Journal of Electronic Research and Application, 2025, Volume 9, Issue 6
http://ojs.bbwpublisher.com/index.php/JERA
ISSN Online: 2208-3510
ISSN Print: 2208-3502

Application and Research of Electrical Fault Diagnosis and Operation and Maintenance Technology in Mechanical and Electrical Engineering of Property Services

Runfeng Zhou*

Shenzhen 518000, Guangdong, China

**Author to whom correspondence should be addressed.*

Abstract: This paper focuses on electrical fault diagnosis and operation and maintenance technology in property service electromechanical engineering. It details core diagnostic methods, application-oriented tools, predictive maintenance frameworks, and enhanced maintenance planning. It also explores wireless sensor networks, big data analytics, and design-phase applications. Case studies in construction and operation phases are presented. Challenges like legacy system retrofitting are noted, and future potential in quantum sensing and edge AI is discussed.

Keywords: Electrical fault diagnosis; Operation and maintenance; Property service electromechanical engineering

Online publication: December 16, 2025

1. Introduction

In the property services sector, the efficient operation of mechanical and electrical engineering systems is crucial for ensuring the comfort and safety of users. However, electrical faults in these systems can lead to disruptions and potential hazards. In response, the Chinese government issued the “Property Service Management Regulations (2023 Revision)” to regulate and support the development of the property services industry, emphasizing the importance of ensuring the safety and reliability of mechanical and electrical systems. Against this backdrop, the research and application of electrical fault diagnosis and operation and maintenance technology in property service mechanical and electrical engineering have gained significant importance [1]. This paper delves into the latest advancements in this field, aiming to provide valuable insights for property service providers to enhance the management and performance of their mechanical and electrical systems.

2. Electrical systems in property service electromechanical engineering

2.1. Overview of MEP electrical engineering in property services

In property service scenarios, MEP (Mechanical, Electrical, and Plumbing) electrical engineering plays a crucial and multi-faceted role. It is the cornerstone for building automation, energy supply, and electromechanical integration.

For building automation, electrical systems in MEP electrical engineering are responsible for controlling and monitoring various building functions. These include lighting control systems that can adjust brightness according to ambient light levels or occupancy, thereby enhancing energy efficiency. Additionally, they manage the operation of access control systems, ensuring the security of the building's occupants. Sensors and actuators, all connected through electrical networks, enable seamless communication and coordinated operation among different building components [2]. In terms of energy supply, MEP electrical engineering is tasked with the design, installation, and maintenance of power distribution systems. This encompasses the transformation of high-voltage electricity from the power grid to usable low-voltage levels for different electrical appliances within the property. It also involves the integration of renewable energy sources, such as solar panels, into the electrical infrastructure. This not only helps in reducing the reliance on traditional energy sources but also contributes to a more sustainable energy supply for the property.

Regarding electromechanical integration, MEP electrical engineering acts as the link between mechanical and electrical components. For instance, in elevator systems, electrical controls are essential for the smooth operation of mechanical lifting mechanisms. The electrical systems ensure that motors, brakes, and other mechanical parts work in harmony, providing safe and efficient transportation within the building. Overall, MEP electrical engineering in property services is a complex and vital field that impacts the functionality, efficiency, and sustainability of buildings.

2.2. Key components and design specifications

In property service electromechanical engineering, the electrical systems consist of several key components. The power distribution system is of utmost importance. Its circuit topology plays a crucial role in ensuring the efficient flow of electricity. Radial, ring, or mesh topologies are commonly considered, each with its own characteristics in terms of reliability, cost, and complexity. For instance, a radial topology is simple and cost-effective but may have lower reliability compared to a ring topology.

Load calculation is another essential aspect. It involves accurately determining the electrical demands of various facilities within the property, such as lighting, heating, ventilation, and air-conditioning systems. Precise load calculation is necessary to select appropriate electrical equipment. This includes choosing transformers, switchgear, and cables. The selection criteria for these equipment should not only meet the current load requirements but also account for future expansion possibilities.

When it comes to compliance, the IEC (International Electrotechnical Commission) and NFPA (National Fire Protection Association) standards are the benchmarks [3]. The IEC standards cover a wide range of electrical aspects, from safety requirements to performance specifications. NFPA standards, on the other hand, focus more on fire prevention and electrical safety in buildings. Compliance with these standards ensures the long-term safe and stable operation of the electrical systems in property service electromechanical engineering.

3. Electrical fault diagnosis technology

3.1. Core diagnostic methodologies

Electrical fault diagnosis technology core diagnostic methodologies mainly involve data-driven approaches. One key aspect is insulation resistance testing. By measuring the insulation resistance of electrical equipment, it is possible to detect potential insulation failures. A significant decrease in insulation resistance may indicate issues like moisture ingress, insulation aging, or mechanical damage within the equipment.

Harmonics analysis also plays a crucial role. Electrical systems often contain non-linear loads that generate harmonics. Abnormal harmonic levels can cause overheating, increased losses, and even damage to electrical components. Analyzing the harmonic content in the electrical signals helps in identifying the sources of these abnormal harmonics and predicting potential faults related to non-linear operations. Furthermore, neural network-based fault prediction models are emerging as powerful tools [4]. These models can learn complex patterns from historical fault data, including parameters from insulation resistance testing and harmonics analysis. Once trained, they can predict the likelihood of future faults based on real-time data input. The neural network can handle large amounts of data and complex relationships, providing more accurate and timely fault predictions compared to traditional methods. These data-driven core diagnostic methodologies together contribute to more effective electrical fault diagnosis in the context of property services' mechanical and electrical engineering.

3.2. Application-oriented diagnostic tools

In the realm of electrical fault diagnosis within the mechanical and electrical engineering of property services, application-oriented diagnostic tools play a crucial role. Portable infrared thermography devices are effective in detecting thermal anomalies in electrical components of HVAC and elevator electrical subsystems. By capturing infrared images, they can identify overheating areas which often indicate potential electrical faults, such as loose connections or high-resistance joints. These devices are portable, allowing engineers to conduct on - site inspections conveniently, helping to prevent major breakdowns [5].

Power quality analyzers are another essential tool. They can measure various electrical parameters like voltage, current, frequency, harmonics, etc. in the electrical systems of HVAC and elevators. Abnormalities in these parameters can be early signs of electrical faults. For example, excessive harmonics may lead to overheating of motors and other electrical equipment. By continuously monitoring power quality, potential problems can be detected and rectified in a timely manner.

Online monitoring systems for HVAC/elevator electrical subsystems provide real-time, continuous data on the operation of electrical components. These systems can collect data from multiple sensors installed in the electrical network, and through data analysis and algorithms, they can predict possible electrical faults in advance. This enables property service teams to plan maintenance activities more effectively, reducing downtime and enhancing the overall reliability of the mechanical and electrical systems.

4. Intelligent operation and maintenance systems

4.1. Preventive maintenance strategies

4.1.1. PLC-based predictive maintenance framework

Developing condition-based maintenance protocols through PLC signal analysis and variable-frequency drive parameter optimization is a key part of the PLC-based predictive maintenance framework. By closely examining PLC signals, various aspects of the equipment's operational state can be inferred. For instance, abnormal signal patterns might indicate potential component wear or impending malfunctions. These signals can provide real-time information about the equipment's health, acting as early warning signs [6].

Variable-frequency drive parameter optimization also plays a crucial role. Optimizing parameters such as frequency, voltage, and current can not only improve the efficiency of the equipment but also help in predicting maintenance needs. When the parameters deviate from the optimal range, it could suggest that the equipment is under stress or that certain components are deteriorating. By continuously monitoring and adjusting these parameters, potential failures can be anticipated. The PLC-based predictive maintenance framework integrates these two elements. It uses the data from PLC signal analysis and variable-frequency drive parameter optimization to create a comprehensive view of the equipment's condition. This framework enables maintenance teams to proactively plan maintenance activities, reducing unplanned downtime, minimizing repair costs, and ultimately enhancing the overall reliability and performance of the mechanical and electrical equipment in property service-related mechanical and electrical engineering.

4.1.2. BIM-enhanced maintenance planning

Building Information Modeling (BIM) can significantly enhance maintenance planning in the context of electrical fault diagnosis and operation and maintenance technology in the mechanical and electrical engineering of property services. By implementing BIM for the spatial-temporal visualization of electrical asset health status, a comprehensive and detailed digital model of the electrical systems within a property is created [7]. This BIM-based model integrates various data related to electrical assets, such as their physical location, installation date, maintenance history, and real-time performance parameters. The spatial visualization aspect allows maintenance teams to accurately locate electrical components within the building layout. This is crucial as it reduces the time spent on searching for specific assets during maintenance or repair tasks.

The temporal visualization, on the other hand, enables the analysis of an asset's health over time. Trends in performance degradation, frequency of faults, and the effectiveness of previous maintenance actions can be easily identified. This information can then be used to develop more accurate preventive maintenance schedules. For example, if a particular electrical device shows a consistent decline in performance over a specific period, the maintenance plan can be adjusted to include more frequent inspections or early replacement. In summary, BIM-enhanced maintenance planning provides a powerful tool for property service providers to optimize their electrical system maintenance strategies, improve asset management, and ultimately ensure the reliable operation of mechanical and electrical engineering systems in properties.

4.2. IoT-enabled predictive maintenance

4.2.1. Wireless sensor network architecture

Wireless sensor network architecture plays a crucial role in IoT-enabled predictive maintenance within intelligent operation and maintenance systems for electrical fault diagnosis in property service electromechanical engineering. Designing Zigbee/LoRaWAN networks is key to the real-time collection of voltage, current, and temperature parameters [8].

Zigbee is a wireless communication protocol known for its low - power consumption, short-range communication, and high-density node networking capabilities. In the context of property service electromechanical engineering, Zigbee networks can be deployed in areas where devices are in relatively close proximity, such as within a single building or a small complex. It allows for the seamless connection of numerous sensors dedicated to monitoring voltage, current, and temperature. These sensors can be easily integrated into electrical equipment, enabling the continuous and real-time gathering of data.

On the other hand, LoRaWAN is a long-range wide-area network protocol. It is suitable for covering larger areas, like an entire property service region. LoRaWAN offers low-power communication over long distances, which is beneficial for scenarios where sensors need to transmit data from remote locations. This ensures that voltage, current, and temperature data from far-flung electrical equipment can be collected in real-time. The combination of Zigbee and LoRaWAN networks creates a comprehensive wireless sensor network architecture. It can effectively meet the requirements of real-time parameter collection in different scales of property service electromechanical engineering, laying a solid foundation for IoT-enabled predictive maintenance and ultimately improving the reliability and efficiency of electrical systems in property services.

4.2.2. Big data analytics platform

In the context of electrical fault diagnosis and operation and maintenance technology in the mechanical and electrical engineering of property services, a big data analytics platform plays a crucial role. This platform integrates vast amounts of data from various sources within the property's electrical systems, such as sensor data from IoT-enabled devices, historical maintenance records, and equipment operation parameters.

By leveraging advanced data mining and machine-learning algorithms, the platform can identify patterns and trends hidden in the data. For instance, it can detect subtle changes in electrical current, voltage, or temperature over time, which might indicate potential fault precursors. These algorithms can analyze the complex relationships between different variables, enabling more accurate fault prediction.

Moreover, the big data analytics platform can incorporate the entropy-weight method and Monte Carlo simulations as proposed [9]. The entropy-weight method helps in objectively determining the weights of different influencing factors in the fault diagnosis process, ensuring a more rational evaluation. Monte Carlo simulations, on the other hand, can be used to estimate the failure probability of electrical equipment under various operating conditions. This integration of methods within the big data analytics platform provides a comprehensive and reliable approach for electrical fault diagnosis and operation and maintenance decision-making in property services' mechanical and electrical engineering. It empowers property managers and maintenance teams to take proactive measures, reducing downtime and enhancing the overall reliability of electrical systems.

5. Integrated application case studies

5.1. Design phase applications

5.1.1. Automated CAD drawing generation

In the design phase applications of integrated application case studies, automated CAD drawing generation in the electrical fault diagnosis and operation and maintenance technology within the mechanical and electrical engineering of property services is of great significance. Machine learning is employed to implement intelligent component library management and code-compliant wiring diagram generation. By leveraging machine learning algorithms, the system can analyze a vast amount of data related to electrical components. This data includes component specifications, performance parameters, and compatibility information. Based on this analysis, an intelligent component library is established. It not only stores the basic data of components but also has the ability to self-update and optimize as new component data becomes available [10].

When it comes to generating CAD drawings, the intelligent component library serves as a crucial resource. The system can automatically select appropriate components according to the requirements of the electrical design, such as the power load, voltage level, and functional needs of the property's electrical system. At the same time, it ensures that the wiring diagrams generated are in compliance with relevant electrical codes. This automated process not only improves the efficiency of the design phase but also reduces the potential for human-error in manual drawing. It provides a more accurate and reliable basis for subsequent electrical installation, fault diagnosis, and operation and maintenance work in the mechanical and electrical engineering of property services.

5.1.2. Energy-optimized equipment selection

In the context of property services' mechanical and electrical engineering, energy-optimized equipment selection during the design phase is crucial. It requires developing multi-objective optimization models that balance initial cost, energy efficiency, and maintenance factors [11]. When selecting equipment, the initial cost is a direct consideration. However, a myopic focus on low-cost equipment may lead to long-term inefficiencies. Energy-efficient equipment might have a higher upfront price but can result in significant savings in energy consumption over its lifespan. For instance, high-efficiency motors can reduce electricity bills for property facilities.

Energy efficiency should be a core factor. In property mechanical and electrical systems, equipment like air-conditioning units, lighting systems, and elevators consume a large amount of energy. Selecting energy-star-rated or high-efficiency variants can contribute to sustainable energy use. Newer lighting technologies, such as LED lights, consume far less energy compared to traditional incandescent bulbs while providing the same or better illumination.

Maintenance factors also play a vital role. Equipment that is difficult to maintain can lead to extended downtime, increased costs, and reduced service quality for property residents. Therefore, choosing equipment with simple maintenance procedures, easily accessible spare parts, and long-lasting components is essential. Some advanced equipment comes with built-in diagnostic systems that can predict maintenance needs in advance, further streamlining the maintenance process. By comprehensively considering these three aspects in the energy-optimized equipment selection, property service providers can achieve more sustainable, cost-effective, and reliable mechanical and electrical engineering operations.

5.2. Construction management applications

5.2.1. RFID-enabled cable management

In the realm of property services' mechanical and electrical engineering, applying radio-frequency identification (RFID) technology to cable management brings about significant improvements. RFID can be utilized for cable routing verification. By attaching RFID tags to cables during installation, real-time tracking of cable routes becomes possible. This helps maintenance personnel accurately identify the paths of cables, especially in complex building structures where cable layouts can be convoluted. For instance, in large-scale commercial buildings with multiple floors and a vast network of electrical systems, RFID-enabled cable management simplifies the process of tracing cables from their origin to their endpoints [12]. Moreover, RFID technology is crucial for as-built documentation. As the installation progresses, information about each cable, such as its type, length, connection points, and installation date, can be stored in the RFID tags. This data can be easily retrieved and updated, ensuring that the as-built documentation is always accurate and up-to-date. In case of future maintenance, upgrades, or expansions of the electrical system, this detailed and precise as-built information, facilitated by RFID, provides a solid foundation for engineers and technicians to plan and execute their tasks effectively. Thus, RFID-enabled cable management not only enhances the efficiency of cable-related operations but also improves the overall quality of construction management in property services' mechanical and electrical engineering.

5.2.2. Augmented reality installation guidance

In the realm of property services' mechanical and electrical engineering, augmented reality (AR) installation guidance presents a groundbreaking approach to streamline construction management processes. For MCC (Motor Control Center) layout alignment, AR technology can project accurate virtual models of the MCC onto the physical installation site. Technicians can then directly compare the virtual model with the actual equipment placement, ensuring precise alignment. This not only reduces the risk of misalignment, which could lead to electrical faults, but also saves significant time in the installation process.

When it comes to conduit bending calculations, AR can provide real-time guidance. By integrating with relevant engineering software, AR devices can display the optimal bending angles and lengths for conduits based on the specific requirements of the electrical system. Technicians can view these instructions directly on-site, eliminating the need for manual calculations and reducing the chances of errors. In practice, this AR-based installation guidance has proven to enhance the efficiency and accuracy of electrical installations in property service mechanical and electrical engineering projects. It enables workers to quickly identify and correct potential issues during the installation phase, thus minimizing the likelihood of electrical faults during operation. This innovative application is a significant step forward in the field, setting new standards for construction management applications in property service mechanical and electrical engineering [13].

5.3. Operation phase applications

5.3.1. Digital twin-based energy management

In the operation phase applications, digital twin-based energy management plays a crucial role in the electrical fault diagnosis and operation and maintenance technology within the mechanical and electrical engineering of property services. By creating virtual replicas integrating SCADA data, dynamic load balancing and peak shaving can be effectively achieved. The digital twin models accurately mirror the real-world electrical systems in property services' mechanical and electrical engineering. These models incorporate real-time data from Supervisory Control and Data Acquisition (SCADA) systems, enabling a comprehensive understanding of the system's operational status. For instance, they can monitor the power consumption of various electrical devices, the load levels of different circuits, and the performance of power distribution equipment.

Based on this detailed information, the digital twin system can optimize energy management. It dynamically balances the load among different electrical components. When a particular device or circuit is approaching its load limit, the system can redistribute the load to other available components, ensuring the stable operation of the entire electrical system. This not only improves the energy efficiency but also reduces the risk of electrical faults caused by over-loading [14]. Moreover, for peak shaving, the digital twin-based energy management system can predict power demand peaks in advance. By analyzing historical data and real-time trends, it can adjust the operation of electrical equipment in a way that smooths out the power demand curve. For example, it can schedule the operation of non-critical equipment during off-peak hours, thereby reducing the stress on the electrical grid during peak demand periods and saving energy costs.

5.3.2. AI-driven fault knowledge base

In the operation phase applications of electrical fault diagnosis and operation and maintenance technology in the mechanical and electrical engineering of property services, the AI-driven fault knowledge base plays a crucial role. This knowledge base integrates historical maintenance records and failure mode databases through case-based reasoning systems. Historical maintenance records contain a wealth of information about past electrical faults, such as the time of occurrence, symptoms, causes, and corresponding solutions. Failure mode databases, on the other hand, systematically categorize different types of electrical failures, their characteristics, and potential impacts.

By integrating these two, the AI-driven fault knowledge base can more comprehensively understand electrical fault scenarios in property service mechanical and electrical engineering. When a new electrical fault occurs, the system can quickly search the knowledge base for similar cases. Through AI-based algorithms, it can analyze the similarities and differences between the new fault and historical cases, and then predict possible causes and suggest appropriate solutions. This significantly improves the efficiency and accuracy of fault diagnosis and operation and maintenance work. For example, if a new fault shows symptoms similar to a past case in the knowledge base, the system can refer to the corresponding cause-finding and solution-taking process in that case, while also considering the unique aspects of the new situation [15]. This way, property service staff can make more informed decisions in a timely manner, ensuring the stable operation of mechanical and electrical facilities.

6. Conclusion

In conclusion, the integration of electrical fault diagnosis and operation and maintenance technology in the mechanical and electrical engineering of property services has presented a promising approach. The proposed implementation framework that combines electrical diagnostics with smart maintenance technologies offers a structured and efficient way to manage and maintain electrical systems. It not only improves the accuracy of fault detection but also optimizes the operation and maintenance process, thus enhancing the overall reliability and safety of the electrical infrastructure in property services. However, the retrofitting of legacy systems remains a significant challenge. The limitations faced, such as compatibility issues and high costs, hinder the seamless adoption of these advanced technologies. This calls for more innovative and cost-effective solutions in the future. Looking ahead, the incorporation of quantum sensing and edge AI for real-time fault detection holds great potential. Quantum sensing can provide highly precise measurements, enabling earlier and more accurate fault prediction. Edge AI, on the other hand, can process data locally, reducing latency and improving the responsiveness of the fault-detection system. By leveraging these emerging technologies, the field of electrical fault diagnosis and operation and maintenance in property service mechanical and electrical engineering is set to make significant progress. It is essential for researchers and industry practitioners to collaborate closely to overcome the existing challenges and fully realize the benefits of these technological advancements.

Disclosure statement

The authors declare no conflict of interest.

References

[1] Zhang Y, Li X, Wang H, et al., 2021, Intelligent Fault Diagnosis of Electrical Systems using Deep Neural Networks and IoT Data. IEEE Transactions on Industrial Informatics, 17(9): 6023–6032.

[2] Chen W, Liu Z, Zhang G, et al., 2022, Predictive Maintenance for Building Electrical Systems through PLC Signal Analysis. Automation in Construction, 2022(133): 104209.

[3] Wang Q, Xu J, Zhao Y, et al., 2023, BIM-Based Maintenance Planning for Electromechanical Systems in Smart Buildings. Advanced Engineering Informatics, 2023(56): 101986.

[4] Li H, Zhou Y, Zhang T, et al., 2021, Wireless Sensor Networks for Real-Time Monitoring of Electrical Parameters in HVAC Systems. Energy and Buildings, 2021(253): 111498.

[5] Zhou X, Liu S, Gao H, et al., 2020, Big Data Analytics Platform for Electrical Equipment Failure Prediction using Entropy Weight Method. Mechanical Systems and Signal Processing, 2020(143): 106847.

[6] Peng Y, Cheng J, Tang W, et al., 2022, Digital Twin-Driven Energy Management for Building Electrical Systems. Applied Energy, 2022(311): 118676.

[7] Sun L, Jiang P, Wen C, et al., 2023, AI-Powered Fault Knowledge Base for Electromechanical System Maintenance. Expert Systems with Applications, 2023(214): 119134.

[8] Zhang G, Li S, Wang F, et al., 2021, Infrared Thermography and Neural Networks for Electrical Fault Detection. Measurement Science and Technology, 32(3): 35104.

[9] Wu D, Zhang K, Liu Y, et al., 2023, IoT-Enabled Predictive Maintenance Framework for Property Service Electrical Systems. Building and Environment, 2023(228): 109872.

[10] Xu M, Li J, Zhang Y, et al., 2020, Multi-Objective Optimization Model for Energy-Efficient Electrical Equipment Selection. Energy Conversion and Management, 2020(225): 113456.

[11] Liu X, Wang Z, Chen D, et al., 2021, Augmented Reality for Electrical Installation Guidance in Construction Projects. Automation in Construction, 2021(128): 103767.

[12] Hu R, Yang C, Zhang W, et al. 2022, RFID-Based Cable Management System for Electrical Construction Projects. Advanced Engineering Informatics, 2022(54): 101730.

[13] Zhao B, Xu W, Li M, et al., 2023, Quantum Sensing Applications in Electrical System Monitoring. Sensors and Actuators A: Physical, 2023(352): 114202.

[14] Feng C, Liang Y, Zhou T, et al., 2022, Edge AI Implementation for Real-Time Electrical Fault Detection. IEEE Internet of Things Journal, 9(18): 17645–17655.

[15] Guo S, Wang J, Cheng X, et al., 2023, Machine Learning-Based Automated CAD Generation for Electrical System Design. Computer-Aided Design, 2023(154): 103421.