Engineering and Technology Journal e-ISSN: 2456-3358

Volume 09 Issue 05 May-2024, Page No.- 3973-3979

DOI: 10.47191/etj/v9i05.13, I.F. – 8.227

Enhancing Power System Reliability Through Advanced Fault Diagnosis Methods: A Deep Learning Approach

Chinedu James Ujam[1], Adebayo Adeniyi D.[2]

[1]Department of Mechatronics Engineering, Federal University Otuoke, Bayelsa State, Nigeria.

[2]Department of Electrical and Electronic Engineering, Federal University, Otuoke, Bayelsa State, Nigeria.

ABSTRACT: In order to attain high reliability in power systems, effective fault detection techniques that can quickly identify and mitigate defects must be developed. In this article, we suggest a novel method for improving power system dependability by using deep learning techniques to identify faults. In order to achieve precise fault identification and classification, our technology uses deep neural networks to automatically learn and extract features from power system data. We thoroughly test our method on a range of fault scenarios and real-world datasets to determine its efficacy. The outcomes show how well our approach performs in comparison to conventional fault identification methods, underscoring the possibility of a major increase in power system reliability. By providing useful insights for improving problem diagnosis techniques in power engineering, this research advances system resilience and minimizing downtime.

KEYWORDS: Power system reliability, Fault diagnosis, Deep learning, Neural networks, Fault detection, Power system stability, Fault classification, Power system resilience.

INTRODUCTION

The demand for electricity in Nigeria is huge.One of the limitations that power supplies face is errors.Therefore, in both the transportation and distribution sectors, errors are a major concern.

A lot of money and facilities are being invested to put the infrastructure in order. According to Rahman et al.(2018), distribution networks have more power interruptions than other sectors. More than 80% of power outages are related to the electricity distribution sector. Due to the size and breadth of the distribution network, locating a fault is often difficult. The errors identified in the distribution sector are transient and permanent errors. One study found that about 80% of errors are temporary while 20% are permanent. Integrating a fault detection and triage system will quickly speed up resolution and reduce downtime. This will in turn improve network efficiency. Lilik et al.(2014) also identified faults as the main cause of grid disruption.

Research also shows that faults account for about 75% of power outages and therefore necessary to localize them to limit the extent of system damage. Currently, the main schemes used for fault localization are: impedance-based method and other fundamental frequency method, high-frequency components and fundamental traveling wave method, on knowledge can be further classified as artificial neural network.

Tailored approaches and hybrid approaches. In this study, artificial neural networks are applied to detect, classify and localize incidents to improve the ability to protect the power system. Artificially intelligent neural networks show great promise in solving error-related problems.

In this study, the interest lies in the ability of the proposed network to effectively classify defects through pattern recognition in the work of Gabriel (2006).

A similar approach of applying artificial intelligence to solve problems related to power distribution system network failures has been widely discussed.

Information obtained from transient signals in time and frequency domains using wavelet transform is applied for fault classification.

LITERATUREREVIEW

In the construction of electrical and control infrastructure, importance is attached to insurance and prevention of defective components. Common control frameworks will require validity, rigor, and stability in the absence of a security framework. A precise understanding of their applications can help integrate renewable energy sources. In this chapter, various insurance issues and plans will be discussed in more depth. The appropriation of information generated through artificial neural organization within the framework of diffusion of control will help overcome some of the challenges associated with conventional insurance plans with comparative advances in transmission quality control, Lai and David 2000. According to Abdulkareem et al, 2016, the main cause of disruption in providing control is blame. The creators describe error as deviation of voltage and current from satisfactory limits.

Therefore, to ensure a continuous supply of control power, it is necessary to secure the line against interfering influences. This will be done by quickly detecting, classifying and blaming, as well as eliminating the faulty area to develop the control supply. For this reason, having a smart framework with overrepresented features is essential.

Horowitz 2006. To reach this conclusion, the fundamental challenge facing the Nigerian 33 kV transmission system as organized today is the need to clearly assign blame to researchers and classify it. Kothrai Nagrath 2003 recognized the neuroprosthetic organization as having exceptional assurance against error-related problems. In considering this issue, the proposed organization's ability to effectively classify defects through design identification in the work of Gabriel (2006) is of interest.

A comparable approach is to apply fabricated ideas in an attempt to blame widely discussed organized traffic control frameworks. Data are determined from repeated temporal and spatial timing signals using connected wavelet changes for error classification.

2.1 The Idea Of Transmission Lines In Power System:

The conversion of mechanical energy into electrical energy is carried out using generators in power plants. These generators supply power to substations through transmission lines. The electricity is then transported to distribution substations before reaching domestic, commercial, and industrial consumers (Wikipedia contributors, 2023a). transmission lines have different resistance, capacitance and inductance, depending on their length, which significantly affects the dynamic behavior of the line.

For ease of modeling, transmission lines are often represented as collections of multiple PI segments along their entire length. Power plants are responsible for producing electricity and are usually located far away from the final consumer for safety reasons. Therefore, electricity is transmitted to consumers through extensive transmission and distribution lines.

Before reaching consumers, transformers are used to lower the voltage. Substation plays an essential role in the operation and control of the power system.

In step-up substations, the operating voltage is usually set at 22 KV, 400 KV or 500 KV, depending on the transmission line parameters. Therefore, the power system consists of many different components, including generating units (GUs), transmission lines, distribution lines, and substations.

These elements work together to form a complete electrical system "EPS".

Initially, power is generated at about 11 KV to 25 KV, later increased up to 220 kV or 500 kV, depending on the specified transmission voltage parameters, especially for transmission lines long distance loading.

Before connecting to the power grid, electricity must pass through high voltage lines as shown in Figure 2.1. A typical transmission line can be divided into three functional sections, as outlined below:

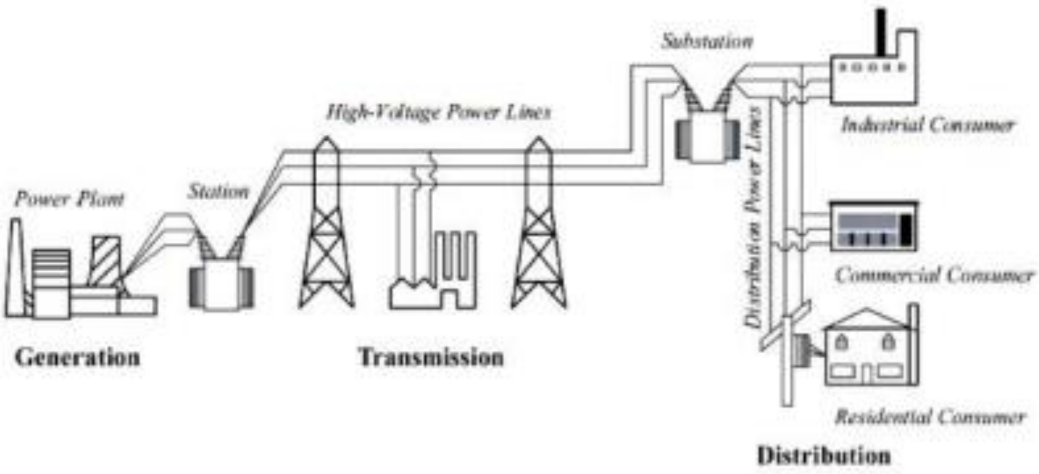

Figure 1: A model of a power system

1. The Generation Site,
2. The Transmission Site, and
3. The Distribution or the Grid Site.

In addition, transmission lines are an important part of the power system and play an important role in the operation and control of the power system. In addition to the operation and control aspects, power system protection is an important issue that needs to be considered, with transmission line protection being the main focus of this thesis.

Transmission line protection plays a central role in meeting power system stability requirements, especially regarding voltage stability. It achieves this by monitoring and protecting against transmission errors.

Additionally, transmission line protection systems perform the essential function of protecting critical electrical components from damage, isolating the system in the event of a power failure, and maintaining operational integrity in the event of a power failure in case of power outage, and preserving operational integrity during fault conditions.

2.2 Faults In Power Systems

Power system failures appear to be somewhat inevitable given the electrical power systems' explosive growth in both size and complexity. Faults are practically inevitable in electrical power systems due to their complex and diverse structure, especially in the transmission line system (Qing Dong & Zhigang Liu, 2013).

Unwanted short-circuit circumstances between two phases or between a phase and the ground are the outward manifestation of faults. Power systems are known to have a variety of failures, which may be related to any of the following circumstances:

1. Lightning,
2. Short Circuits,
3. Faulty Equipment,
4. Miss Operation,
5. Human Errors,
6. Overload, and Aging.

These can be further categorized into three types;

1. Symmetrical Faults,
2. Unsymmetrical Faults and,
3. Open Circuit Faults.

Transmission Line faults are dangerous since it causes overheating or creates mechanical forces with the capability to break equipment and other elements of the power system.

2.2.1 Symmetrical Faults

To have a healthy electrical system, we must ensure it is protected from short circuits. Symmetrical faults include three types of faults, which are:

· Single-phase fault – this is where one phase is short-circuited whether earth is involved or not.

· Two-phase fault – this is where two phases are short-circuited whether they are related to earth or not.

· Three-phase fault – this is where all three phases are short-circuited with or without earth involved.

Symmetrical fault occurs when all three phases experience a short circuit at the same time.

2.2.2 Unsymmetrical Faults

Electrical failures in a power system that do not result in symmetrical current or voltage waveforms are referred to as unsymmetrical faults, asymmetric faults, or unbalanced faults. An uneven distribution of fault currents and voltages among the three phases of a three-phase power system is a defining feature of these problems. Numerous circumstances can result in asymmetrical faults, which can then trigger complicated and dynamic responses from the electrical system. Three primary categories of asymmetrical errors exist:

1. **Single Phase to Ground (L-G) fault** - One phase conductor coming into touch with the ground or a grounded item is known as an LG fault. As a result, the fault current is significantly out of balance, with one phase having a far larger current than the other two. Additionally impacted is the phase-to-ground voltage, which throws the system out of balance.

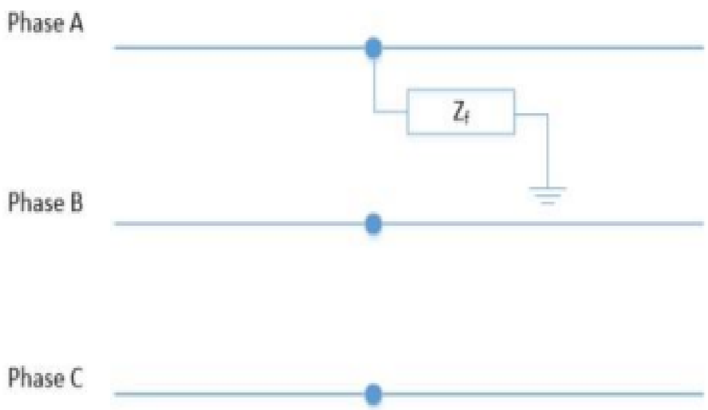

Figure 2 - Line to Ground Fault with Zf Fault Impedance

2. **Two Phases to Ground (L-L-G) Fault** - L-L-G error occurs when two phase conductors simultaneously contact ground or a grounded object.

This leads to a more complex fault condition, where both fault phases are subjected to high currents.

It is important to note that this type of fault may also be referred to as a "two phase ground fault".

· Phase A – Phase B – Earth
· Phase A – Phase C – Earth
· Phase B – Phase C – Earth

Figure 2 provides a visual illustration of a point assumed on the transmission line where stage B is connected to stage C. There has been a ground fault, a double line to ground fault. The fault impedance Zf represents the impedance of the double ground contact.

Since the fault current corresponding to this fault condition will flow through the current-carrying conductors and then through earth, the total fault impedance is indicated on the earth connection.

This impedance value Zf can vary depending on the physical conditions causing the error.

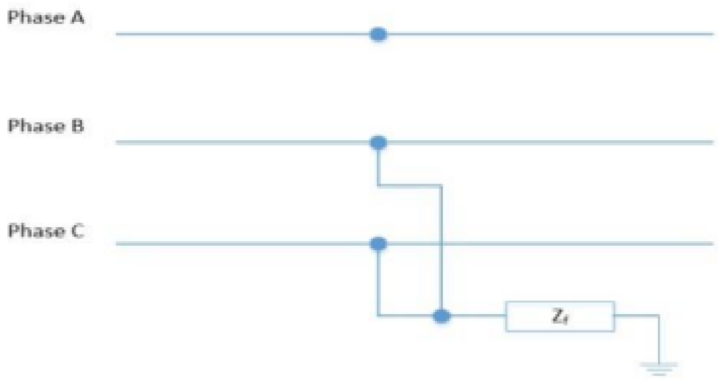

Figure 3 - Line to Line to Ground Fault with Zf Fault Impedance

3. **Phase to Phase (L-L) Fault** - Two phase conductors come into contact with one another in an LL fault, frequently as a result of insulation failure or mechanical failure. Unbalanced currents flow between the two faulted phases and the non-faulted phase as a result of this sort of fault. The system voltage unbalances and there is an increase in current flow via the faulted phases.

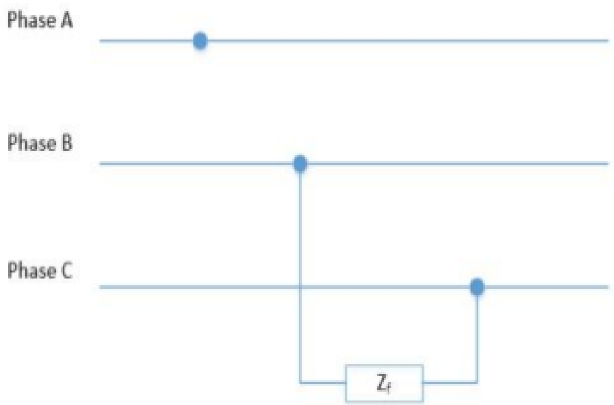

Figure 4 - Line to Line Fault with Zf Fault Impedance

4. **Three-Phase (L-L-L) Fault** - L-L-L is a short circuit found linking whichever two phases of the system.

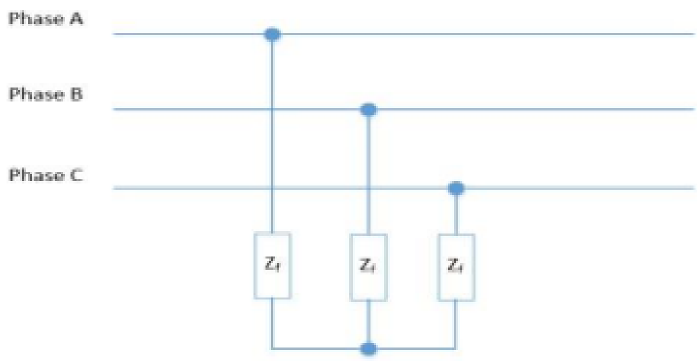

Figure 5 - Three-Phase Fault with Zf Fault Impedance

2.2.3 Open Circuit Faults

Open circuit errors often occur due to interruptions in the electrical path. These faults are typically seen when one or more phases of the conductor are disconnected or when there is a problem in the cable or wire connection on the overhead line.

These types of faults can manifest when multiple phases of the power system become disconnected, affecting the rest of the transmission line equipment. They usually involve situations where one or more phases of conductors are disconnected or cable connections or jumpers in the overhead power network are damaged.

Additionally, these errors can occur when circuit breakers or isolators do not close properly on one or more phases. Conversely, these faults can also be seen when the circuit breaker or isolator opens but fails to close on one or more phases. In case either phase is open circuited, this can lead to unbalanced current flow in the system, leading to heat buildup in rotating machinery.

To cope with such unusual conditions, protection programs must be implemented (ElectronicsHub, 2022b). It is important to acknowledge that transmission lines contribute significantly to power system instability, highlighting the importance of prioritizing their protection.

Many leading companies specializing in transmission line protection offer a variety of solutions to protect these critical components. However, these solutions are not without limitations, creating opportunities for further research to improve existing methods.

Transmission line protection requires the deployment of devices capable of detecting faults and taking corrective measures.Because of the potential for many different types of faults to occur at random locations, it is imperative to fully understand the steps required for effective transmission line protection. This protection process is often divided into three important stages: error detection, error classification, and error location.

2.2.4 Fault Detection

Fault detection (FD) has been a fundamental goal in the field of power systems engineering since the beginning of power systems technology. It not only plays an important role in operating and controlling the electrical system but also significantly improves operating performance. The effectiveness of the detection mechanism is measured by its accuracy and detection speed, with faster detection mechanisms increasing device protection. The importance of timely error detection is directly proportional to the amount of damage it can prevent and repair.

Despite the existence of previous error detection schemes, continuous efforts are devoted to the development of various error detection methods in order to improve their performance and accuracy.

Each error detection method operates independently, and when one or more error detection mechanisms are detected, the detection time is recorded.

In case an anomaly is observed, further procedures such as fault classification and fault location can be performed. However, if the anomaly is recorded at only one end of the transmission line, it may be written to the microprocessor memory as a potential error.

Implementing an error detection system is not a complicated process due to the availability of high-speed electronic microprocessors, advanced digital signal processing techniques, and specialized embedded hardware systems.

However, challenges arise when dealing with irregularly shaped fields, which require additional steps in the error detection process to reduce false alarms and improve accuracy.

All error detection calculations are performed independently and identically for both ends of the transmission line, and interaction of calculations from both ends occurs only when a potential error is detected.

2.2.5 Fault Classification

Transmission line errors are classified into different types based on their unique error signature. The separate behavior of voltage and current transients allows precise fault identification and classification.

Therefore, the fault detection section in the fault protection relay initiates fault classification and ensures fault location. Fault classification is important to determine the type of fault on the transmission line, which in turn is essential for the fault location process.

It is also used to classify faults such as phase-to-earth, phase-to-phase and phase-to-earth faults on transmission lines. The circuit breaker receives data from the fault classification and location components to determine the type and location of the fault. It then makes a decision to activate (open) or remain closed. Tripping the circuit breaker results in a loss of power on the transmission line, while the decision not to disconnect still maintains normal power.

3. MATERIALS AND METHOD

3.1 AN OVERVIEW OF THE MODEL

The system analyzed as the basis for this study includes a 400 KV transmission line system.

The protection strategy used involves the use of an artificial neural network (ANN), which is responsible for the diagnostic and classification functions in the ANN protection relay. Figure 7 illustrates a simple one-line diagram of the system.

This system consists of generating units or alternating current sources connected to both ends of transmission lines with various electrical loads associated with them. Model the system based on distribution line parameters using PI Networks, a well-documented model commonly found in the literature and is the basis for this analysis.

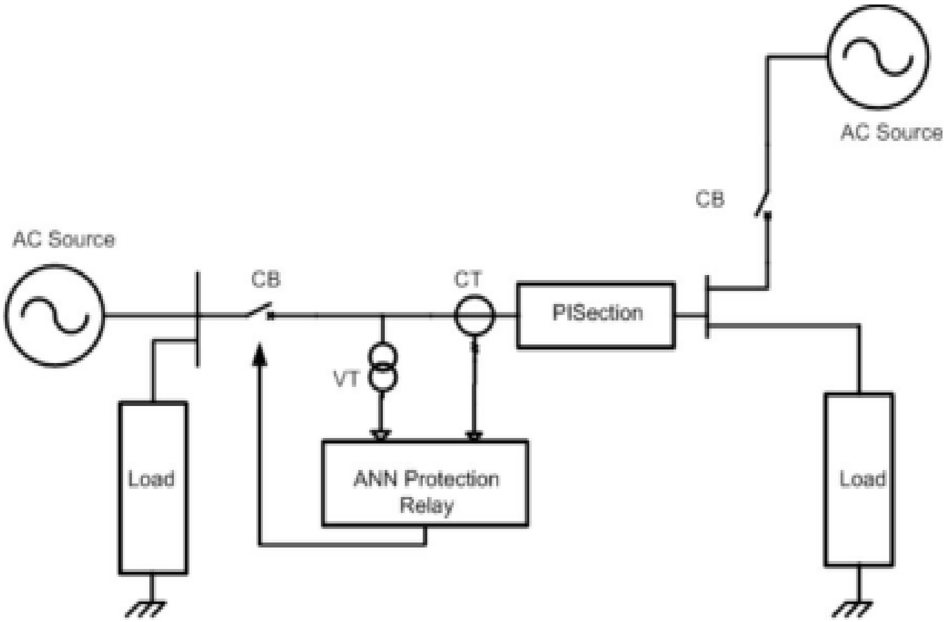

Figure 7: A simple block diagram model of a power system

In the event of a fault on the transmission line, the INS relay detects the presence of a fault and immediately issues a command to turn off the circuit breaker CB . This measure is taken to protect the transmission line TL from possible adverse effects and failures, as shown in Figure 7.

The ANN relay serves as a protection device for the transmission line network. Its main task is to constantly monitor the state of the network and perform protective functions. Therefore, when a fault detection is triggered, the INS relay evaluates the type of fault, a process called fault classification. At the same time, fault location devices are used to precisely locate the fault location. In contrast, fault relays provide more general information about the location of the fault.

In the context of ANN fault detection (FD) applications, the ANN fault detector operates in real time and takes voltage and current measurements. It is critical for FD-ANNs to perform their calculations as quickly as possible to ensure efficient and timely error detection and response.

3.2.1 Mathematical Model

Weights, biases, and activation functions are used in the neural network to execute computations that convert inputs into outputs, which are represented by the equation at each layer. Mathematically speaking, the forward pass equation of a neural network can be represented as follows: weights W, biases B, activation functions f, and inputs X (which stand for Va, Vb, Vc, Ia, Ib, and Ic).

$Z1 = X \times W_1^T + B1$

$A1 = ReLU (Z1)$

$Z2 = A1 \times W_2^T + B2$

Output = Z2

Where:

X is the input matrix.

W is the weight matrix for the connections between the input layer and the hidden layer. B1 is the bias vector for the hidden layer.

W is the weight matrix for the connections between the hidden layer and the output layer. B2 is the bias vector for the output layer.

ReLU is the activation function applied element-wise to the elements of Z1 to get A1. Z1 and Z2 represent the intermediate outputs of each layer.

Output represents the final output of the neural network.

Z1 is the result of the linear transformation (weighted sum of inputs and biases) before the ReLU activation function is applied.

A1 is the output of the ReLU activation applied to Z1 x Z2 is the result of the linear transformation (weighted sum of A1 and biases) to produce the final output.

The values of W1, B1, W2, and B2 are learned during the training process as the neural network adjusts its parameters to minimize the loss function while fitting the provided data. These equations represent the flow of computations through the layers of the neural network from the input to the output.

CONCLUSION

In summary, our study has shown that deep learning approaches can be effectively used to improve power system reliability by utilizing sophisticated problem identification methodologies. Through the application of deep neural network skills, we have created a strong framework that can reliably identify and categorize power system failures. Our technique outperforms traditional methods, as demonstrated by the results of rigorous experimentation and real-world case studies. This work advances power engineering defect diagnosis techniques and provides workable solutions to increase system resilience and reduce downtime. Potential avenues for future study encompass refining deep learning models, integrating them with nascent technologies like the Internet of Things, and implementing real-time problem diagnosis systems to augment power network reliability.

REFERENCES

1. Abdulkareem, A.C., Awosope, O.A., & Awelewa, A.A. (2016). The use of three-phase fault analysis for rating circuit breakers on Nigeria 330 kV transmission lines. Journal Engineering and Applied Sciences, 11(12), 2612-2622
2. Abdulkareem, A.C., Awosope, O.A., Adoghe, A.U. & Alayande, S.A. (2016). Investigating the Effect of Asymmetrical Faults at Some Selected Buses on the Performance of the Nigerian 330-
3. kV Transmission System. International Journal of Applied Engineering Research, 11(7), 5110-5122.
4. Aggarwal, R. K. (2012). A Feedforward Artificial Neural Network Approach to Fault Classification and Location on a 132kV Transmission Line Using Current Signals Only. In the Proceedings of the Upper Peninsula Environmental Coalition.
5. Li, B., Delpha, C., Diallo, D., & Migan-Dubois, A. (2021). Application of Artificial Neural Networks to photovoltaic fault detection and diagnosis: A review. Renewable & Sustainable Energy Reviews, 138, 110512. https://doi.org/10.1016/j.rser.2020.110512
6. Sulaiman, A., Bharathiraja, N., Kaur, G., Karuppaiah, P., Alshahrani, H., Reshan, M. S. A., Alyami, S., & Shaikh, A. (2023). Artificial Intelligence-Based Secured Power Grid Protocol for Smart City. Sensors, 23(19), 8016. https://doi.org/10.3390/s23198016
7. Qing Dong, Zhigang Liu, "The method of short circuit fault identification and location in high-voltage transmission lines," in Advanced Computational Intelligence (ICACI), Sixth International Conference, pp.150 - 154, Oct 2013.
8. Tavakoli, M., & Nafar, M. (2020). Human reliability analysis in the maintenance team of power transmission system protection. Protection and Control of Modern Power Systems, 5(1). https://doi.org/10.1186/s41601-020-00176-6
9. Raza, A., Benrabah, A., Alquthami, T., & Akmal, M. (2020b). A review of fault diagnosing methods in power transmission systems. Applied Sciences, 10(4), 1312. https://doi.org/10.3390/app10041312