligence techniques.

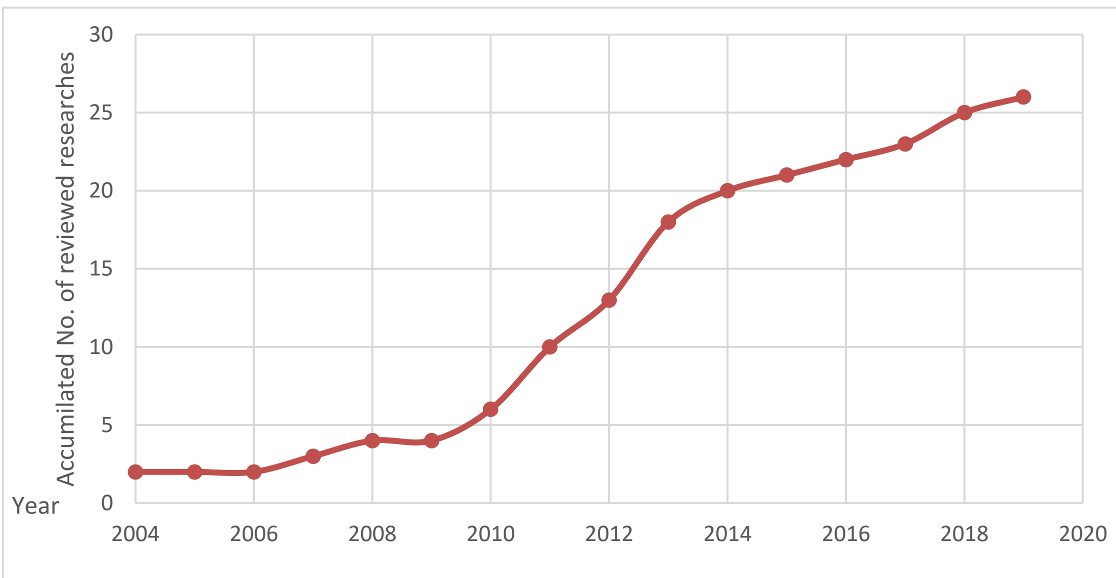


Figure 1 Accumulated number of reviewed researches each year

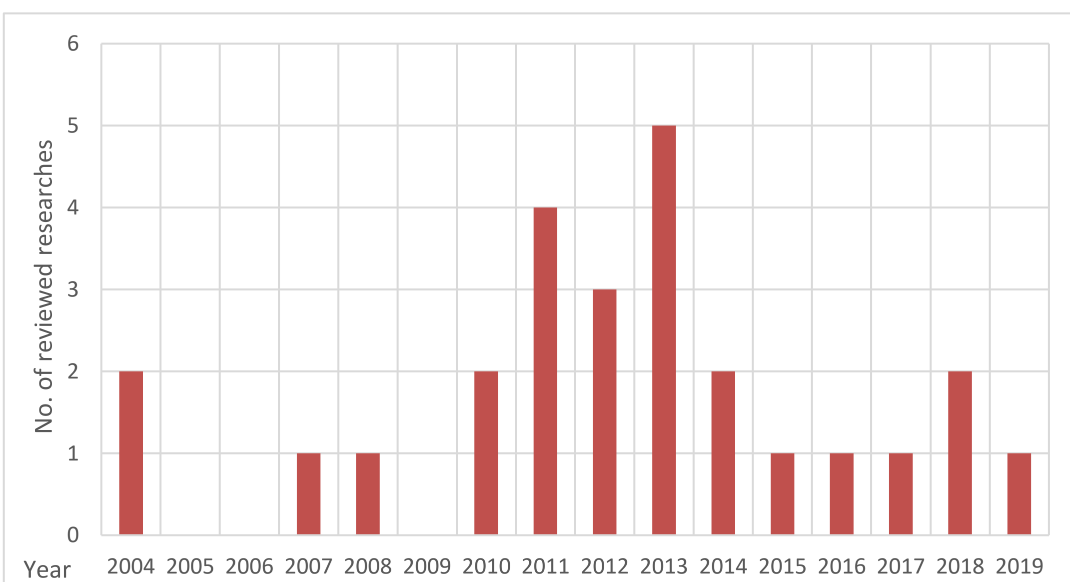
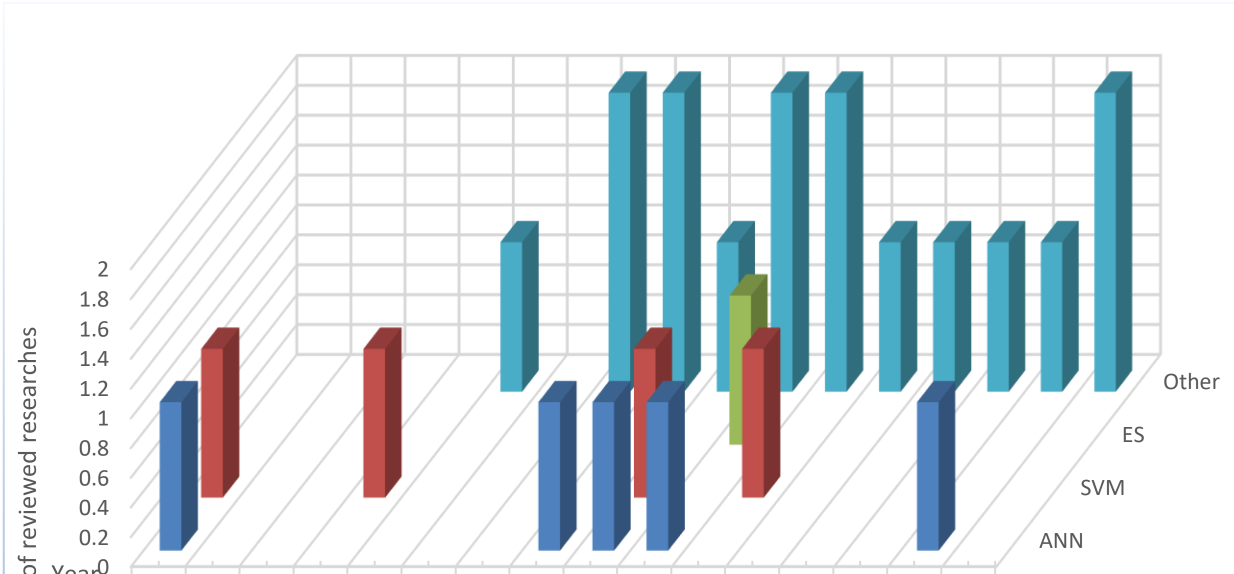


Figure 2 Number of reviewed researches each year



Year	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19
ANN	1							1	1	1					1	
SVM	1			1					1		1					
ES										1						
Other					1		2	2	1	2	2	1	1	1	1	2

Figure 3 No. of research and the used technique

Artificial Neural Networks (ANNs)

In 2004, M. Joorabian published a paper that presents how to detect faults using another artificial intelligence (AI) technique. This technique is called artificial neural networks (ANN). Generally, the network consists of several neurons to import the inputs called "Input Layer" and another number of neurons to export the outputs called "Output Layer" as shown in Figure 4 and in between that two layers (input and output), there may be number of neurons arranged in layers called "Hidden Layers". The neurons of each layer are connected to the neurons of the previous and the subsequent layers by "Links", each link has a particular strength called "weight". Thus, the data passes through links from the input layer to the hidden layers to the output layer [10]. The study clearly shows that ANN is giving very accurate and robust results[11]. In 2011, Joe-Air Jiang tried to bridge the gap between theoretical modeling and the practical implementation in the fault detection, classification, and location methods in the power systems. By using ANN, he identified fault type and detected its location. Using a well-trained framework, fault detection, classification, and location tasks are accomplished in 1.28 cycles, significantly shorter than the critical fault clearing time[12]. In 2012, Eisa Bashieraa noticed that transmission lines are one of the most components which suffer from unexpected failures due to various random causes. These failures interrupt the reliability of the operation of the power system. When unpredicted faults occur, protective systems are required to prevent the propagation of these faults and safeguard the system against the abnormal operation resulting from them.

The features of neural networks, such as their ability to learn, generalize, and parallel processing, have made their applications for many systems ideal. The use of ANN as pattern classifiers is among their most common and robust applications. The use of back-propagation (B.P.) ANN architecture as an alternative method for fault detection, classification, and isolation in a transmission line system[13], [14]. In 2013, Eisa Bashier used ANN to study and detect faults. Unpredicted faults that occur in power systems are required to prevent propagation to other areas in the protective system.

Then, at last, for isolation of the faulty line, the protective relay has to send a signal to the circuit breaker. The ability to learn, generalize and parallel processing pattern classifiers is a powerful application of N.N. used as an intelligent means for detection. It aims to implement a complete scheme for distance protection that is subdivided into different neural networks zones. Data generated is used for single phase to ground faults, double phase faults, and double phase to ground faults. The multi-layer neural networks were trained with the generated data. The results obtained for transmission line fault detection, classification, and location finding all were highly satisfactory using BPNN architecture[15]. In 2018, M. Gowrishankar focused on fault diagnosis in his research, a significant investigation area for power system and intelligent system applications. This paper presents a Discrete Wavelet Transform and Artificial Neural Network approach to fault detection and classification in transmission line faults. The data sets obtained from the Discrete Wavelet Transform are used to train and test the ANN architecture. The feasibility of the proposed algorithm is tested on a transmission line using MATLAB software. A feed-forward BP-ANN structure using a scaled conjugate gradient algorithm is presented for fault classification. He proved that ANN is the best way to determine the correct fault type in transmission line fault classification[16].

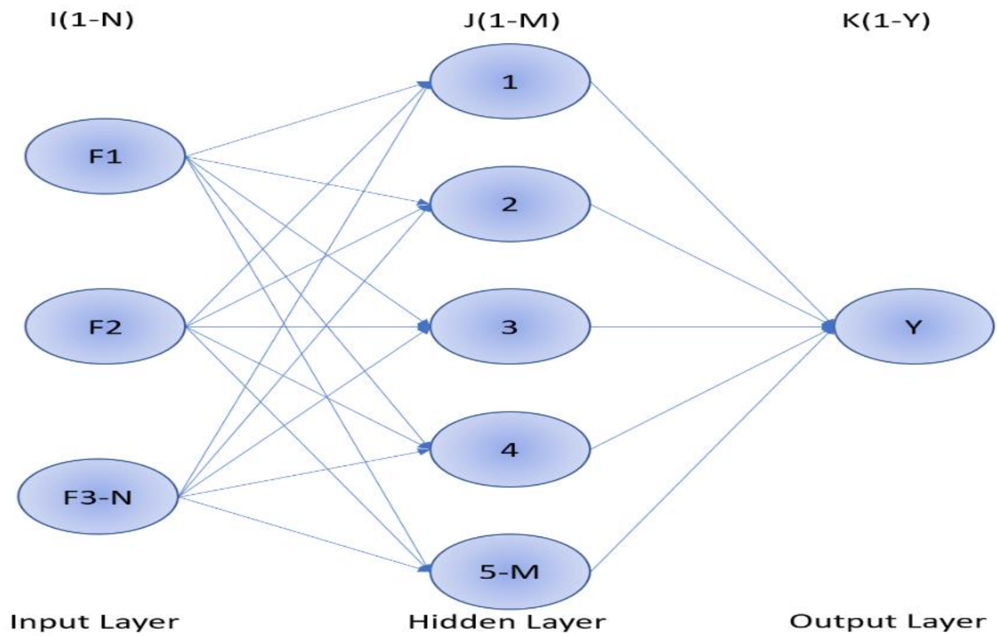


Figure 4 Artificial Neural Network

Support Vector Machine (SVM)

In 2004, Robert Salat presented in his paper a new approach to the fault detection in a more accurate way. He focused on a high voltage power system (HVPS). He used a support vector machine (SVM) application, an AI technique, a computer algorithm that learns by example to assign labels to objects, as shown in Figure 5 [17]. This HVPS is used to transfer electricity for long distances. The SVM used in this research and made the error never exceed 2 Km, and most of them are below 100 m in lines 200 Km long[18]. In 2007, P. K. Dash classified faults and section identification. The author presents a new approach for the protection of thyristor-controlled series compensator (TCSC). Again, the author used the SVM technique. In this research 3 SVMs used to optimize the classifier, different parameter values were used with polynomial kernel and Gaussian kernel. SVM is more efficient and accurate compared to ANN[19]. In 2012, Sami Ekici presented a new approach to classify fault types and predict the fault location in high-voltage power transmission lines using SVM and Wavelet Transform (W.T.) of the measured one-terminal voltage and current transient signals. The fault classification error is below 1% for all tested fault conditions. The average error of fault location in a 380 kV–360-km transmission line is below 0.26%, and the maximum error did not exceed 0.95 km. The mean of all average errors of fault classification is about 1% for all fault types, and the overall accuracy of fault locator is 0.26484% for SLG, 0.20516% for L.L., 0.74856% for LLG, and 0.39816% for LLLG faults, respectively, in the 360-km transmission line[20]. In 2014, A.A. Yusuff proposed a novel transmission line fault location scheme, combining stationary wavelet transform (SWT), determinant function feature (DFF), SVM, and support vector regression (SVR). Various faults are investigated at different locations, fault impedance, and fault inception angles on a 400 kV, 361.297 km transmission line. A classifier (SVM) and regression (SVR) schemes are subsequently trained with features obtained from DFF. The scheme is then used in the precise location of the fault on the transmission line. Compared with other methods, the scheme only used 1/4 cycle to accurately decide where a fault has occurred along a transmission line. It indicates that the scheme proposed in this paper can correctly and rapidly locate faults with different fault types and different fault inception angles. The result shows that fault location on transmission lines can be determined rapidly and correctly irrespective of fault impedance[21].

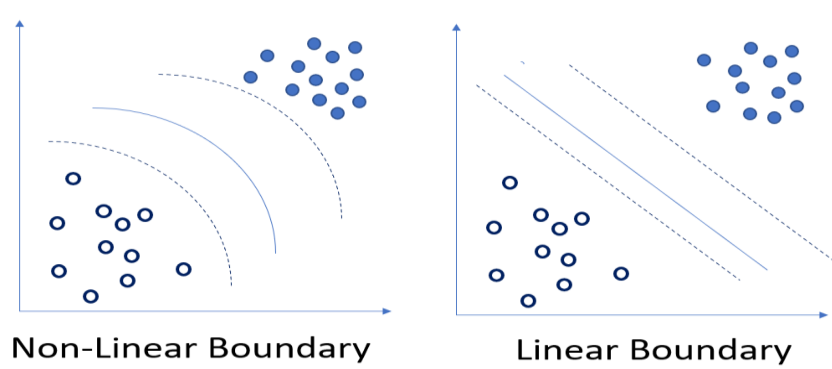


Figure 5 Support Vector Machine

Expert System (E.S.)

Ernest Vhquez made research dependent on artificial inelegance (AI). He used a specific technique called expert system (E.S.). E.S. refers to programs that adapt, learn, invent, and accumulate the combined wisdom of a profession, as shown in Figure 6 [10]. In this research, the author pre

sends the E.S. structure with discerption included, and this method is used to determine the most probable failures places [22]–[25]. In 2013, Deyin Ma published

A paper on research studying fault diagnosis using the Backpropagation neural network expert system (BPES). From his point of view, fault detection and assessment is a challenging and crucial problem. However, with the layer numbers increasing, BPES becomes time-consuming and even hard to converge. Experimental results show that the Multi-BP expert system (MBPES) obtains higher accuracy than the two commonly used methods. Furthermore, by comparing the Back propagation neural network (BPNN) and multi-BP expert system (BPES), we can see that the results from Multi-BP are more accurate. Using a multi-BP network to diagnose a power system, not only can we diagnose the transformer online and offline, but the system will also give us the diagnosis advice quickly[26].

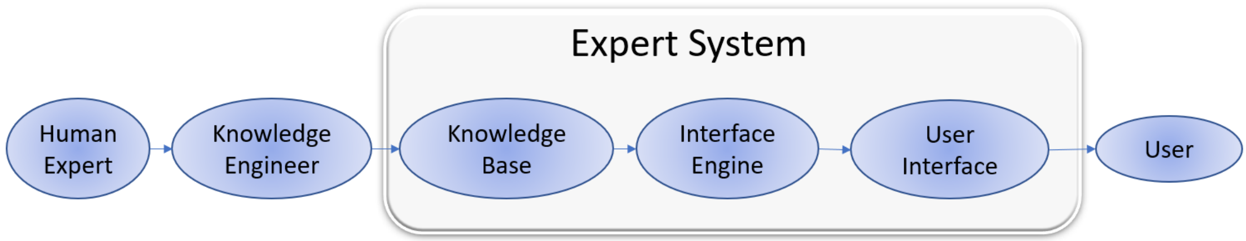


Figure 6 Expert System

Other Techniques for Fault Detection

In 2008, M. Babita Jain published a paper to develop a web-based on ES. The advantage in this research is the ability to be used by anyone due to the friendly graphical user interface. Moreover, this web is linked to a significant knowledge database [27]. In 2010, A. Chouder presented a new fault detection procedure for P.V. systems based on power losses analysis. This automatic supervision system has been tested experimentally and gives good results [28]. In 2010, J. Cusidó wrote this scientific paper to propose a different signal processing method, which combines wavelet and power spectral density techniques. Current signature analysis is used many times and experimentally used for fault diagnosis. In this research, the author presents a comparison between different time-frequency signal processing techniques[29]. In 2011, Mariya Babiy published her thesis, which concerns fault detection in one of the most critical and expensive components in power systems. This component is the power transformer. This thesis studied and presented a new, effective and efficient protection technique. With this technique, we can detect minor internal turn-to-turn faults. It can also differentiate between internal and external faults[30]. In 2011, Iman Shames wrote a research that proved that we could make a system to construct a bank of unknown input observers and use them to detect and isolate faults in the network. Presented results show distributed implementations. Infeasibility results with respect to available measurements and faults are also provided, and methods to remove faulty agents from the network are provided. This paper recommends future work that includes reducing the dimension of the unknown input observers at each node in the current scheme and exploring the applicability of other fault detection methods to the problems considered here that are more robust to the noise[31]. In early 2012, H. Braun said that Photovoltaics (P.V.) is an important and rapidly growing area of research. After studying the intelligent grid, an opportunity exists to apply signal processing techniques to monitor and control P.V. arrays. A fault detection algorithm was formulated as a clustering problem and addressed using the robust minimum covariance determinant (MCD) estimator. This estimator described as its performance on simulated instances of arc and ground faults is evaluated. Although the algorithm shows good performance in simulations, several opportunities for improvement exist. One of them is the sampling period of the monitoring system[32]. another research talking about P.V. was published in 2013 by Ye Zhao. Uncleared fault current appears when utilizing conventional overcurrent protection devices. Solar P.V. arrays are unique power sources for these faults. 3-Sigma rule, Hampel identifier, and Boxplot rule are the 3 rules this paper discussed. The rule may be recommended for P.V. fault detection. Furthermore, the proposed models in this paper become more reliable as the number of P.V. measurements increases. The developed methods may be integrated with a P.V. monitoring system for real-time operation. Besides using P.V. string current, the measurement may also be broadened to include some readily available P.V. parameters, such as P.V. insulation impedance, output power, or energy yield. This could bring more flexibility into the fault detection methods[33]. In 2013, Md. Nazmul Alam presented in his paper a novel conformal surface wave (CSW) launcher, which can excite electromagnetic (E.M.) surface waves along with unshielded power line cables non-intrusively. For nonintrusive open fault detection, the error is less than 5% when the cable length is less than 10 m, comparable to other direct-connect fault finding techniques. For a cable length of 15.14 m, 7.6% error is noted. Besides cable fault detection, the potential applications of the proposed launcher include broadband power line (BPL) communication and high-frequency power transmission. Given the depth and breadth of the problem, outstanding issues that will need to be solved in future research include detecting other types of faults, e.g., insulation degradation, cable defects, defect resolution, and developing more sophisticated waveforms and algorithms. Furthermore, issues such as possible power line currents interfering with the sensor onboard electronics and developing a true independent sensors node where the signal processing occurs on the sensor node are also important[34]. In 2013, Paresh Kumar Nayak made a novel fault detection technique for the series-compensated line during the power swing presented in this paper. It uses a cumulative sum of the change in the magnitude of negative-sequence current to detect faults. The performance of the proposed algorithm is tested for balanced and unbalanced faults for different series-compensated systems. Conditions such as high resistance, close-in, and fault during single-pole tripping are considered for testing the algorithm. The method is compared with available techniques, and it is found that the method is accurate and fast in detecting faults during the power swing in a series-compensated line[35]. In 2014, Abouzar Rahmati presented a paper focusing on fault classification techniques for transmission lines based on the fault sequence components for the fast and reliable protective relays operation. First, symmetrical components of fault current and voltage signals are extracted. Next, the fault type is classified using the zero and negative sequences. A criterion index based on the zero and negative sequences is defined to realize in-ground faults' faulted phases. The imaginary part of the defined criterion index is used. This index is maximum in the faulted phase in single-phase-to-ground faults, and it is minimum in one of the faulted phases in phase-to-phase-to-ground faults. The results show that the scheme provides a fast fault classification without a threshold to operate. Another advantage compared to the existing methods is that the proposed method is settings-free, comparing only the different sequence components to identify all fault types[36], [37]. In 2015, Amin Ghaderi published research. Talking about a new method to detect faults called high-impedance fault (HIF). This method uses time-frequency analysis for feature extraction is proposed. A pattern classifier is trained whose feature set consists of current wave-form energy and normalized joint time-frequency moments. The proposed method shows high efficacy in all of the detection criteria defined in this paper. The method is verified using real-world data acquired from HIF tests on three different materials (concrete, grass, and tree branch) and under two different conditions (wet and dry). A new set of criteria for fault detection is proposed. The proposed method is evaluated using these criteria, and its performance is compared with the existing methods. Accuracy, dependability, security, safety, sensibility, cost, objectivity, completeness, and speed. A comparison is made between the proposed and existing methods, and it is shown to be more reliable and efficient than its existing counterparts. An increased number of false alarms (negligible imperfection insecurity) is the inevitable consequence of the current wave-form distortion in experimental conditions. It should be noted that the salient shortcoming of this method is that, similar to most of the existing techniques, it is only applicable to radial distribution systems. Therefore, one of the main future goals of this research team is to comply with the fast-growing distributed-generation paradigm and extend the proposed HIF detection technique to bidirectional distribution systems[38]. In 2016, Prakash K. Ray created this paper about fault detection in Wavelet transform. Fault detection and disturbances in distributed generation (D.G.) based power system has been studied. Solar and wind energy systems are interconnected with buses with varied penetration levels to create the power system. The voltage signal is retrieved from the point of common coupling (PCC) and processed using wavelet transform to detect the disturbances. A comparison between the existing and proposed detection is conducted to prove that wavelet transform has superior performance. Further, quantitative analysis using performance indices (P.I.)'s in terms of standard deviation (STD) and energy were also presented for disturbance detections. Qualitative and quantitative analysis shows the proposed transform's effectiveness and accuracy in detecting the islanding and faults[39]. In 2017, Kavaskar Sekar wrote this research using combined mathematical morphology and data mining to detect faults. The current signals are preprocessed using mathematical morphology, and estimation of the signal features is used to generate a decision tree model. The final relaying operation is based on generating a certain data mining decision tree model. The proposed method is the decision tree model. The final relaying operation is based on generated data mining decision tree model. The proposed method is tested on a standard test system with a wide range of power system operating conditions. Simulation results show that the District heating networks are commonly addressed in the literature as one of the most effective solutions for decreasing the proposed method can be highly reliable in detecting high impedance fault for harmless and secured operations. Hence, the proposed method can reliably detect high impedance fault for secured and stable operations in electrical power systems [40]. In 2018, Maziar Babaei surveyed fault detection Isolation and Reconfiguration Methods. As we mentioned before, fault detection is a hard and complex problem in power systems. Maziar wrote that One of the major challenges with electric shipboard power systems (SPS) is preserving the system's survivability under fault situations. Many recent studies in this area take different approaches to address fault tolerance in SPSs. This paper provides an overview of the concepts and methodologies utilized to deal with faults in the electric SPS. An in-depth review of current fault management methods and techniques to mitigate the effect of faults on the system's reliability and performance has been presented. Furthermore, some potential research directions in designing and implementing fault management systems have been proposed and discussed. This survey aims to help researchers comprehend the existing fault handing approaches and the challenges in designing the future fault management system for SPS applications[41]. In 2019, Wen Fan and Yuan Liao published a paper in Protection and Control of Modern Power Systems. They studied wide-area measurements-based fault detection. To maximize the utilization of assets, it is desirable to increase the power transferred over transmission systems. Reliable protection of transmission systems is essential for safeguarding the integrity and reliability of the power grid. Most existing protection systems use local measurements to decide, while pilot protection is used in some circumstances. The scheme partitions the system into subnetworks or protection zones and employs current measurements to derive a fault identification vector indicating the faulted zone. Then the fault location is pinpointed based on wide-area measurements and network data. Finally, Protection systems play a pivotal role in maintaining the safety and reliability of electric power grids. Case studies have shown that the fault zone identification method and fault location algorithm are accurate. The method and algorithm utilize wide-area measurements, which are not necessarily at the terminals of faulted lines. Moreover, case studies show that no-fault types are needed to identify the fault zones and pinpoint the fault locations[42]. In 2019, Yu Li noticed the power systems leakage, high temperature, and physical damage. The capsule network model achieves the core of deep learning. The model is trained and tested by a self-built image dataset of the power system. After being preprocessed and feature-extracted, the visible image is used as the fusion image background. The infrared image provides the thermal information of power equipment. The ultraviolet image provides the electric field information on the exterior of power equipment. The ultraviolet, infrared, and visible light image datasets built in this work are composed of more than 12,000 images of oil transformers and power lines and will be made available. The method of image fusion is based on a capsule network. As a fused result, the faults in the power system can be detected and displayed accurately in the fused image. The author recommends designing a real-time fault detection system and attempting to use Visual Reality (V.R.)[43].

Conclusions

After reviewing many researches in the field of faults detection, treatment, classification, and locating, it was found that there are many broad and large areas for research follow-up and development. Artificial intelligence (AI) has taken the most significant part of the research because of its great merit in saving time and effort and obtaining better results with the continuation of time due to self-education and the speed of completing tasks. However, many artificial intelligence techniques have been used in a small number of researches, and we would like to point out the need to complete the research in them. In the end, with the continuation of technological progress, more faults and errors will appear. Therefore, the scientific community and researchers must continue to develop the field of fault detection to keep pace with technological development and save time, effort, and energy resulting from these faults.

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