

Transmission Line Fault Detection and Classification for Overhead Cables Using MATLAB Software

Jashveendas N.Kannadhas¹, Muhammad Nafis Ismail^{1*}

¹ Faculty of Electrical and Electronic Engineering,
Universiti Tun Hussein Onn Malaysia, Batu Pahat, 86400, Johor, MALAYSIA

*Corresponding Author: nafis@uthm.edu.my

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Abstract

The prompt and exact detection of problems in transmission line systems is vital for assuring dependable operation and sustaining service continuity. This study intends to replicate the detection and categorization of faults in a 33kV transmission line system. Faults in transmission lines occur when two or more conductors has contact with each other or the ground, resulting to poor power quality and potential damage to electrical equipment. In this research, MATLAB Simulink software is employed to construct a model of a transmission line and to simulate several sorts of faults, including single line-to-ground faults, line-to-line faults, double line-to-ground faults, and triple line-to-ground faults. A wavelet transform-based technique is then utilized for fault identification and classification inside the modeled three-phase system. This approach employs the energy percentage at the greatest degree of approximation and the maximum threshold value, adopting a "remove near-zero" strategy by compressing the signal to identify distinct fault circumstances. The results reveal that this technique can successfully distinguish and categorize fault situations, boosting the reliability of fault detection in power transmission systems.

1. Introduction

Increased operational efficacy has been associated with a notable rise in the size of power distribution networks [1]. The fact that these networks have higher transmission and distribution losses than other parts of the power system suggests that these networks are becoming more and more important. The electrical grid's vulnerability to a variety of unfavorable physical occurrences highlights the need for creative solutions [2]. In the past, circuit indicators have been a major tool used by electric power transmission companies to identify damaged transmission lines. Still, the Wavelet Transform Analysis method has revolutionized the way certain issues with the current system are resolved. This advanced monitoring system not only makes it possible to accurately diagnose faults and discern between mechanical and electrical problems, but it also speeds up the process of localizing faults, gives real-time fundamental awareness, and reduces expenses by substituting condition-based servicing procedures for regular maintenance schedules [3]. Many power transmission firms continue to mostly rely on circuit indications to identify potentially dangerous transmission line segments, even despite these advancements [4]. A network design that is responsive in addition to dependable and economical is crucial for success in this field. A paradigm for creating a real-time, low-cost data transmission network is presented in this research. The study investigates several fault detection systems to increase the accuracy of failure detection technology in power transmission.

2. Materials and Methods

2.1 Flowchart of the Project

This project first models fault scenarios in an electrical power system using the MATLAB Simulink tool. The electrical power system's guiding principles will be applied to create the fault condition. After a few surveys of the literature on fault identification and diagnosis in transmission line systems, wavelet transform analysis was found to be a useful method for determining the fault status. The flowchart shows how to set up an overhead wire transmission line fault detection system. Gathering pertinent data and doing research on existing systems is the first step. After that, a comprehensive plan is created with panel and supervisor involvement. The method is then selected, and a MATLAB simulation model is created. Data from the model is generated and examined using wavelet analysis. A thorough report with accompanying documentation is produced when data has been collected and processed. This meticulous approach guarantees thorough research and development of the fault detection system. The development of the project flow is depicted in Fig. 1.

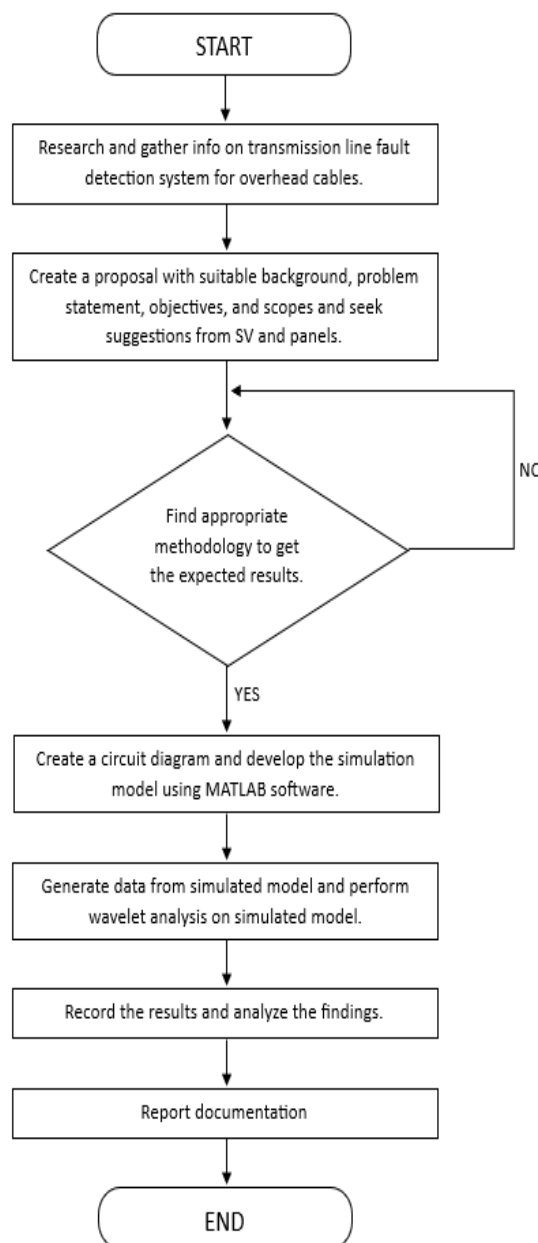


Fig. 1 Whole flowchart of the project

2.2 Simulation and Analysis Works

The SimPowerSystems module from Simulink is being used in the MATLAB environment to simulate this power system model [5]. The entire transmission line model that is used for training and testing is shown in Fig. 2.

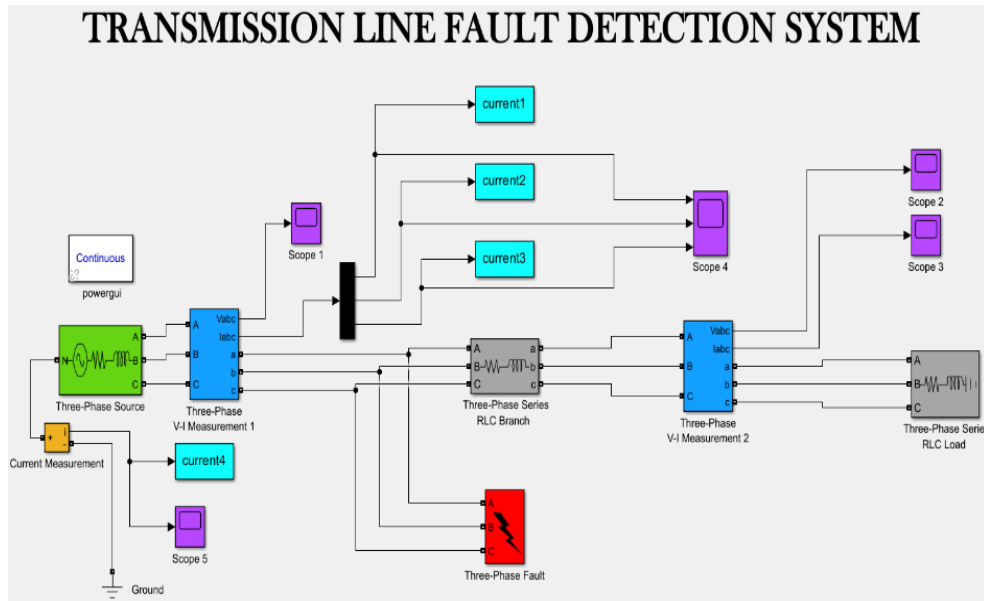


Fig. 2 The model of the transmission line for testing and training

The analysis describes a methodical way to use travelling wave analysis with MATLAB Simulink to simulate and analyze fault scenarios in power transmission lines. While travelling waves are used to examine transient phenomena and identify defects, MATLAB Simulink is used to model and analyze dynamical systems [6]. The procedure entails building a model of a transmission line, causing defects, and then employing wavelet transform to identify and define these faults through the examination of high-frequency signals.

i) Wavelet Transform Analysis

Wavelet transform is often helpful in identifying the beginning of faults. It can analyze non-stationary signals with components at both low and high frequencies. Numerous studies have demonstrated that the initial decomposition level coefficients of the voltage or current signal, as measured by the Haar and Daubechies wavelet, can provide information about the problem in the power distribution line [7]. High frequencies are present at this level and are typically linked to problems. By looking at the discrete wavelet transform coefficient of these basic frequency components under normal conditions, the problem may be found. The discrete wavelet transform coefficient norm for line current is less than a threshold if there is no problem and the lines are running normally. Nevertheless, defects are identified when the threshold value is exceeded by the norm of one or more current discrete wavelet transform coefficients [8]. The simulated system includes the ability to induce four different types of faults: L-L (line to line), L-L-L (three-phase), L-G (line to ground), and L-L-G (line to line to ground).

ii) Detection of Fault

The traveling wave method of fault detection in transmission lines entails the analysis and detection of high-frequency waves produced by faults. Traveling waves are produced by a fault and move along the transmission line [9]. Using sensors at several locations to record these waves and analyze their arrival time, the precise position of the fault may be ascertained. These signals are frequently processed using the wavelet transform, which offers a thorough frequency and temporal analysis and improves the precision and effectiveness of problem localization and detection in power systems.

iii) MATLAB code

This MATLAB script uses the Simulink model 'TLFDS1.slx' to simulate and evaluate a power transmission line fault. Following the simulation, current data for the four phases (A, B, C, and ground) are extracted, and the Daubechies wavelet ('db4') is used in a wavelet decomposition to provide detail coefficients. The script utilizes the maximum coefficients for each phase to determine the kind of issue and where in the transmission line it is located. The fault type is determined by the combination of phases impacted by the fault detection logic, which determines if these maximum coefficients are above a threshold (200). If a defect is found, the distance between the problem and the transmission line's beginning is determined using the line's overall length and impedance

per kilometer. The script detects if the fault site is within the line's range and can discriminate between several sorts of faults, such as single-line-to-ground, double-line-to-ground, and three-phase faults.

To achieve the intended outcome on the signal, data generated by the simulation system, the Wavelet Transform Technique was integrated into the analysis process. The Wavelet Transform's workflow for analyzing and composing the sinusoidal signal data to obtain the desired value in this simulation is depicted in Figure 3 [10].

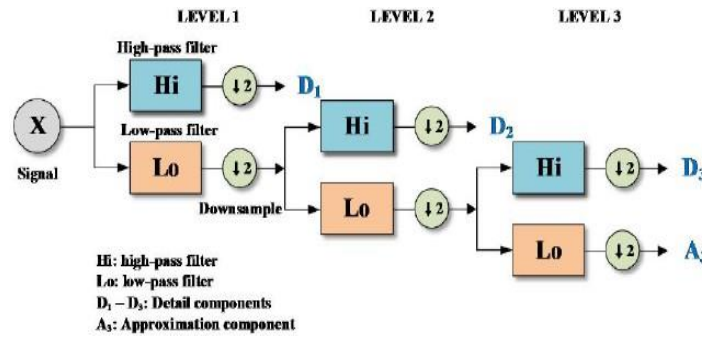


Fig. 3 The Wavelet Transform technique to analyze signal data

Based on the coding of the system, it used the Wavelet Transform syntax to apply on signal.

$$[c, 1] = wavedec(x, n, wname); \text{ Eq. 1}$$

where,

- wavedec = function which decomposes the signal. x = signal
- n = wavelet layer (default = 1)
- wname = name of the wavelet type (such as haar, Daubechies etc)
- c = output wavelet decomposition vector
- 1 = number of coefficients by level

Afterwards, the system used a separate nomenclature for the individual coefficients of each phase current and ground current signal [11]. To determine the threshold value for each error that occurred throughout the simulation, details will be collected.

$$D = detcoef(C, L, N); \text{ Eq. 2}$$

Where,

- detcoef = function which obtains the detailed coefficients of the signal
- c = output wavelet decomposition vector
- l = number of coefficients by level
- n = wavelet layer (default = 1)
- D = extracts the detail coefficients at the coarsest scale from the wavelet decomposition structure [C, L]

The system displays the highest coefficient value for every phase's current and ground current. If a defect occurs, the system will not only provide the result but also classify the type of fault based on the predetermined threshold value [12]. The system will display the specific type of flaw that it has discovered in the result.

3. Results and Discussions

The next section presents the results derived from the simulation. Due to the cabling breakdown, these findings will provide valuable information regarding the timing of the issue on the transmission networks in the ongoing inquiry [13]. The results are displayed under four distinct conditions: no fault, single line to ground fault, line to line fault, and double line to ground fault.

3.1 Results on Waveform of Phase Current

Fig. 4(a) displays the waveform of the phase current, while Fig. 4(b) illustrates the ground current in a simulated system with no-fault condition. From the result, the plot displays many colored sinusoidal waveforms, each representing a measurement from a different system point or phase of the same point. Time is shown by the x-axis, which displays the voltages' temporal behavior. The voltage readings are shown on the y-axis. The voltage waveforms in a healthy transmission line should normally be periodic, stable, and have constant amplitude and frequency [14].

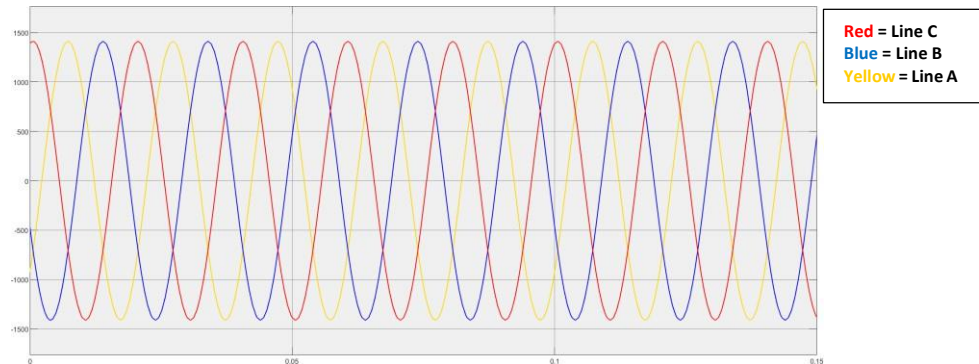


Fig. 4(a) The 3-phase current waveform with no fault added to the simulation

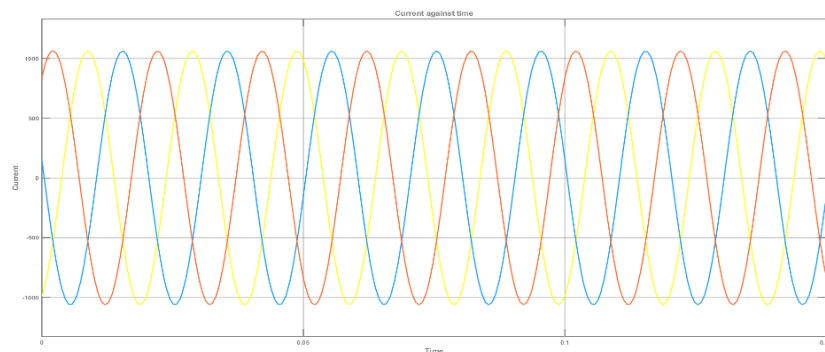


Fig. 4(b) The ground current waveform with no fault added to the simulation

Fig. 5 displays the highest coefficient of the current value, as well as the identification and categorization of fault types that occurred during the simulation. Therefore, the result reported indicates that the system is unable to detect any faults that occurred throughout the simulation.

```

Command Window
Max coefficient of A: 77.8171
Max coefficient of B: 59.0118
Max coefficient of C: 93.4915
Max coefficient of G: 9.4676e-09
No fault is detected.
fx >>

```

Fig. 5 The value max. coefficient of current and the detection of no fault

The findings display the waveform produced by the phase current during the occurrence of different sorts of faults. When a failure occurs, it can be determined that there is a brief overcurrent which leads to instabilities in the waveform. Fig. 6 displays the waveform results for four different conditions: line to ground fault, line to line fault, line to line to ground fault, and three phase faults.

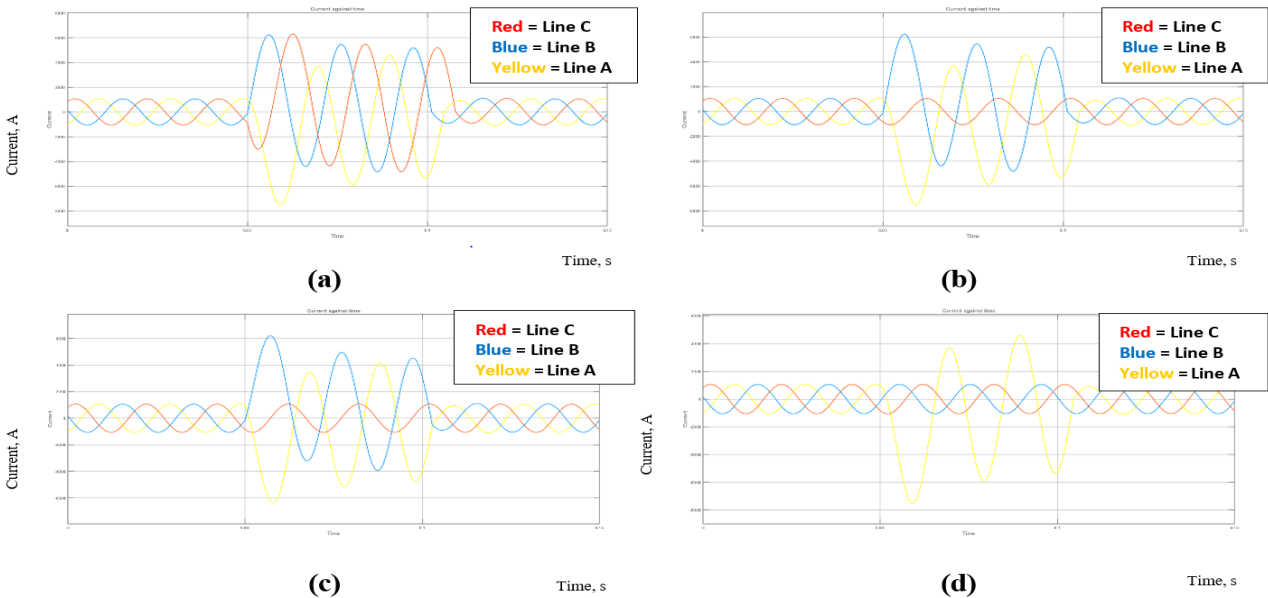


Fig. 6 The 3-phase current waveform with fault added (a) for 3-phase to ground fault (b) for double line-to-ground fault (AB-G); (c) for line-to-line fault (A-B); and (d) for line-to-ground fault (phase A)

Fig. 7 displays the ground current associated with each type of failure. The recorded waveform indicates that the ground current was affected during the occurrence of the event. Fig. 8 displays the system's output, which identifies the specific type of failure that occurred during the simulation. It includes the maximum coefficient for every phase of current. The findings provide the classification of the fault detected in the simulation system, namely the type of fault variables that occurred.

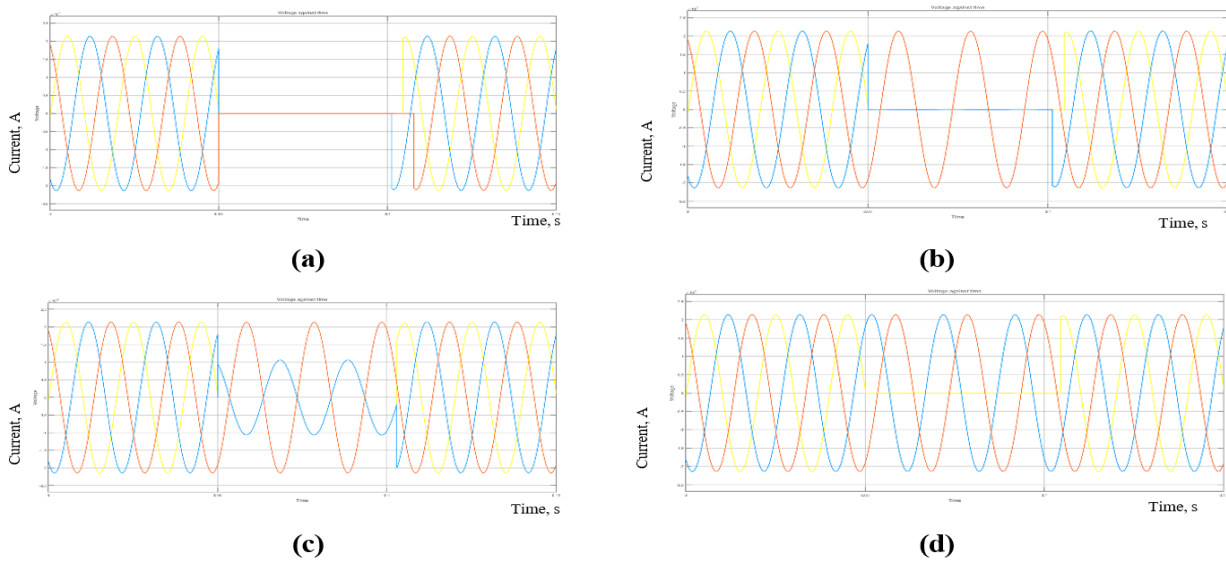


Fig. 7 The ground current waveform with fault added (a) for 3 phase to ground fault (b) for double line to ground fault (AB-G); (c) for line-to-line fault (A-B); and (d) for line to ground fault (phase A)

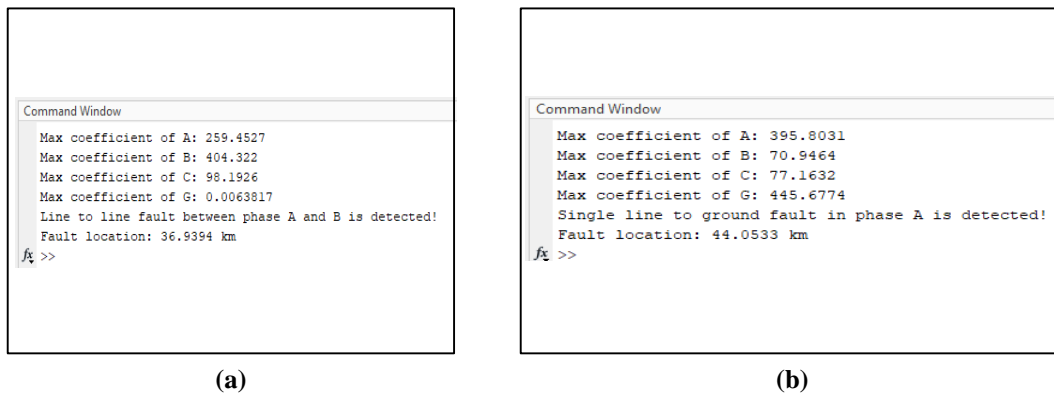


Fig. 8 The value max. coefficient of current and the detection of (a) line-to-line fault (A-B) and (b) line-to-ground fault (phase A)

3.2 Discussions on Waveform of Phase Current

The study conducted is founded on the transient overcurrent observed during the simulation, and the data acquired are derived from the transient signal in the power system, utilizing the Wavelet approach. The estimated threshold value for this project is 200 A, as stated earlier. The number was selected based on the condition that, without any line fault, the highest current coefficient in each phase will not exceed 200 A. For example, the ground current coefficient is lower than the threshold value for three phase faults. The fault data can be utilized to classify various sorts of faults based on the maximum coefficient for the phase current threshold value. The result displays the specific fault variables that occurred in the transmission line. This threshold value is employed in the coding to specify the nature of the malfunction. The simulation results depict the current and voltage waveforms of 11 transmission line breakage scenarios. The highest fault indications were indicated by the greatest coefficient values that were obtained. The categorization of faults was conducted based on the fluctuations in the waveform. The investigation revealed clear patterns that facilitated the identification of defects and ensured the reliability of the system in any failure scenario. The simulation's high classification accuracy affirms its utility in diagnosing transmission line concerns.

4. Conclusion

The study involved analyzing transmission line parameters using MATLAB's Simulink program and the SimPowerSystems module. The goal was to analyze and simulate three-phase breakdowns. The objective of the study was to evaluate various fault scenarios involving all 11 commonly observed forms of flaws in power transmission networks, using the Wave Traveling technique. The Wave Traveling technique allows researchers to study the behavior of voltage and current waveforms during failures by mimicking transient conditions and fault events in power systems. This strategy aids in the identification and categorization of issues within transmission line systems, with the goal of enhancing their performance and dependability. However, the investigation did uncover certain precision problems associated with this method. The research utilized wavelet transform analysis to enhance the identification and classification of faults. This process involved calculating parameters such as the maximum threshold ratio and the percentage of energy in the highest approximation coefficient. The inclusion of these parameters is essential for accurately identifying characteristics that delineate different types of failures. Simulink was an essential tool for reproducing the fault detection and classification approach based on wavelet transform in MATLAB. The objective of the study was to enhance the precision of problem identification and facilitate proactive maintenance techniques in power transmission networks by leveraging these simulation capabilities. While this study successfully showcases the application of wavelet transforms in detecting and classifying faults in power transmission lines, further research is required to explore the implementation of advanced machine learning algorithms, such as Artificial Neural Networks (ANN) and Adaptive Neuro-Fuzzy Inference Systems (ANFIS), to improve the accuracy and reliability of fault detection in different operating conditions. Subsequent investigations could explore the immediate application of the proposed method in functioning power systems to verify its efficacy and capacity to adapt in real-life situations.

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Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: **study conception and design:** Jashveendas N.Kannadhas, Muhammad Nafis Ismail; **data collection:** Jashveendas N.Kannadhas; **analysis and interpretation of results:** Jashveendas N.Kannadhas; **draft manuscript preparation:** Jashveendas N.Kannadhas, Muhammad Nafis Ismail. All authors reviewed the results and approved the final version of the manuscript.

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