International Journal of
AI ELECTRICAL CIVIL AND MECHANICAL ENGINEERING
Peer Reviewed, Referred & Indexed Journal
ISSN: 3070-0434 www.zesterapublications.com Original Research Paper

AI ASSISTED ELECTRICAL FAULT CLASSIFICATION

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Abstract

The AI Assisted Electrical Fault Classification project focuses on developing an intelligent system for detecting and classifying different types of electrical faults in power systems. Electrical faults such as single-line-to-ground, line-to-line, double-line-to-ground, and three-phase faults can cause equipment damage, power interruptions, and safety hazards. Therefore, fast and accurate fault identification is essential for maintaining the reliability and stability of electrical networks.

The proposed system uses artificial intelligence and machine learning techniques to analyze electrical parameters such as voltage, current, and other relevant signal characteristics. The collected data is processed and supplied to an AI-based classification model that learns the patterns associated with different fault conditions. Based on the extracted features, the system identifies the type of fault and provides a corresponding classification result.

The methodology involves data collection, preprocessing, feature extraction, model training, testing, and fault classification. Machine learning algorithms can be trained using normal and fault-condition datasets to improve classification accuracy. The trained model can then classify new electrical conditions automatically without requiring extensive manual analysis.

The system helps reduce the time required for fault identification and can support engineers in making faster decisions during abnormal operating conditions. It can also be integrated with monitoring and protection systems to provide real-time fault information.

Overall, the AI Assisted Electrical Fault Classification project demonstrates the application of artificial intelligence, machine learning, electrical signal processing, and power-system analysis for automated fault identification. The system can be further enhanced using deep learning, real-time monitoring, IoT connectivity, and larger fault datasets to improve classification accuracy, reliability, and practical applicability.

I. Introdution

Electrical power systems are essential for supplying electricity to residential, commercial, and industrial applications. During normal operation, the system is expected to maintain stable voltage, current, and frequency conditions. However, unexpected faults can occur due to equipment failure, insulation damage, short

Received: 24-07-2026 | Accepted: 30-08-2026 | Published: 05-09-2026

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circuits, lightning, or other abnormal conditions. These faults can cause excessive current, voltage disturbances, equipment damage, and power interruptions.

Common electrical faults include single-line-to-ground fault, line-to-line fault, double-line-to-ground fault, and three-phase fault. Identifying the type of fault quickly is important for protecting electrical equipment and maintaining the reliability of the power system. Conventional fault identification methods generally depend on predefined rules, threshold values, and manual analysis of electrical parameters.

With the development of Artificial Intelligence (AI) and Machine Learning (ML), intelligent techniques can be used to automatically recognize patterns in electrical signals. Parameters such as voltage, current, phase angle, and frequency can be collected during normal and faulty operating conditions. These signals can then be processed and provided to a trained machine learning model for fault classification.

In this project, an AI Assisted Electrical Fault Classification system is developed to analyze electrical parameters and classify different types of faults. The system involves stages such as data collection, preprocessing, feature extraction, model training, testing, and classification. The trained model learns the characteristics of different fault conditions and predicts the fault category when new electrical data is provided.

The proposed approach can reduce the time required for fault identification and provide consistent classification results. It can also assist engineers and protection systems in making faster decisions during abnormal operating conditions. The system can be implemented using suitable machine learning algorithms and electrical fault datasets.

Overall, the project demonstrates the application of artificial intelligence, machine learning, electrical signal processing, and power-system analysis for automated electrical fault classification. The system can be further enhanced using deep learning, real-time monitoring, IoT connectivity, larger datasets, and advanced feature extraction techniques to improve accuracy and reliability.

II. Literature Survey

Research on AI-assisted electrical fault classification has increased with the development of machine learning, digital signal processing, and intelligent power-system monitoring. Traditional protection systems mainly depend on predefined relay settings, threshold values, and mathematical fault calculations. Although these methods are effective for many conventional applications, they can become challenging when power-system conditions are complex or when different fault types produce similar electrical characteristics.

Several researchers have investigated the use of artificial neural networks (ANNs) for electrical fault detection and classification. Neural networks can learn the relationship between measured electrical quantities and different fault conditions from previously collected data. Voltage and current signals from transmission or distribution systems

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can be used as inputs to the network, allowing it to identify whether the system is operating normally or experiencing a particular type of fault.

Other studies have explored support vector machines (SVMs) for fault classification. SVM-based approaches can classify electrical faults by learning boundaries between different fault categories using extracted features from voltage and current signals. These methods have shown potential for handling nonlinear relationships and providing accurate classification with relatively limited training data.

Researchers have also applied decision trees and ensemble machine learning algorithms to power-system fault diagnosis. These techniques can analyze multiple electrical features and determine the most likely fault category. Their relatively simple decision structure can also make the classification process easier to interpret compared with some complex neural-network models.

Wavelet transform and signal-processing techniques have been widely studied for extracting useful features from transient electrical signals. Wavelet-based methods can capture both high-frequency and low-frequency characteristics of voltage and current signals during fault events. The extracted features can then be supplied to machine learning algorithms to improve fault detection and classification performance.

Recent research has increasingly focused on deep learning techniques, including convolutional neural networks (CNNs) and recurrent neural networks (RNNs). These models can learn complex patterns directly from electrical signals and reduce the need for manually selected features. Deep-learning approaches are particularly useful when large datasets containing different operating and fault conditions are available.

Another important research area is the use of simulation-generated datasets for training AI models. Software tools can simulate different fault types by changing parameters such as fault location, fault resistance, system loading, and fault initiation time. These datasets provide a controlled way to generate a large number of training and testing samples before deploying the model on real electrical networks.

Recent approaches also combine AI with real-time monitoring and IoT technologies. Electrical measurements can be collected continuously from sensors or intelligent electronic devices and transmitted to a processing platform. An AI model can then analyze the incoming data and classify abnormal conditions, potentially supporting faster fault identification and improved maintenance decisions.

Based on the existing research, the proposed AI Assisted Electrical Fault Classification project focuses on collecting voltage and current data, preprocessing the signals, extracting relevant features, and training a suitable machine learning model to classify different electrical faults. The system can identify fault categories such as single-line-to-ground, line-to-line, double-line-to-ground, and three-phase faults. Further improvements can include deep learning, real-time data acquisition, IoT-based monitoring, larger datasets, and hybrid AI models to achieve higher accuracy and faster fault classification.

III. System Analysis

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System analysis is an important stage in developing the AI Assisted Electrical Fault Classification system. The system is designed to detect and classify different types of electrical faults automatically. Electrical parameters such as voltage, current, phase values, and fault characteristics are considered as input data. The collected electrical data is first processed to remove unwanted noise and inconsistencies. Relevant features are then extracted from the processed signals for classification. A suitable machine learning algorithm is selected based on the required accuracy and performance. The model is trained using normal and different fault-condition datasets. Testing is performed using unseen electrical data to evaluate the classification performance. The system identifies faults such as single-line-to-ground, line-to-line, double-line-to-ground, and three-phase faults. The predicted fault category is displayed as the output of the system. Accuracy and other performance measures can be used to evaluate the trained model. Overall, the system analysis provides the requirements for developing an accurate and efficient AI-based electrical fault classification system.

Existing System

In the existing system, electrical faults are commonly detected using conventional protective relays, circuit breakers, threshold-based methods, and manual analysis. Protective devices monitor electrical parameters such as voltage and current and operate when predefined limits are exceeded. Traditional relay systems are designed according to specific operating conditions and protection settings. Fault identification may depend on measured current, voltage, impedance, and phase relationships. These methods provide reliable protection for many conventional power-system applications. However, identifying the exact fault type may require additional calculations or analysis. Changes in network configuration and operating conditions can affect the performance of fixed threshold-based approaches. Conventional systems generally have limited learning capability because their decision rules are predefined. Large amounts of historical fault data are also not automatically utilized for improving classification. Manual analysis can increase the time required to identify complex fault conditions. Therefore, an intelligent data-driven approach can improve automatic fault classification and provide faster analysis.

Disadvantages of Existing System

- Depends heavily on predefined protection settings.
- Limited learning capability.
- Difficult to handle complex fault patterns.
- Manual analysis may be required for detailed classification.
- Fault identification can take additional time.
- Performance may vary with changing operating conditions.
- Limited use of historical fault data.
- Difficult to classify similar fault patterns accurately.
- Requires careful relay setting and coordination.
- Conventional methods may require additional calculations.
- Limited adaptability to changing power-system conditions.
- Advanced analysis may require experienced engineers.

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Proposed System

The proposed system uses artificial intelligence and machine learning techniques to automatically classify electrical faults. Voltage and current signals are collected from normal and faulty operating conditions. The collected data is preprocessed to remove noise and improve the quality of the input signals. Important characteristics are extracted from the electrical signals and used as features for the AI model. A suitable machine learning algorithm is trained using different fault-condition datasets. The training dataset includes normal operation and multiple fault categories. The trained model learns the electrical patterns associated with different types of faults. During testing, new electrical data is supplied to the trained model for prediction. The system can classify faults such as single-line-to-ground, line-to-line, double-line-to-ground, and three-phase faults. The predicted fault type is displayed through a suitable user interface or monitoring system. Model performance can be evaluated using accuracy, precision, recall, and confusion matrix analysis. Overall, the proposed system provides an intelligent, automated, and adaptable approach to electrical fault classification.

Advantages of Proposed System

- Provides automated fault classification.
- Uses AI for intelligent pattern recognition.
- Reduces dependence on manual analysis.
- Can classify multiple fault types.
- Provides fast prediction of fault conditions.
- Can learn from historical electrical data.
- Adaptable to different operating conditions.
- Reduces complex manual calculations.
- Provides measurable classification accuracy.
- Supports real-time monitoring applications.
- Can be integrated with IoT systems.
- Can be improved using advanced machine learning and deep learning.

IV. Methodology

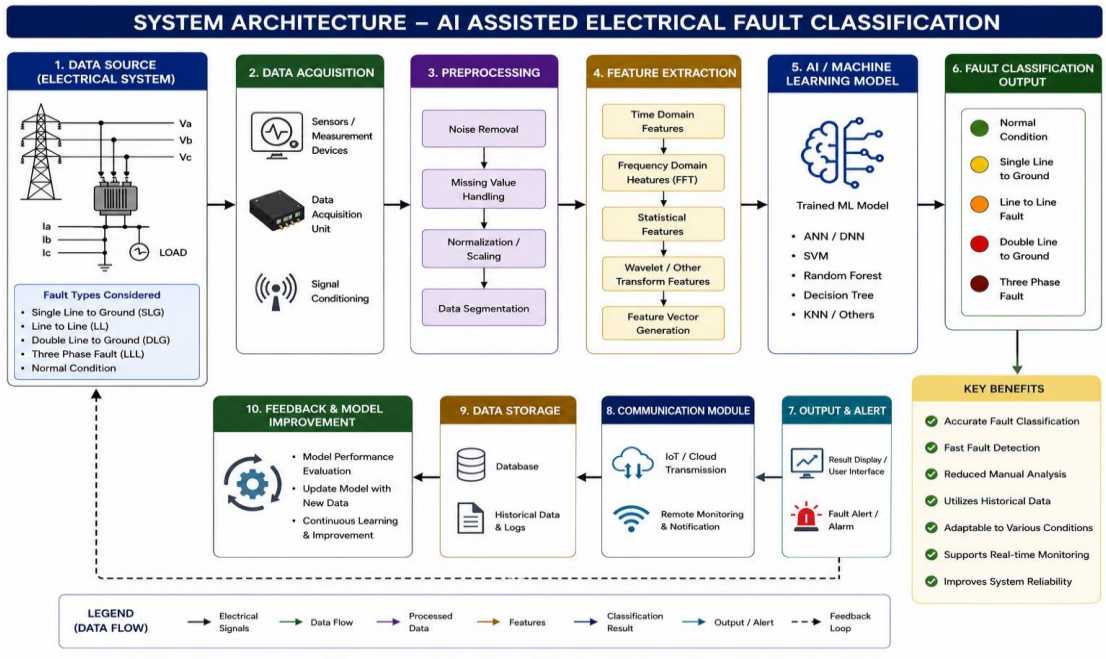
The methodology begins with collecting electrical data representing normal and faulty operating conditions. Voltage, current, phase information, and other relevant electrical parameters are obtained through simulation or suitable data-acquisition methods. The collected dataset is organized according to different fault categories. Data preprocessing is then performed to remove noise, missing values, and unwanted variations. The processed signals are normalized or scaled when required by the selected machine learning algorithm. Important features are extracted from the electrical signals to represent the characteristics of different fault conditions. The dataset is divided into training and testing portions for model development and evaluation. A suitable machine learning algorithm is selected and trained using the training dataset. The trained model is tested using previously unseen electrical samples. Classification results are evaluated using accuracy, precision, recall, F1-score, and a confusion matrix. Incorrect classifications are analyzed to identify possible improvements in the model or dataset. Finally, the optimized AI model is

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used to automatically classify new electrical fault conditions and display the predicted result.

System Architecture

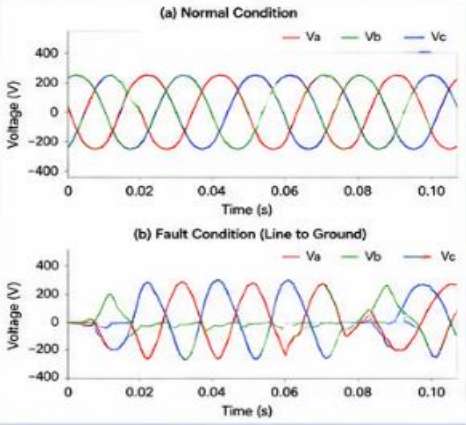
The system architecture represents the complete workflow of the AI Assisted Electrical Fault Classification system. The process begins with the electrical power-system model or real-time electrical network from which voltage and current signals are obtained. A data-acquisition module collects the required electrical parameters from the system. The collected signals are transferred to the preprocessing module for noise removal, normalization, and data preparation. The feature-extraction module identifies important characteristics from the voltage and current signals. The prepared features are then supplied to the AI or machine learning classification model. The trained model analyzes the input patterns and compares them with learned fault characteristics. The classification module determines whether the condition is normal or represents a particular electrical fault. The system can identify single-line-to-ground, line-to-line, double-line-to-ground, and three-phase faults. The prediction results are transferred to the output or monitoring interface for visualization. An alert module can generate a warning when a fault is detected. The system can also connect to an IoT or communication module for remote monitoring. The complete architecture provides an automated workflow of data acquisition, preprocessing, feature extraction, AI classification, fault identification, and result visualization.



V. Result and Output

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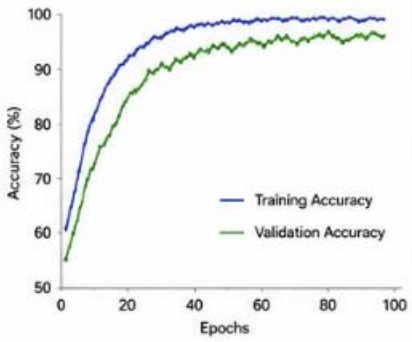
1. DATA ACQUISITION (SAMPLE WAVEFORMS)



2. FEATURE EXTRACTION (SAMPLE)

Feature	Normal	SLG	LL	DLG	LLL
RMS Voltage (V)	230.1	210.6	198.4	205.7	176.2
RMS Current (A)	5.21	18.47	22.31	20.15	30.62
Active Power (W)	1193	815	652	742	432
Reactive Power (VAR)	214	381	501	468	689
Frequency (Hz)	50.02	49.98	49.95	49.96	49.90
THD (%)	1.21	4.67	5.38	4.92	6.71
Wavelet Energy	0.35	0.87	1.06	0.95	1.48
Peak Current (A)	7.12	26.41	31.53	28.13	40.62

3. MODEL TRAINING PERFORMANCE



Final Training Accuracy : 98.76 %
Final Validation Accuracy: 96.32 %

4. CONFUSION MATRIX (TEST DATA)

Actual Class	Normal	SLG	LL	DLG	LLL	Recall (%)
	Predicted Class					
Normal	197	2	1	0	0	98.50
SLG	1	195	3	1	0	97.50
LL	0	2	196	2	0	98.00
DLG	0	1	2	194	3	97.00
LLL	0	0	1	2	197	98.50
Precision (%)	99.50	97.50	97.50	96.50	98.50	Accuracy 97.60%

5. REAL-TIME CLASSIFICATION OUTPUT (SIMULATION)

INPUT PARAMETERS

RMS Voltage (V)	201.3
RMS Current (A)	23.48
Frequency (Hz)	49.96
THD (%)	5.12
Active Power (W)	684
Reactive Power (VAR)	512

Time Stamp
20-05-2024 15:36:52

PREDICTED FAULT CLASSIFICATION

LINE TO LINE FAULT

Confidence Score
97.84 %

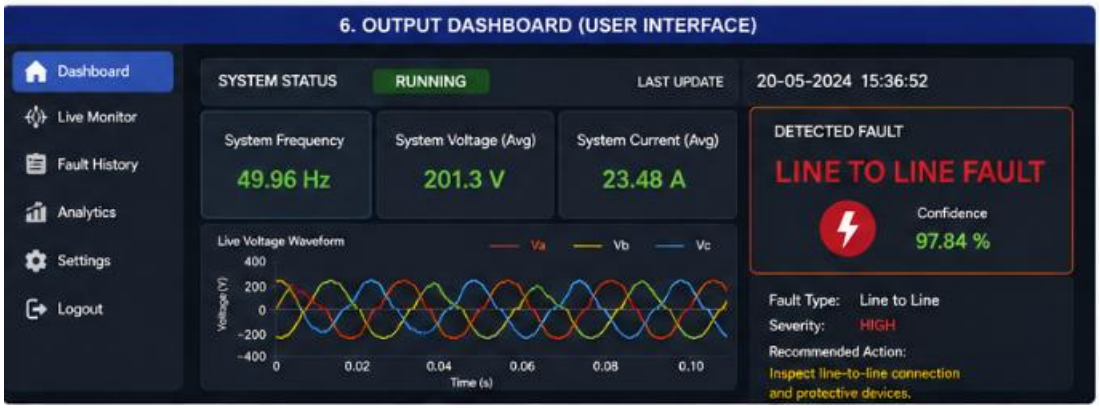
Fault Severity
HIGH

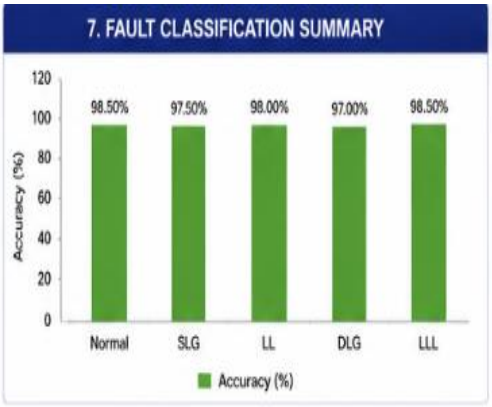
PROBABILITY SCORES

Normal	0.78 %
Single Line to Ground	1.25 %
Line to Line	97.84 %
Double Line to Ground	0.82 %
Three Phase Fault	0.31 %

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8. COMPARISON WITH EXISTING METHODS

Method	Accuracy (%)	Precision (%)	Recall (%)	F1-Score (%)
Decision Tree	91.23	91.05	91.12	91.08
SVM	93.84	93.65	93.71	93.68
Random Forest	95.28	95.12	95.21	95.16
ANN	96.31	96.14	96.22	96.18
Proposed (AI Model)	97.60	97.43	97.51	97.47

9. SAMPLE TEST CASE RESULTS

Test Case	Actual Fault	Predicted Fault	Confidence (%)	Result
TC-01	Normal	Normal	99.12	Correct
TC-02	SLG	SLG	96.35	Correct
TC-03	LL	LL	97.84	Correct
TC-04	DLG	DLG	95.68	Correct
TC-05	LLL	LLL	98.47	Correct

VI. Conclusion

The AI Assisted Electrical Fault Classification project successfully demonstrates the use of artificial intelligence and machine learning for the automatic identification and classification of electrical faults. The system analyzes electrical parameters such as voltage, current, frequency, and other extracted features to identify abnormal operating conditions.

The proposed system can classify different fault conditions such as single-line-to-ground, line-to-line, double-line-to-ground, and three-phase faults, along with normal operating conditions. Data preprocessing and feature extraction help provide suitable input to the machine learning model and improve the reliability of the classification process.

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The AI-based approach reduces dependence on manual fault analysis and can provide faster classification results. Performance evaluation using parameters such as accuracy, precision, recall, and F1-score helps determine the effectiveness of the trained model.

Overall, the project demonstrates that AI and machine learning can provide an efficient and intelligent approach to electrical fault classification. The system can be further improved by integrating deep learning, real-time data acquisition, IoT-based monitoring, larger datasets, and real-time protection mechanisms to achieve faster, more accurate, and reliable fault detection in practical power-system applications.

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