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A Review Paper Of Artificial Intelligence-Based Power Fault Detection and Power Restoration

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Abstract:
It has become increasingly challenging to ensure stability and reliability in electrical power systems. Although significant research and technological advancements have been made, a fast and accurate fault detection and classification technique is still needed to ensure security and reduce power outages caused by faults. With a rising population, the demand for electrical power has surged, leading to an increase in power generation units. These units are interconnected through a complex power system network. Malfunctions in the power system can result in significant electrical disruptions, which in turn may lead to substantial economic losses. Therefore, uninterruptible and reliable power transmission is essential to support the country's economic activities. To maintain stability and improve reliability, accurate fault localisation is crucial. In real-life scenarios, faulty sections are isolated from healthy parts of the system using relays and circuit breakers, though relay activation may cause a slight delay. Machine learning (ML) models are trained using available data, such as fault voltage and fault current. Currently, research is focused on fault detection and classification using Deep Learning (DL) and ML techniques.

Keywords: Artificial Intelligence, Fault Detection, Power Restoration, Smart Grid, Machine Learning, Deep Learning.

1. Introduction: Maintaining a high level of service continuity is a primary objective for all power systems, aiming to minimise downtime during exceptional situations. Continuity and reliability are paramount, especially in managing power outages and faults. While weather events, accidents, and equipment failures can disrupt power, it is critical to minimise service interruptions and ensure precise fault localisation. For instance, natural events may cause short circuits, commonly referred to as faults. Faults can be symmetrical or asymmetrical, each presenting distinct challenges. In electrical systems with overhead line networks, line-to-ground faults are a primary source of issues, often caused by lightning strikes or trees falling onto lines during windy conditions. When faults occur within the power system, they typically cause significant changes in system parameters. The purpose of power system protection is to minimise false alarms during normal operations and to enhance sensitivity to faults and unusual conditions through the strategic use and design of relays, fuses, or a combination of both. Therefore, it is crucial for protective devices to accurately determine whether an issue indicates an abnormal condition or a transient event that the system can handle and recover from.

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Types of Faults in Power Systems:

1. Unsymmetrical Faults (Unbalanced)
These faults involve only one or two phases and cause the system to become unbalanced, meaning the fault currents and phase angles are unequal in the three phases. They are the most common type of fault, accounting for about 95% of power system faults.
2. Symmetrical Faults (Balanced)
These faults involve all three phases equally, maintaining the balanced nature of the system (i.e., the phase currents are equal in magnitude and displaced by 120^\circ electrically). They are the least common but the most severe, resulting in the highest fault current.

2. Literature Reviews

Advanced LSTM ELM-Based Artificial Intelligence Technique for Fault Detection, Classification, and Localisation in Modern Electrical Power System Sahoo, Anjan Kumar (January 2025)
In this paper, we propose a rapid and precise technique for fault categorisation and identification, based on a hybrid approach combining Deep Learning (DL) and Machine Learning (ML). The IEEE 11-bus, 2-area, 4-machine system was simulated under both faulty and non-faulty conditions. The proposed power system model was tested using both DL-based LSTM methodology and ML-based Extreme Learning Machine (ELM). The performance of both methodologies was compared and analysed.[1].

AI-Driven Fault Detection and Diagnosis in Smart Grids for Enhanced Power System Reliability Dr Gaurav Goyal, Ismot Tasmary Salsabil, Dr Ashutosh Kumar, Manda Ukey, Dr Velumani P.S., e-ISSN: 2468-4376 Issue 22, February 2025.
This study explores how AI, using machine learning and deep learning, can improve fault detection and diagnosis in smart grids. It highlights that AI-based systems analyse real-time data from sensors to quickly and accurately identify and classify faults, outperforming traditional methods in speed and precision.[2].

Three Phase Transmission Line Fault Detection & Protection Abhijeet Lad *1, Ajaykumar Khopkar*2, Sahil Lad*3, Vaishnavi Kalaskar*4, AS Yadav*5 (IJPREMS) Volume. 03, Issue 05, May 2023
This paper analyses techniques for fault localisation, classification, and detection in three-phase transmission lines and distribution systems. Transmission lines are critical for moving large amounts of power across different regions, but they are sensitive to various atmospheric disasters and faults.[5].

Artificial Intelligence-based Power Fault Detection and Power Restoration B Selvin Sanjay, Saurabh Bansod, Shashank Kumar Singh, Prashant Pal, ISBN: 978-1-6654-8271-4, Issue ICECA 2022.
This research uses Artificial Intelligence (AI), specifically Artificial Neural Networks (ANN), to proactively detect faults in a power system. By analysing data from both the transmission and consumer ends, the ANN model can rapidly identify potential faults. The study's results, visualised in MATLAB, demonstrate the system's ability to predict faults on a simulated transmission line before they cause a widespread outage.[8].

An Intelligent Approach to Locate and Classify Fault in Transmission and Distribution Line Using Computational Intelligence Technique, Mishra D.P. (May 2019)
This paper depicts an approach with an artificial neural network (ANN) for the classification and localisation of faults on the power transmission line. A huge number of transmission and distribution lines

are used for the transportation of electrical energy in the power system. Moreover, developing a completely reliable system is not possible within the economic and technical limitations. So, there always remains a probability of faults in the transmission lines. When it occurs, it is aimed at locating and classifying the fault to restore the sound condition of the transmission line. For analysing the transmission line fault, this paper adopts the fault-tolerant neural network-based method, as it can process incomplete and noisy data. This approach can deal with non-linear problems and can carry out the prediction if trained. Feedforward neural networks, along with the backpropagation algorithm, are used in each of the three phases of the transmission line for the fault localisation process. The proposed method uses the instantaneous measure of the fault current to return the fault type and the distance from the experimental end. The modelling of the power system and the development of the neural network for this method have been conducted in the MATLAB/Simulink environment. The simulation results illustrated in this paper manifest that the proposed model is promising in performance.[12]

3. Methodology

The AI-based fault detection and restoration process includes the following stages:

1. Data Acquisition: Sensors capture voltage and current values.
2. Preprocessing: Removes noise and normalizes input signals.
3. Feature Extraction: Key indicators such as RMS current, voltage dips, and phase angle shifts are extracted.
4. Model Training: Historical fault data is used to train ML/DL models.
5. Fault Detection: Real-time data is compared with trained patterns to identify fault type.
6. Isolation & Restoration: Faulty sections are isolated, and the power supply is restored using automated switching.

3.2 Block Diagram

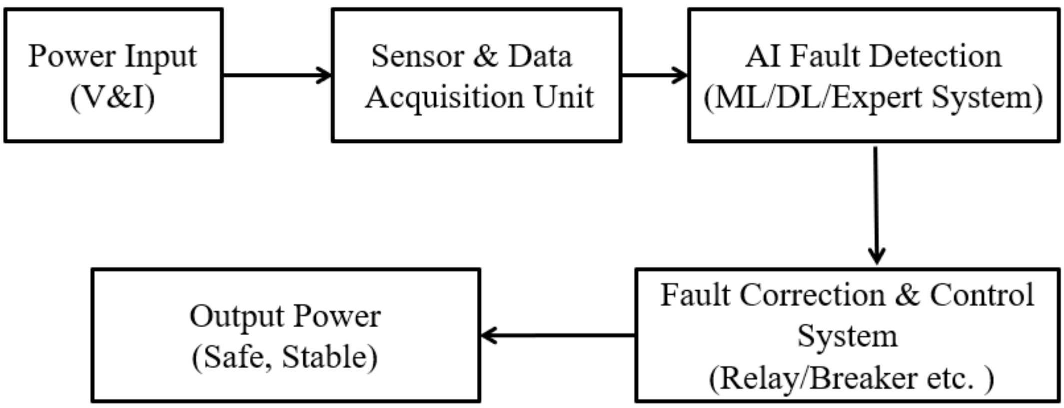

Fig. 3.1 Block Diagram

3.3 System Components: System Components: The system architecture includes both hardware and software components.

3.3.1 Hardware Components

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1. Current & Voltage Sensors (CT/PT): These sensors continuously measure the voltage and current levels of transmission and distribution lines. They detect sudden variations in electrical quantities during faults, such as short circuits or overloads. The data is then sent to the controller or RTU for processing.
2. RTU (Remote Terminal Unit): RTUs are field devices used to collect real-time data from sensors and transmit it to the central control system. They convert analogue signals from sensors into digital data for AI algorithms. RTUs are often used in substations to gather data from multiple feeders.
3. IED (Intelligent Electronic Device): IEDs are smart protective devices that can execute control actions such as tripping circuit breakers or isolating faulty sections. They have embedded processors that make local decisions based on AI or pre-programmed logic.
4. Microcontroller/Processor: The processing unit where initial data processing and decision-making occur. Microcontrollers such as Arduino, Raspberry Pi, or DSP boards are often used to implement AI-based algorithms and control switching operations.
5. Step-Down Transformer: Since grid voltages are very high, a step-down transformer converts high-voltage signals into a lower, measurable range suitable for sensors and controllers. This ensures that monitoring and data acquisition can be done safely.
6. Communication Module (Wi-Fi/GSM): These modules enable wireless or wired communication between substations, control centres, and AI servers. Real-time communication is essential for the quick detection, isolation, and restoration of faults.

3.3.2 Software Components

1. AI Algorithm (ML/DL Models): Used for data analysis, classification, and fault prediction.
2. Database: Stores historical data for model training.
3. Visualisation Dashboard: Displays grid health and restoration actions.

3.3.3 Programming Language Used

1. **React** – Used for building interactive frontend user interfaces for web applications.
2. **JSON (JavaScript Object Notation)** – Used for data exchange between frontend and backend systems.
3. **TensorFlow** – Used for developing and training machine learning and deep learning models.
4. **Uvicorn** – Used as a high-performance server to run asynchronous Python web applications.
5. **Fast API** – Used to build fast and scalable APIs using Python.
6. **Pydantic** – Used for data validation and parsing in Python applications.
7. **NumPy** – Used for numerical computations and handling arrays/matrices in Python.
8. **Scikit-learn** – Used for implementing machine learning algorithms and data analysis.

4. Advantages

1. Improved Accuracy: AI-based fault detection techniques can accurately identify faults, reducing false alarms and misclassification.
2. Faster Restoration: AI-based power restoration techniques can quickly identify the optimal restoration strategy, minimise downtime, and reduce power outage duration.
3. Enhanced Reliability: AI-based techniques can predict potential faults, enabling proactive maintenance and reducing the likelihood of power outages.
4. Increased Efficiency: AI-based techniques can optimise power flow, reducing energy losses and improving overall system efficiency.

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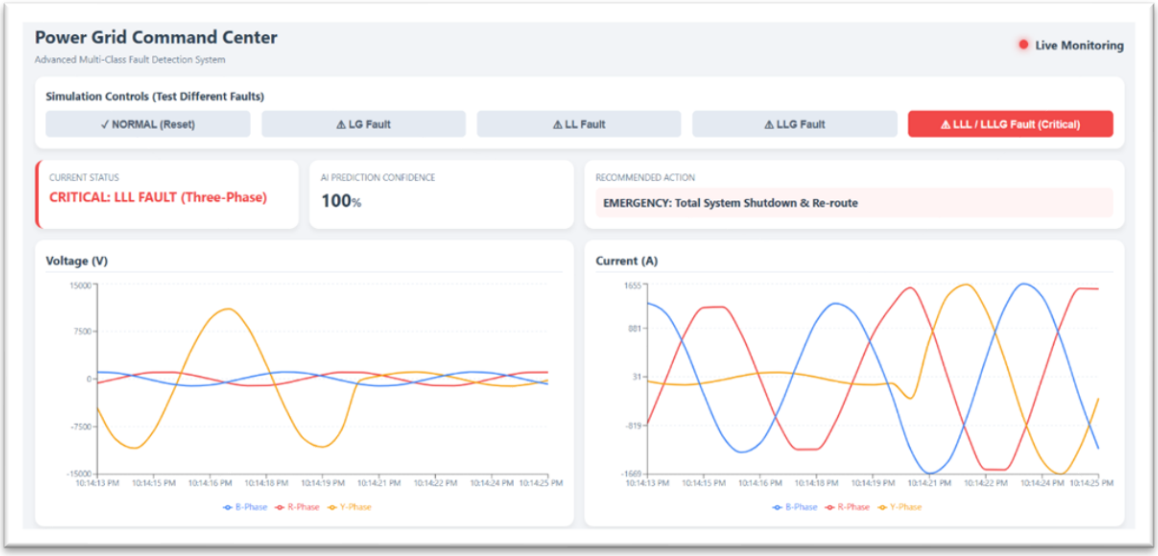
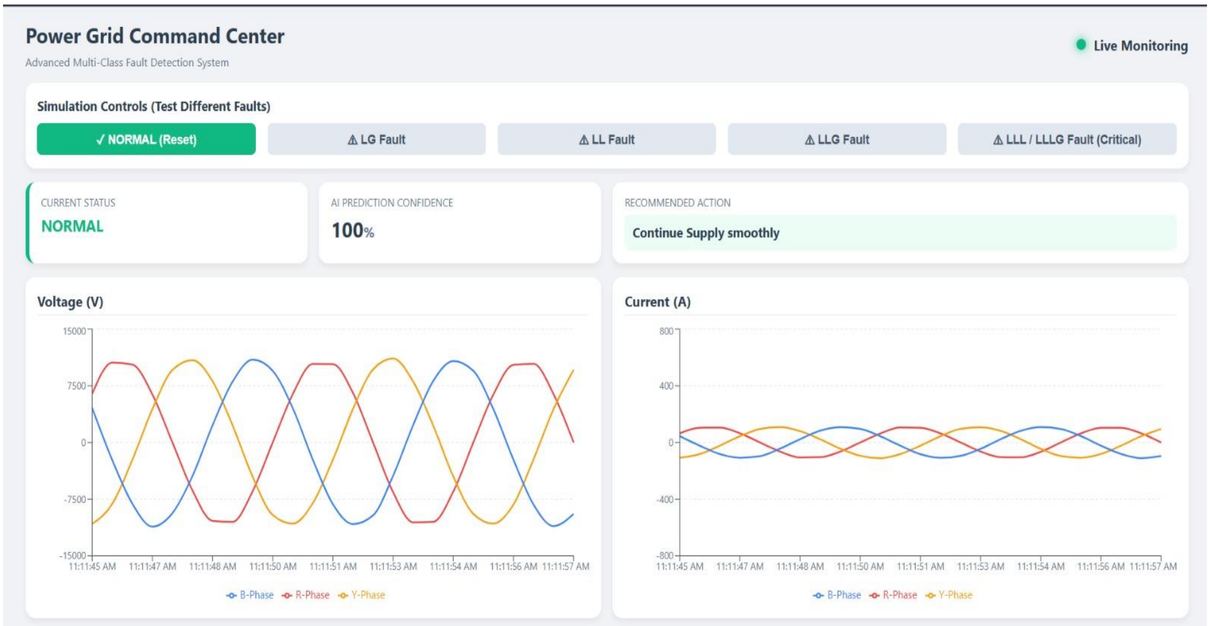
5.Result



5.1: Power grid command centre (Fault)



5.2: Power grid command centre (Normal)

6. Conclusion

AI-based power fault detection and power restoration techniques have the potential to transform the power industry, enabling efficient, reliable, and secure power supply. However, addressing the challenges and future directions will be crucial to realizing the full potential of AI in power systems. The benefits of AI-based techniques, including improved accuracy, faster restoration, enhanced reliability, and increased efficiency, make them an attractive solution for modernizing power systems.

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