A Review of Fault Detection and Diagnosis in Power Systems Using Artificial Intelligence

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Abstract

Electricity is crucial to modern society, requiring a stable and uninterrupted supply. Faults in power systems present significant challenges, underscoring the importance of effective fault detection and diagnosis. This review paper offers a concise overview of artificial intelligence-based methods for fault detection and diagnosis in power systems, with a particular emphasis on deep learning. It serves both as an introduction for newcomers and as a comparison of various works in the field. The paper also explores the use of UV-visible video processing to detect early-stage faults by analyzing corona discharge and air ionization. Furthermore, this state-of-the-art review highlights the application of deep learning, especially in UV-visible video processing, for the detection of incipient faults through corona discharge and air ionization analysis. Despite ongoing research, the field remains without a clear direction or structure, highlighting the need for further development in applying AI for effective fault detection and diagnosis in power systems.

Index Terms: *Artificial Intelligence, Computing Machines, Fault Detection, Fault Diagnosis, Electrical Power System.*

I. INTRODUCTION

Electrical energy is the most widely used form of energy today, and modern society depends heavily on its continuous availability. Whether for computers, telecommunications, industrial, or domestic use, the importance of electrical power cannot be overstated [1], [2]. This growing reliance increases the demand for uninterrupted power supply. It's important to recognize that no power system is immune to failures; faults are inevitable. The key lies in preventing faults as much as possible and mitigating their effects when they occur [1]. Since 80% of faults happen in distribution lines, this area is of particular interest to researchers [3]. Additionally, the integration of renewable sources like wind and solar introduces two-way power flows, further complicating distribution systems [4], [5].

This paper focuses on distribution networks, discussing only faults and their impact within this context. The work by Bhide, et al., on power system protection provides an excellent discussion of fault types, their effects, and traditional methods of fault detection and mitigation [1]. Faults in power systems not only disrupt power supply but can also lead to serious accidents. Our abstract pseudocode provides a clear summary of the overall fault detection process, with each function call representing a specific type of fault detection, making the system more understandable.

Our review also includes Table I, which outlines different detection methods using pseudocode, offering a comprehensive overview of the subject.

A. Motivation

This review paper provides a comprehensive overview of recent advancements in AI-based diagnosis and detection of power system malfunctions. It effectively consolidates findings from various studies, making it a valuable resource for practitioners and researchers. The paper is distinguished by its organized structure, clear explanations, and detailed presentation of methodologies and results.

B. Contribution

The paper offers two main contributions: first, it provides an extensive introduction to AI-based fault detection and diagnosis in power systems, with a particular focus on deep learning techniques. It includes both an overview and a comparative analysis of different studies in the field. Second, it presents a novel approach by highlighting the use of deep learning in UV-visible video processing to detect incipient faults through corona discharge and air ionization analysis. This innovative application of deep learning represents a significant finding. The paper acknowledges the current lack of a clear framework in the field and advocates for further research and development, positioning itself as a driver of future progress.

Table I: Types of Detection

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# Power System Fault Detection Abstract Pseudo Code

# Incipient Faults Detection
severity_levels = detect_incipient_faults (video_data)

# Earth Fault Detection
detected_faulty_feeders = detect_earth_fault (current_signals)

# Islanding and Grid Fault Detection
fault_types, deep_learning_results, bayesian_network_results =
detect_islanding_and_grid_faults (system_data)

# Fault Detection for DERs
svdd_results, hisvdd_results, pca_results, ica_results =
detect_faults_for_ders (der_data)

# High Impedance Fault Detection
stft_results, cnn_results, dwt_results, lstm_results, vpe_results,
decision_tree_results = detect_high_impedance_faults (grid_data)

# Insulator Fault Detection
renn_results, mask_renn_results = detect_insulator_faults
(image_data)

# Series Arc Fault Detection
rf_results, dnn_results, cnn_lstm_results, clustering_results,
svm_results = detect_series_arc_faults (arc_data)
```

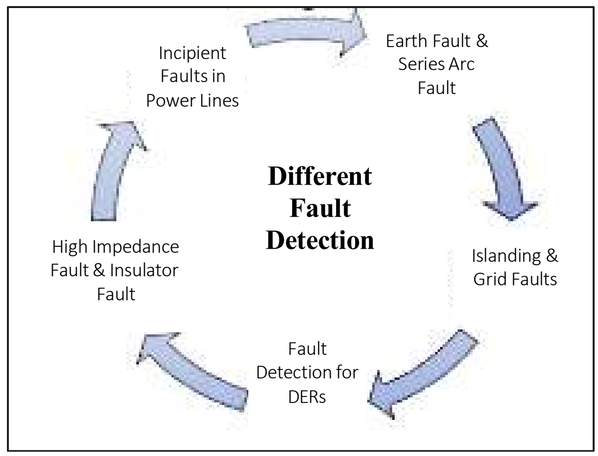

Figure I: Fault Categories

A. *Paper Organization*

The structure of the paper is organized as follows: Section II explains the rationale behind the study. Section III provides a comparative analysis of recent advancements in fault detection. Section IV reviews several notable research papers related to fault tolerance. Section V presents the data and findings discussed in the previous section. Section VI concludes the paper, and Section VII outlines future research directions and limitations of the study.

II. PURPOSE OF THIS STUDY

Recent advancements in Artificial Intelligence (AI), driven by the availability of large datasets and powerful computing resources, have expanded its application across various fields, including electrical power systems. AI is increasingly being used to achieve results that conventional methods cannot achieve. One notable area of application is fault detection in electrical systems, where the majority of failures occur in distribution networks. As a result, ongoing research is exploring new AI-driven methods for enhanced fault identification and diagnosis.

This paper offers a concise review of the progress made in applying AI to electrical power systems, providing an overview of advancements in this field. It highlights various fault detection methods, illustrated in Figure I, with detailed discussions on their methodologies.

RELATED WORK

This section reviews the main AI techniques used for fault detection in power networks, outlining their advantages and limitations. Figure II illustrates the business landscape, algorithm frameworks, data collection methods, and high-performance computing infrastructure associated with these techniques.

A. Expert Systems

Expert Systems (ES) offer a scientifically grounded approach to fault detection by combining deterministic information with logical reasoning. However, ES faces challenges in managing complex or large-scale grids and maintaining an extensive knowledge base, which can be labor-intensive. Additionally, ES has limited learning and error tolerance capabilities. Recent advancements, such as integrating fuzzy set theory, have improved fault tolerance but still face challenges in maintaining knowledge bases for large-scale power systems.

B. Bayesian Networks

Bayesian Networks (BN) use probability theory to handle uncertainty in fault identification by uncovering causal relationships. While BN can effectively diagnose faults in ambiguous situations, it requires substantial prior knowledge and is challenging to model in dynamic grid systems. Enhancements and monitoring technologies have improved BN's ability to predict potential faults, though obtaining statistical samples for significant grid outages remains a challenge.

C. Artificial Neural Networks (ANN)

Artificial Neural Networks (ANN) emulate the biological nervous system to detect faults, offering advantages such as fault tolerance, generalization, rapid processing, and multitasking capabilities. Despite these benefits, ANN's diagnostic methods are often opaque and require a large number of representative samples. Advances like extreme learning machines have improved generalization, but the challenges of applying ANN to large-scale grids and interpreting results remain significant.

The Multi-Agent System

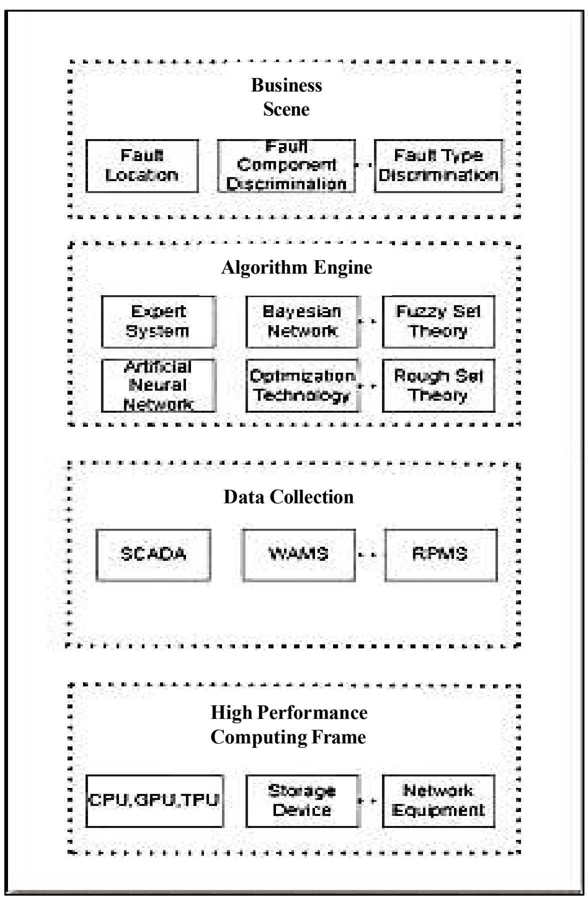

Figure II: Artificial Intelligence Fault Diagnosis System-Based Overall Framework

Multi-Agent Systems (MAS) offer resilience, scalability, and educational advantages by breaking down the grid fault diagnosis process into distinct agent groups. However, challenges remain in reasoning, learning, and collaborative problem-solving among these agents. Further research is needed to enhance agent capabilities and address hardware and software issues.

Information Fusion Technology involves integrating and analyzing multiple data sources for problem diagnosis, which improves accuracy, fault tolerance, and real-time performance. Its effectiveness is further enhanced by advancements such as fuzzy integral theory and wavelet technology. Challenges include selecting appropriate training cases.

Rough Set Theory (RST) offers strong fault tolerance and adaptability to incomplete data by managing uncertainty and analyzing partial information to identify defects. Key lessons include dealing with the impact of missing or inaccurate critical data and the issue of "combined explosion" in dimensionality. Future work will focus on reducing knowledge complexity and integrating AI with other technologies.

A. *Methods of Optimization*

Optimization methods are fundamental to creating mathematical models for defect detection, offering a robust mathematical framework that is also straightforward to implement and program. However, obtaining comprehensive samples for accurate diagnosis can be challenging. To address this, continuous integration combined with genetic algorithms has been proposed as an enhanced approach. Optimization techniques have been shown to deliver effective diagnostic results, whether locally or globally, even when only partial information is available.

METHODOLOGY

A review of journal papers from the IEEE Xplore Digital Library was conducted using search terms such as distribution, power system, AI, defect diagnosis, and fault detection. The review focused on papers published between 2014 and 2023. The selection criteria included the number of citations and the relevance of the papers to the topic.

AI techniques for error identification, fault tolerance, and detection in power systems have been explored by various researchers. Table II below highlights some notable papers and the AI techniques they employed.

Table II: AI Techniques used for Different Faults Detection

FAULT TYPE	METHOD	DESCRIPTION
Incipient Faults In Power Lines	R-CNN	The research paper proposes a method for diagnosing incipient faults in power distribution lines using UV-visible videos captured by corona cameras. The method includes faster R-CNN for power equipment detection, color thresholding for UV section extraction, median filtering for UV noise elimination, and severity level estimation based on UV discharge area to equipment area ratio [2].
	LSTM	The article proposes an Adaptive Time-Frequency Memory (AD-TFM) cell embedded in Long Short- Term Memory (LSTM) to detect incipient faults in power distribution systems. The model, called the AD-TFM-AT model, uses learnable scale and translation parameters to detect faults in time and frequency domains [28].

Earth Fault	CWT & CNN	The research paper presents a novel method for detecting earth faults in resonant grounding distribution systems using Continuous Wavelet Transform (CWT) and Convolutional Neural Networks (CNN). CWT constructs grayscale images of transient zero-sequence current signals, while CNN extracts and classifies features to identify faulty feeders. The method outperforms conventional methods like Adaboost and SVM, demonstrating better performance and robustness under various fault conditions and interference factors [29].
	SVM	The proposed method utilizes a Support Vector Machine (SVM) to efficiently detect islanding and grid faults in real-life photovoltaic plants. The SVM-based algorithm handles the dilemma of discriminating between islanding and grid fault events [30].

	Ensemble Method	The paper proposed a new framework based on an optimization-enabled weighted ensemble method that combines essential ML algorithms. In the proposed method, the system will select and compound appropriate ML algorithms based on Particle Swarm Optimization (PSO) weights [31].
Islanding and Grid Faults	SVM	The paper presents a precision-based method for islanding and grid fault detection in active distribution networks using a Support Vector Machine (SVM). The method accurately detects islanding and grid faults, ensuring power quality and reducing the impact on power quality [4].
	LSTM	The proposed approach focuses on detecting islanding in wind and PV DGs using a novel deep-learning classifier based on a Long Short-Term Memory (LSTM) network. The method extracts valuable features from voltage and current signals, analyzes them for the second harmonic, calculates symmetrical components, and applies a novel deep learning classifier [32].
	Bayesian Network	The paper presents Bayesian networks that are used to model the complex relationships between power system parameters and detect islanding conditions. These networks can provide probabilistic reasoning for decision-making in islanding detection [33].
Fault Detection for DERS	SVDD & HISVDD	The paper proposes a data-driven protection framework for distribution systems with varying penetration levels of distributed energy resources. The model uses Support Vector Data Description (SVDD) and vectors for training, incorporating new data and previous support vectors. Hybrid Incremental SVDD (HISVDD), is an online updating model that incorporates new data and previous support vectors to retrain the SVDD model and adapt to system changes [34].
	PCA & ICA	The paper proposed data-driven approaches, such as Principal Component Analysis (PCA) and Independent Component Analysis (ICA), to identify unusual patterns and outliers in DER data [35].
	STFT & CNN	The research paper proposes a sustainable deep learning-based approach for real-time high-impedance fault detection in power grids. It uses edge computing, a Short-Time Fourier Transform (STFT), and a Convolutional Neural Network (CNN) to analyze

High Impedance Fault		high-frequency components and classify feature maps into High Impedance Fault (HIF) and healthy classes. This approach reduces network latency and traffic, enabling faster and more reliable fault detection in power grids [36].
	DWT & LSTM	The paper proposed an LSTM approach to detect High Impedance Fault (HIF) in solar Photovoltaic (PV) integrated power systems. The three-phase current signals during non-faulty and faulty conditions are used for feature extraction, employing the Discrete Wavelet Transform (DWT) [37].
	1D VPE7 & DT	The paper presents 1D VPE (Voltage-Phase-Excursion) and the Decision Tree (DT) algorithm for HIF fault detection [38].
Insulator Fault	R-CNN	The paper presents an algorithm using deep learning to detect insulator self-detonation defects, using a Faster R-CNN target detection network, semantic segmentation, and a classification network [39].
	Mask R-CNN	The method in this paper involves the use of the Mask R-Convolutional Neural Network (CNN) for automatic extraction of multiple insulators in the infrared images, followed by transfer learning and dynamic learning rate algorithm for training [40].
Series ARC Fault	RF & DNN	The paper employs Random Forest (RF) feature selection to identify specific arc features, reducing Gini impurity. Time-domain, frequency-domain, and wavelet packet energy analysis are used to extract arc features. These features are then input into a Deep Neural Network (DNN) for training, resulting in a comprehensive arc detection model for different load types [41].
	CNN-LSTM	The proposed method combines three-dimensional features and Convolutional Neural Network-Long Short Term Memory (CNN-LSTM) to detect arc faults in aviation cables. The method uses vibration series tests, cutting parallel tests, and wet arc trajectory parallel tests to analyze arc current signals under different loads [42].
	Clustering & SVM	The paper uses the CEEMDAN method to obtain arc fault current components, employing 16 feature indexes and a feature selection method. It also proposes a hierarchical clustering algorithm and a sensitive component selection strategy to eliminate redundant components. A strong discriminative feature library is constructed for series arc fault detection based on a Support Vector Machine (SVM) [43].

III. DATA AND RESULTS

- Varied Approaches

The references employ a broad spectrum of techniques, such as corona detection, support vector machines, one-class classifiers, ensemble deep learning, and convolutional neural networks, showcasing methodological diversity [2].

- Advanced Technologies

The methods reflect a commitment to leveraging cutting-edge tools for defect detection by incorporating advanced technologies like deep learning, ensemble techniques, and novel classifiers [4].

- Targeted Applications

Each reference tackles a unique challenge in power system protection and fault detection, addressing different aspects of power distribution and electrical fault identification [13]. Innovation Terms like "Revolutionary Approach" and "Innovative Ensemble Deep Learning Technique" suggest a focus on advancing the field and possibly introducing novel methods.

- Practical Application

The references highlight real-world applications, from fault diagnosis in power distribution lines to islanding and grid fault detection, indicating a focus on practical use [29]. The research on AI-based fault detection in power systems yielded significant findings. Comparing various approaches underscored the importance of deep learning, especially in UV-visible video processing. This method, focusing on corona discharge and air ionization, proved effective for early fault detection. While the successful use of deep learning in UV-visible data processing is a key finding, the study stresses that the field is still in its early stages. It calls for continued research to develop a more structured and definitive approach to using AI for power system fault detection and diagnosis.

IV. CONCLUSION

Various AI approaches, such as SVDD, HISVDD, CNNs, 1-D VPE, RNN-based LSTM, Mask R-CNN, and cloud-based CNN models, provide valuable tools for fault detection in power systems. Each method has its own strengths and weaknesses. SVDD and HISVDD offer reliable techniques for fault detection and diagnosis by defining boundaries around normal data and identifying anomalies. CNNs excel at analyzing spatial and image data, extracting crucial features for fault identification and diagnosis. 1-D VPE is effective at representing features, while RNN-based LSTM models are adept at capturing temporal relationships in power system data. Mask R-CNN enables precise fault localization in images, and cloud-based CNN models offer the advantage of scalability.

LIMITATION AND FUTURE WORK

Only a limited number of papers are reviewed, and the analysis provided is not very detailed. The scope of the work should be expanded to include more studies, and the broader domain should be categorized further [44-48]. Classification could be based on the type of fault detected, the power equipment involved, or the AI method applied. As this field is still relatively new, with the rise of smart grid technologies, it has the potential to shape the future of global power systems [49, 50].

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Authors' Contributions

All authors made equal contributions to this study.

Conflict of Interest

The authors declare no conflicts of interest related to this research work.

Data Availability Statement

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References

Paithankar, Y. G., & Bhide, S. R. (2022). Fundamentals of power system protection. PHI Learning Pvt. Ltd.

Davari, N., Akbarizadeh, G., & Mashhour, E. (2020). Intelligent diagnosis of incipient fault in power distribution lines based on corona detection in UV-visible videos. *IEEE Transactions on Power Delivery, 36*(6), 3640-3648.

Sun, J., Yang, Q., Xu, W., & He, W. (2022). A distribution line fault location estimation algorithm based on electromagnetic time-reversal method calculated in the finite difference time domain. *IEEE Transactions on Electromagnetic Compatibility, 64*(3), 865- 873.

Baghaee, H. R., Mlakić, D., Nikolovski, S., & Dragicević, T. (2019). Support vector machine-based islanding and grid fault detection in active distribution networks. *IEEE Journal of Emerging and Selected Topics in Power Electronics, 8*(3), 2385-2403.

Lin, Z., Duan, D., Yang, Q., Hong, X., Cheng, X., Yang, L., & Cui, S. (2020). One-class classifier based fault detection in distribution systems with varying penetration levels of distributed energy resources. *IEEE Access, 8*, 130023-130035.

Ramos, C., & Liu, C. C. (2011). AI in power systems and energy markets. *IEEE Intelligent Systems, 26*(2), 5-8.

Nasim, S. F., Qaiser, A., Abrar, N., & Kulsoom, U. (2023). Implementation of AI in Traffic Management: Need, Current Techniques and Challenges. *Pakistan Journal of Scientific Research, 3*(1), 20-25.

Israr, A., Ali, Z. A., Alkhammash, E. H., & Jussila, J. J. (2022). Optimization methods applied to motion planning of unmanned aerial vehicles: A review. *Drones, 6*(5), 126.

Chandio, H. R., & Memon, A. P. (2023). Time-Frequency Transformation Technique with Various Mother Wavelets for DC Fault Analysis in HVDC Transmission Systems. *Sir Syed University Research Journal of Engineering & Technology (SSURJET), 13*(1).

Khan, A., Khuhro, A. A., Memon, A. A., & Memon, A. A. (2022). An Investigation to Reduce Electricity Bills using Inverter AC in Pakistan. *Sir Syed University Research Journal of Engineering & Technology, 12*(2), 07-12.

Nasim, S. F., Ali, M. R., & Kulsoom, U. (2022). Artificial intelligence incidents & ethics a narrative review. *International Journal of Technology, Innovation and Management (IJTIM), 2*(2), 52-64.

Antonopoulos, I., Robu, V., Couraud, B., Kirli, D., Norbu, S., Kiprakis, A., ... & Wattam, S. (2020). Artificial intelligence and machine learning approaches to energy demand-side response: A systematic review. *Renewable and Sustainable Energy Reviews, 130*, 109899.

Elmasry, W., & Wadi, M. (2022). EDLA-EFDS: A novel ensemble deep learning approach for electrical fault detection systems. *Electric Power Systems Research, 207*, 107834.

Haleem, A. M., Sharma, M., Sajan, K. S., & Babu, K. D. (2018, June). A comparative review of fault location/identification methods in distribution networks. In *2018 1st International Conference on Advanced Research in Engineering Sciences (ARES)* (pp. 1-6). IEEE.

Aleem, S. A., Shahid, N., & Naqvi, I. H. (2015). Methodologies in power systems fault detection and diagnosis. *Energy Systems, 6*, 85- 108.

Demirci, M., Gözde, H., & Taplamacioglu, M. C. (2023). Improvement of power transformer fault diagnosis by using sequential Kalman filter sensor fusion. *International Journal of Electrical Power & Energy Systems, 149*, 109038.

Kezunovic, M., Spasojevic, P., Fromen, C. W., & Sevcik, D. R. (1993). An expert system for transmission substation event analysis. *IEEE Transactions on Power Delivery, 8*(4), 1942-1949.

Lee, H. J., Park, D. Y., Ahn, B. S., Park, Y. M., Park, J. K., & Venkata, S. S. (2000). A fuzzy expert system for the integrated fault diagnosis. *IEEE Transactions on Power Delivery, 15*(2), 833-838.

Teive, R. C. G., Coelho, J., Camargo, C. D. B., Charles, P. C., Lange, T., & Cimino, L. (2011, September). A bayesian network approach to fault diagnosis and prognosis in power transmission systems. In *2011 16th International conference on intelligent system applications to power systems* (pp. 1-6). IEEE.

Zhang, X., Wei, J., Zhao, D., Zhang, D., & Liu, Y. (2013). Research course and prospects of power grid fault diagnosis. *Power System Technology, 37*(10), 2745-2753.

Wang, J. L., Xia, L., Wu, Z. G., Yang, X. F., & Li, Z. (2010). State of arts of fault diagnosis of power systems. *Power System Protection and Control, 38*(18), 210-211.

Xia, W., Zhang, L., Yuan, Q., Chen, G., Ma, S., Liu, Y., & Li, H. (2015). Improved extreme learning machine applied in power system fault diagnosis. *Power System and Clean Energy, 31*(4), 15- 19.

Lin, X., Ke, S., Li, Z., Weng, H., & Han, X. (2010). A fault diagnosis method of power systems based on improved objective function and genetic algorithm-tabu search. *IEEE Transactions on Power Delivery, 25*(3), 1268-1274.

Guo, W., Wen, F., Liao, Z., Wei, L., & Xin, J. (2009). An analytic model-based approach for power system alarm processing employing temporal constraint network. *IEEE Transactions on Power Delivery, 25*(4), 2435-2447.

Refaat, S. S., Mohamed, A., & Kakosimos, P. (2018, April). Self- Healing control strategy; Challenges and opportunities for distribution systems in smart grid. In *2018 IEEE 12th International conference on compatibility, power electronics and power engineering (CPE-POWERENG 2018)* (pp. 1-6). IEEE.

Guo, C., You, J., Peng, M., Tang, Y., Liu, Y., & Chen, J. (2010). A fault intelligent diagnosis approach based on element-oriented artificial neural networks and fuzzy integral fusion. *Diangong Jishu Xuebao(Transactions of China Electrotechnical Society), 25*(9), 183-190.

Shoupeng, W., & Dongmei, Z. (2017). Research Review and Prospects for Power Grid Fault Diagnosis [J]. *Automation of Electric Power Systems, 41*(19), 164-175.

Li, Q., Luo, H., Cheng, H., Deng, Y., Sun, W., Li, W., & Liu, Z. (2023). Incipient Fault Detection in Power Distribution System: A Time–Frequency Embedded Deep-Learning-Based Approach. *IEEE Transactions on Instrumentation and Measurement, 72*, 1-14.

Guo, M. F., Zeng, X. D., Chen, D. Y., & Yang, N. C. (2017). Deep-learning-based earth fault detection using continuous wavelet transform and convolutional neural network in resonant grounding distribution systems. *IEEE Sensors Journal, 18*(3), 1291-1300.

Baghaee, H. R., Mlakić, D., Nikolovski, S., & Dragicević, T. (2019). Support vector machine-based islanding and grid fault detection in active distribution networks. *IEEE Journal of Emerging and Selected Topics in Power Electronics, 8*(3), 2385-2403.

Yavuz, L., Soran, A., Önen, A., Li, X., & Muyeen, S. M. (2021). Adaptive Fault Detection Scheme Using an Optimized Self-healing Ensemble Machine Learning Algorithm. *CSEE Journal of Power and Energy Systems, 8*(4), 1145-1156.

Abdelsalam, A. A., Salem, A. A., Oda, E. S., & Eldesouky, A. A. (2020). Islanding detection of microgrid incorporating inverter based DGs using long short-term memory network. *IEEE Access, 8,* 106471-106486.

Najy, W. K., Zeineldin, H. H., Alaboudy, A. H. K., & Woon, W. L. (2011). A Bayesian passive islanding detection method for inverter- based distributed generation using ESPRIT. *IEEE Transactions on Power Delivery, 26*(4), 2687-2696.

Lin, Z., Duan, D., Yang, Q., Hong, X., Cheng, X., Yang, L., & Cui, S. (2020). One-class classifier based fault detection in distribution systems with varying penetration levels of distributed energy resources. *IEEE Access, 8*, 130023-130035.

James, J. Q., Hou, Y., Lam, A. Y., & Li, V. O. (2017). Intelligent fault detection scheme for microgrids with wavelet-based deep neural networks. *IEEE Transactions on Smart Grid, 10*(2), 1694- 1703.

Sirojan, T., Lu, S., Phung, B. T., Zhang, D., & Ambikairajah, E. (2018). Sustainable deep learning at grid edge for real-time high impedance fault detection. *IEEE Transactions on Sustainable Computing, 7*(2), 346-357.

Veerasamy, V., Wahab, N. I. A., Othman, M. L., Padmanaban, S., Sekar, K., Ramachandran, R., ... & Islam, M. Z. (2021). LSTM recurrent neural network classifier for high impedance fault detection in solar PV integrated power system. *IEEE access, 9*, 32672-32687.

Xiao, Q. M., Guo, M. F., & Chen, D. Y. (2021). High-impedance fault detection method based on one-dimensional variational prototyping-encoder for distribution networks. *IEEE Systems Journal, 16*(1), 966-976.

Li, X., Su, H., & Liu, G. (2020). Insulator defect recognition based on global detection and local segmentation. *IEEE Access, 8*, 59934- 59946

Wang, B., Dong, M., Ren, M., Wu, Z., Guo, C., Zhuang, T., ... & Xie, J. (2020). Automatic fault diagnosis of infrared insulator images based on image instance segmentation and temperature analysis. *IEEE Transactions on Instrumentation and Measurement, 69*(8), 5345-5355.

Jiang, J., Li, W., Wen, Z., Bie, Y., Schwarz, H., & Zhang, C. (2021). Series arc fault detection based on random forest and deep neural network. *IEEE Sensors Journal, 21*(15), 17171-17179.

Liu, X., Huang, D., Jing, T., & Zhang, Y. (2022). Detection of AC arc faults of aviation cables based on HIW three-dimensional features and CNN-LSTM neural network. *IEEE Access, 10*, 106958-106971.

Zou, G., Fu, G., Han, B., Wang, W., & Liu, C. (2023). Series Arc Fault Detection Based on Dual Filtering

Feature Selection and Improved Hierarchical Clustering Sensitive Component Selection. *IEEE Sensors Journal, 23*(6), 6050-6060.

Zhang, Y., Wang, X., He, J., Xu, Y., Zhang, F., & Luo, Y. (2020). A transfer learning-based high impedance fault detection method under a cloud-edge collaboration framework. *IEEE Access, 8*, 165099-165110.

Guo, M. F., Liu, W. L., Gao, J. H., & Chen, D. Y. (2023). A data-enhanced high impedance fault detection method under imbalanced sample scenarios in distribution networks. *IEEE Transactions on Industry Applications.*

Dubey, K., & Jena, P. (2023). A Novel High Impedance Fault Detection Technique in Smart Active Distribution Systems. *IEEE Transactions on Industrial Electronics.*

Cui, L., Liu, Y., Wang, L., Chen, J., & Zhang, X. (2023). High- impedance fault detection method based on sparse data divergence discrimination in distribution networks. *Electric Power Systems Research, 223*, 109514.

.Chandrakar, R., Dubey, R. K., & Panigrahi, B. K. (2023). Synchro- Squeezing Transform for High-Impedance Fault Detection in Power Distribution Systems. *IEEE Systems Journal.*

.

Kumar, R. S., Saravanan, S., Pandiyan, P., & Tiwari, R. (2023). Impact of artificial intelligence techniques in distributed smart grid monitoring system. In *Smart Energy and Electric Power Systems* (pp. 79-103). Elsevier.

Ucar, F. (2023). A Comprehensive Analysis of Smart Grid Stability Prediction along with Explainable Artificial Intelligence. *Symmetry, 15*(2), 289.