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Bus Short-Circuit Fault Detection and Repair Technology for Improving Inverter System Reliability

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Abstract

The advancement of modern power electronics technology has elevated the importance of inverter systems within power applications, where their reliability is pivotal to the overall stability of power systems. Among the primary challenges faced are bus short-circuit faults, which can arise from external natural factors, internal aging, and installation issues. These faults often result in significant equipment damage and economic losses. This paper explores the synergistic application of fault detection technologies, including current, voltage, and temperature monitoring, alongside intelligent algorithms, to enhance detection accuracy and response speed. In the realm of fault repair, techniques such as automatic reclosing, sectional protection, online repair, and preventive maintenance have proven effective in minimizing power outage duration. Looking ahead, fault detection and repair technologies are anticipated to progress towards greater intelligence, automation, integration, and environmental sustainability. This evolution will likely involve the use of big data and artificial intelligence for intelligent prediction and diagnosis, as well as the adoption of green materials to bolster system reliability and sustainability. This paper underscores the critical importance of developing a comprehensive fault detection and repair system. Such a system is essential for ensuring the stable operation of power systems and for laying a robust foundation for future technological advancements.

Subject Areas

Electric Engineering

Keywords

Inverter System, Power System Reliability, Bus Short-circuit Fault, Fault Detection and Repair

1. Introduction

With the rapid development of modern power electronics technology, inverter systems play an increasingly important role in various power applications. The reliability of inverter systems directly affects the stable operation of the entire power system. However, in long-term operation, bus short-circuit faults often become a significant factor affecting the reliability of inverter systems [1]. Therefore, researching effective bus short-circuit fault detection and repair technology holds important theoretical significance and practical application value.

In recent years, with the large-scale application of renewable energy, the demand for inverter systems has increased significantly, especially in the fields of photovoltaic and wind power generation. According to data from the International Energy Agency (IEA), the installed capacity of global photovoltaic and wind power generation has grown at an annual rate of over 20% in the past decade. This growth poses higher demands on the reliability of inverter systems. Bus short-circuit faults not only lead to reduced system efficiency but can also trigger severe safety incidents [2]. In response to these challenges, this study aims to explore and develop more advanced fault detection and repair technologies to enhance the operational reliability and safety of inverter systems. Specifically, the study will focus on analyzing the limitations of existing detection technologies and propose innovative solutions that combine intelligent algorithms and real-time monitoring methods to improve the accuracy and response speed of fault detection. Furthermore, the study will also explore the application of automated repair technologies to minimize the impact of faults on system operations. Through this research, it is expected to provide solid technical support for the efficient and safe operation of inverter systems and lay a foundation for the development of related technologies in the future.

2. Causes and Impacts of Bus Short-Circuit Faults

2.1. Causes of Bus Short-Circuit Faults

Bus short-circuit faults are typically caused by various factors, primarily including external factors such as lightning strikes and natural intrusions, which may cause physical damage and electrical interference [3]; Internal factors such as material aging and loose connections, where material deterioration and mechanical connection instability over time can increase the risk of short-circuits; and design and installation issues, where improper design or nonstandard installation may lead to system failures during operation. Furthermore, environmental conditions such as temperature and humidity changes may exacerbate these problems, further increasing the probability of bus short-circuits [4]. Understanding these causes is crucial for formulating effective prevention and repair strategies, which helps improve the reliability of inverter systems and the overall stability of power systems. Bus short-circuit faults are typically caused by various factors, mainly including:

2.1.1. External Factors

Natural events such as lightning strikes, tree falls, and animal intrusions can cause mechanical damage or insulation failure of the bus. According to a study by the National Electrical Safety Code (NEC), about 20% of short-circuit faults are caused by external factors. Lightning strikes may cause transient overvoltage, thus damaging the bus insulation layer. Tree falls and animal intrusions can directly cause physical damage [5].

2.1.2. Internal Factors

Including issues such as bus material aging, loose connections, and insulation layer damage, which may gradually manifest over time. Studies have shown that material aging is one of the main internal factors leading to bus short-circuits, especially in equipment operating in high-temperature and high-humidity environments. Material aging not only reduces mechanical strength but may also lead to a decline in insulation performance.

2.1.3. Design and Installation Issues

Initial design flaws or errors during installation may sow the seeds for short-circuit faults. For example, unreasonable electrical load distribution and improper grounding design may increase the risk of short circuits [6]. According to statistics from a power equipment manufacturer, about 15% of short-circuit faults are related to design and installation issues. Negligence during the design phase may lead to unbalanced loads in the power system during operation, thereby exacerbating the stress on the bus.

2.2. Impacts of Bus Short-Circuit Faults

The impacts of bus short-circuit faults on inverter systems and their connected power networks are mainly reflected in the following aspects.

2.2.1. Equipment Damage

Short-circuit faults may cause severe damage to inverters and related equipment, and even trigger a larger-scale power system collapse. Fault currents can far exceed the equipment's tolerance, causing catastrophic outcomes such as component burnout or explosions. According to reports from power equipment manufacturers, short-circuit faults are one of the main causes of equipment damage, accounting for more than 35% of all equipment failures [7]. Such damage not only increases the cost of equipment repair and replacement but may also result in long-term system downtime, affecting the overall reliability of power supply.

2.2.2. Power Supply Interruption

Short-circuits can lead to unstable or interrupted power supply, severely affecting users' normal electricity needs. According to a survey by an international power grid company, short-circuit faults are one of the main causes of power interruptions, accounting for more than 30% of total interruption events. Power interruptions not only inconvenience residents' daily lives but may also severely impact industrial production, resulting in production line shutdowns, product losses, and damage to corporate reputation [8]. Long-term power supply interruptions may also affect the operation of critical infrastructure, such as hospitals, financial systems, and transportation networks.

2.2.3. Economic Losses

The costs of equipment repair or replacement, as well as the economic losses caused by power outages, can be enormous. According to data from the United States Department of Energy, power outages cause annual losses of up to 150 billion USD to the U.S. economy. These losses not only include direct costs of equipment repairs and replacements but also indirect losses due to production delays, contract breaches, data loss, and customer attrition resulting from power outages [9]. Additionally, frequent power outages may lead enterprises to increase investments to improve the reliability of power infrastructure, further increasing operational costs.

3. Bus Short-Circuit Fault Detection Technologies

The detection technologies for bus short-circuit faults mainly include the following methods, which can effectively identify and locate short-circuit faults, improving the safety and reliability of power systems.

3.1. Current Monitoring Method

The current monitoring method determines whether a short-circuit fault has occurred by monitoring changes in bus current in real-time, utilizing the characteristic of current surges. This method is simple and feasible but requires high precision and response speed from current sensors.

Working Principle: Current sensors are installed on the bus, detecting the magnitude and changes of current in real-time. When the current exceeds the set threshold, the system will issue an alert to take timely measures.

Advantages: Low cost, easy to implement, suitable for most power systems.

Limitations: Requires high precision and response speed from current sensors and is easily affected by current fluctuations and noise, which may lead to false alarms or missed detections [10].

3.2. Voltage Monitoring Method

The voltage monitoring method identifies short-circuit faults by detecting abnormal changes in bus voltage. Short-circuit faults usually cause a sharp voltage drop, allowing for quick judgment through voltage monitoring.

Working Principle: Voltage sensors are installed on the bus, detecting the magnitude and changes of voltage in real time. When the voltage falls below the set threshold, the system issues an alert, indicating a need to check the power system [11].

Advantages: Quick response speed, able to quickly identify short-circuit faults, reducing impact on the power system.

Limitations: It requires high precision from voltage sensors, is easily affected by voltage fluctuations and noise, and may need to be combined with other methods for validation.

3.3. Temperature Detection Method

The temperature detection method utilizes the characteristic of local temperature rapidly increasing due to short-circuit faults, effectively detecting such temperature anomalies through infrared thermal imaging technology or thermocouple sensors.

Working Principle: Temperature sensors are installed on the bus, detecting temperature changes in real-time. When the temperature exceeds the set threshold, the system issues an alert, indicating a possible short-circuit fault.

Advantages: It effectively detects temperature anomalies caused by short-circuit faults and is suitable for fault detection in high-temperature environments.

Limitations: It requires high precision from temperature sensors, is easily affected by changes in environmental temperature, and may require periodic calibration of sensors.

3.4. Intelligent Algorithm Detection

By combining artificial intelligence technology, utilizing intelligent algorithms such as neural networks and fuzzy logic to analyze detection data, the accuracy and response speed of fault detection can be improved.

Working Principle: By analyzing historical data, a fault detection model is established. When the detection data does not match the model, the system issues an alert, indicating a need for further inspection.

Advantages: Effectively improves the accuracy and response speed of fault detection, and adapts to complex power system environments.

Limitations: Requires a large amount of historical data for training, model accuracy depends on data quality, and development and maintenance costs are high.

3.5. Comparison of Bus Short-Circuit Fault Detection Technologies

3.5.1. Comparison Methods

In the realm of Bus Short-Circuit fault detection, various technologies such as current monitoring, voltage monitoring, temperature detection, and intelligent algorithm detection each have distinct characteristics and are suitable for different application scenarios. Here is a comparison of these methods:

Current Monitoring Method: This technique identifies faults by monitoring real-time changes in the current. It is cost-effective and easy to implement, making it suitable for most power systems, especially those with budget constraints. However, it requires high precision and fast response from current sensors, and it is susceptible to noise and current fluctuations, which can lead to false alarms or missed detections.

Voltage Monitoring Method: This method uses the characteristic voltage drop associated with short-circuit faults to quickly identify issues. It offers rapid response, minimizing impact on the power system. However, like the current monitoring method, it requires highly accurate voltage sensors and can be affected by voltage fluctuations and external noise, often necessitating validation with other methods.

Temperature Detection Method: By detecting abnormal temperature rises, this method is effective in high-temperature environments for fault detection. It can effectively identify temperature anomalies caused by short-circuit faults, but it requires precise temperature sensors and is influenced by environmental temperature changes, necessitating regular sensor calibration.

Intelligent Algorithm Detection: Leveraging artificial intelligence, this method analyzes large volumes of historical data to enhance detection accuracy and speed. It is well-suited for complex power system environments, offering more precise fault localization. However, it demands a significant amount of historical data for training, and the model's accuracy depends on data quality, with higher development and maintenance costs.

3.5.2. Overall Comparison

Cost and Implementation Difficulty: Current and voltage monitoring methods are relatively low-cost and easy to implement, whereas intelligent algorithm detection involves higher development and maintenance costs.

Detection Speed and Accuracy: Intelligent algorithm detection excels in speed and accuracy but relies on high-quality data; voltage monitoring offers quick response but depends on sensor precision.

Environmental Adaptability: Temperature detection performs well in high-temperature settings but is highly influenced by environmental temperature variations.

Application Scenarios: In practical applications, a combination of methods is often necessary to enhance reliability and accuracy. For instance, in complex power systems, integrating current monitoring with intelligent algorithms can compensate for the limitations of single methods, achieving more precise fault localization and faster response.

Choosing and combining these detection technologies wisely is key to achieving efficient and reliable Bus Short-Circuit fault detection. In bus short-circuit fault detection technology, four main methods are employed: current monitoring method, voltage monitoring method, temperature detection method, and intelligent algorithm detection. The current monitoring method determines faults by monitoring current changes in real-time, with advantages of low cost and ease of implementation, but requires high precision from sensors [12]. The voltage monitoring method utilizes the characteristic of sharp voltage drops to quickly identify faults, with fast response speed, but also reliant on high-precision sensors. The temperature detection method identifies faults by detecting temperature anomalies, which are suitable for high-temperature environments but susceptible to environmental temperature influences. Intelligent algorithm detection combines artificial intelligence technology to improve detection accuracy and speed by analyzing large volumes of historical data, but requires high-quality data support [13].

Overall, each method has its strengths and weaknesses, and in practical applications, a combination of methods is often needed to enhance detection reliability and accuracy.

4. Bus Short Circuit Fault Repair Technology

Timely and effective repair measures are crucial for restoring normal system operation after detecting a Bus short circuit fault. Swiftly adopting appropriate repair techniques can not only reduce power outage time but also enhance the overall stability and reliability of the power system. The following are some commonly used repair techniques:

4.1. Automatic Reclosing Technology

Automatic reclosing technology can automatically disconnect the faulty line after a short circuit fault occurs and then reclose it after a certain period to determine whether the fault has been cleared. This technology effectively reduces power outage time caused by transient faults and is a commonly used fault-handling method in power systems.

Working Principle: When a short circuit fault is detected, the automatic reclosing device immediately disconnects the faulty line to protect electrical equipment and lines. After a preset period, the device automatically recloses. If the fault has been cleared, the system resumes normal operation; if the fault persists, the device disconnects the faulty line again to prevent further damage to the system [14].

Advantages: It can effectively reduce power outage time caused by transient faults, improving the reliability and stability of the system. Additionally, this technology has a high degree of automation, capable of handling faults automatically without human intervention.

Limitations: It requires high response speed and device reliability and may cause a secondary impact on the system, especially if the fault is not completely cleared. Moreover, automatic reclosing technology is not suitable for persistent faults and needs to be combined with other technologies for comprehensive handling [15].

4.2. Sectional Protection Technology

By managing Buss in segments, only the faulty section can be cut off when a fault occurs, retaining normal power supply to other parts. This technology requires reasonable planning during the design phase to ensure system flexibility and reliability.

Working Principle: The bus is divided into several segments, each equipped with protection devices. When a fault occurs in a segment, only the power supply to the faulty segment is cut off, retaining the normal power supply to other parts, thereby reducing the range and impact of power outages.

Advantages: It effectively reduces the range of power outages caused by faults, improving system reliability and continuity of power supply. This technology allows the power system to maintain partial power supply during a fault, minimizing impact on users.

Limitations: It requires reasonable planning during the design phase, increasing system complexity and cost. Additionally, sectional protection technology requires precise fault location capabilities to accurately identify the faulty segment.

4.3. Online Repair Technology

For minor short circuit faults, online repair technology can be used for rapid handling, such as using robots for localized insulation repair or replacement. This technology allows repairs without affecting the overall system operation.

Working Principle: Robots or other automated equipment are used to perform online repairs on the fault location, such as localized insulation repair or replacement of damaged components. These devices can operate while the power system is running, reducing power outage time.

Advantages: It can quickly handle minor short circuit faults, reducing power outage time and impact on users. The application of online repair technology improves fault handling efficiency, enabling the power system to resume normal operation more quickly [16].

Limitations: It requires high precision and reliability of the equipment and may not handle severe faults. Additionally, the implementation of online repair technology requires specialized equipment and technicians, increasing maintenance costs.

4.4. Preventive Maintenance

Regular inspection and maintenance of bus systems to identify and address potential hazards in a timely manner is an important measure to enhance system reliability. Preventive maintenance can effectively prevent faults and ensure stable operation of the power system.

Working Principle: Regular inspection and maintenance of the bus system to timely identify and address potential hazards. Through regular checks and tests, factors that may cause faults can be identified, and corresponding preventive measures can be taken.

Advantages: It can effectively improve system reliability, reduce the probability of faults, and extend equipment lifespan. Preventive maintenance helps reduce the economic losses and social impact caused by faults.

Limitations: It requires investment of human and material resources, increasing operating costs. Moreover, preventive maintenance requires professional technicians and equipment, which may pose challenges to resource allocation for enterprises.

4.5. Comparison of Busbar Short-Circuit Fault Repair Technologies

4.5.1. Comparison Methods

In the realm of busbar short-circuit fault repair, various techniques such as automatic reclosing, sectional protection, online repair, and preventive maintenance each have distinct characteristics and are suitable for different application scenarios. Here is a comparison of these methods:

Automatic Reclosing Technology: This technique can quickly restore power after a transient fault, with a high degree of automation, making it suitable for unattended power systems. However, it may cause secondary impacts on the system, especially if the fault is not completely cleared, and is not suitable for persistent faults.

Sectional Protection Technology: By designing the system to manage sections independently, this method cuts off only the faulty section while maintaining normal power supply to other parts, suitable for systems requiring high continuity of supply. Its advantage lies in minimizing the outage area, but it increases system complexity and cost, requiring precise fault location capabilities.

Online Repair Technology: Suitable for quickly addressing minor faults, this method allows repairs while the system is operational, reducing downtime. It enhances fault handling efficiency but requires high precision and reliability of equipment, cannot handle severe faults, and involves higher implementation costs.

Preventive Maintenance: Through regular inspections and maintenance, this approach effectively prevents faults, enhancing system reliability. It is suitable for systems requiring long-term stable operation but demands significant human and material resources, increasing operational costs.

4.5.2. Overall Comparison:

Response Speed and Applicability: Automatic reclosing and online repair technologies offer quick response and are suitable for scenarios requiring rapid recovery; sectional protection and preventive maintenance are more appropriate for systems needing high reliability and continuity.

Cost and Complexity: Preventive maintenance and sectional protection increase system complexity and cost but improve long-term system stability; automatic reclosing and online repair have lower initial investment but may require more frequent maintenance.

Reliability and Stability: Preventive maintenance is highly effective in enhancing system reliability, while sectional protection maintains partial system stability during faults.

Selecting and combining these repair technologies wisely is key to achieving efficient and reliable busbar short-circuit fault repair. By formulating appropriate repair strategies based on specific system requirements and environmental conditions, the stability and reliability of the power system can be maximized.

Bus short circuit fault repair technology is crucial for the stable operation of power systems. Common repair technologies include automatic reclosing technology, sectional protection technology, online repair technology, and preventive maintenance. Automatic reclosing technology determines if a fault is cleared by automatically disconnecting and reclosing, reducing power outage time caused by transient faults. Sectional protection technology manages Buss in segments, cutting off only the faulty segment and retaining power supply to other parts, reducing outage range. Online repair technology employs robots and other devices for rapid handling of minor faults, reducing power outage time [17]. Preventive maintenance involves regular inspections and maintenance to timely identify potential hazards, and improving system reliability. Each technology has its advantages and disadvantages and often requires combined use to optimize fault-handling effectiveness.

5. Practical Application Scenarios

In modern power systems, the successful application of bus short circuit fault detection and repair technology has been verified and promoted in various fields. These technologies not only enhance the safety and reliability of power systems but also play important roles in different industrial and commercial environments. The following are some specific application cases that demonstrate the effectiveness of these technologies in practical operations:

5.1. Current Monitoring Application in Urban Power Grids

In a large city with millions of residents, a power company faced the challenge of managing a complex distribution network. To ensure the stability and safety of power supply, the company introduced advanced current monitoring technology. A series of high-precision current sensors were installed at critical distribution nodes in the city, capable of capturing subtle changes in current in real-time. One day, the system detected abnormal current fluctuations in a certain area. After quick analysis, the maintenance team swiftly pinpointed the problem, discovering a bus short circuit fault at a transformer station. Due to the rapid response, repair personnel were able to arrive on-site promptly to address the issue, successfully avoiding a widespread power outage and ensuring normal electricity usage for city residents and commercial users.

5.2. Temperature Detection Application in Industrial Parks

In a large chemical park with extensive grounds, temperature detection technology is widely used to monitor the operational status of equipment in high-voltage distribution rooms. There are numerous critical pieces of equipment in the park, whose stable operation is crucial to the entire production process. Technicians use infrared thermal imagers to regularly check the temperature conditions of the equipment. During a routine inspection, they discovered an abnormally high temperature at a bus joint, determining that it was due to aging of the joint which posed a short circuit risk. Based on this finding, the park management immediately implemented preventive replacement measures, successfully avoiding potential equipment failures and production interruptions, and ensuring the continuity and safety of various production activities within the park.

5.3 Intelligent Algorithm Detection Application in Smart Grids

In a large smart grid project, a research team developed and applied machine learning-based intelligent algorithms for predicting and detecting potential bus short circuit faults. This system, by analyzing a large amount of historical operational data and real-time monitoring data, can identify potential short-circuit risks in advance. During a test run, the system successfully predicted a potential short circuit event. Subsequently, based on the system's prompt, the technical team scheduled on-site inspections and maintenance work in advance, preventing the actual occurrence of the fault. This successful case demonstrates the immense potential of intelligent algorithms in grid management, not only improving the accuracy of fault prediction but also providing strong technical support for the stable operation of the grid.

5.4 Automatic Recloser Application in Wind Farms

In a large coastal wind farm, automatic recloser technology was introduced to address instantaneous short-circuit faults caused by lightning strikes. Coastal areas experience frequent thunderstorms throughout the year, posing a severe challenge to wind power equipment. During a severe thunderstorm, the wind farm's automatic recloser system responded swiftly, automatically executing reclosure operations and quickly restoring the normal operational status of the wind turbine units. The application of this technology not only reduced power generation losses due to short circuit faults but also significantly improved the overall operational efficiency of the wind farm.

5.5. Online Repair Application in Photovoltaic Power Stations

In a large photovoltaic power station with extensive land coverage, the management adopted advanced online repair technology, using automated robots to monitor and repair the connections of solar panels in real-time. These robots are equipped with high-precision sensors and repair tools, capable of conducting routine inspections and maintenance without affecting the normal operation of the power station. During a routine inspection, the robot detected a minor short circuit phenomenon and immediately performed insulation repair on-site. The application of this online repair technology avoided larger-scale power losses and ensured the efficient operation of the photovoltaic power station.

These cases fully demonstrate the practical effects and importance of bus short circuit fault detection and repair technology in different application scenarios. The successful application of these technologies not only significantly improves the reliability and stability of power systems but also greatly reduces the economic losses caused by faults, providing a solid technical guarantee for safe production and sustainable development in various industries.

6. Future Development Trends

With rapid technological advancements, Bus short circuit fault detection and repair technology continues to progress to meet modern power systems' higher demands for reliability and efficiency. Future development trends mainly include the following aspects:

6.1. Intelligence

Utilizing big data and artificial intelligence technology to achieve intelligent prediction and diagnosis of Bus faults. This trend will significantly enhance the intelligence level of fault management.

Development Direction: Through in-depth analysis of large volumes of historical data, establish complex fault prediction models to achieve intelligent prediction and diagnosis of Bus faults. These models can identify potential fault patterns and provide real-time diagnostic information to take preventive measures before faults occur.

Advantages: It can effectively improve the accuracy and response speed of fault prediction, reducing economic losses and user impact caused by faults. Intelligent technology can also continuously improve prediction model performance through self-learning.

Challenges: Large amounts of historical data and computing resources are required to support model training and optimization, and model accuracy depends on data quality and completeness. Additionally, data privacy and security issues are important challenges for intelligent technology.

6.2. Automation

Develop more automated repair technologies to reduce human intervention and improve repair efficiency. Automation technology will make the fault repair process more efficient and reliable.

Development Direction: By developing advanced automated equipment and technology, automatic detection and repair of faults can be achieved, reducing reliance on manual operations. This includes using robots, drones, and other devices for fault detection and repair operations.

Advantages: It can significantly improve repair efficiency, reduce power outage time, and minimize user impact. Additionally, automation technology can operate in hazardous environments, enhancing safety.

Challenges: It requires high precision and reliability of equipment, which may increase system complexity and cost. Maintenance and management of automated equipment also require professional technical support.

6.3 Integration

Integrating fault detection and repair technology into inverter systems to achieve integrated fault management. This trend will simplify system architecture and improve overall efficiency.

Development Direction: By integrating advanced fault detection and repair technology into power equipment such as inverters, achieve integrated fault management. This integrated design can provide more comprehensive system monitoring and management functions.

Advantages: It can effectively improve system reliability, reduce the probability of faults, and shorten handling time. Integrated design can also reduce system complexity and simplify maintenance and management [18].

Challenges: It requires reasonable planning in the design phase to ensure compatibility and coordination of system modules. Additionally, integrated design may increase initial development and installation complexity and cost.

6.4 Environmental Protection

Develop green and environmentally friendly materials and technologies to reduce environmental impact. The trend towards environmental protection aligns with global sustainable development requirements.

Development Direction: By developing and using green and environmentally friendly materials and technologies, reduce the environmental impact of power systems. This includes using renewable materials, improving energy efficiency, and reducing harmful substance emissions.

Advantages: It can effectively reduce environmental impact, and enhance system sustainability, and social responsibility. Environmentally friendly technology may also bring new market opportunities and competitive advantages.

Challenges: It requires significant investment in research and development resources and time, possibly increasing initial system cost. Additionally, the performance and reliability of environmentally friendly materials and technologies need long-term verification and improvement.

The future development trends of Bus short circuit fault detection and repair technology mainly focus on intelligence, automation, integration, and environmental protection. Intelligence improves fault prediction and diagnosis accuracy through big data and artificial intelligence; Automation reduces human intervention and improves repair efficiency through advanced equipment; Integration incorporates fault management functions into the power system, enhancing system reliability; Environmental protection aims to use green materials and technologies to reduce environmental impact. While these trends enhance system efficiency and reliability, they also face challenges such as data demands, technical complexity, and costs [19].

7. Conclusions

Improving the bus short-circuit fault detection and repair technology to enhance the reliability of inverter systems is crucial for ensuring the stable operation of power systems. This paper systematically analyzes the detection and repair technologies for bus short-circuit faults in inverter systems, aiming to improve their reliability within power systems. Through an in-depth study of the causes of faults, we found that bus short-circuit faults mainly originate from external natural factors and internal material and design defects. To address these issues, we evaluated various fault detection technologies, including current, voltage, and temperature monitoring, as well as intelligent algorithm detection, emphasizing the academic value of multi-technology integration in enhancing fault detection accuracy and response speed.

In terms of fault repair, we explored technologies such as automatic reclosing, sectional protection, online repair, and preventive maintenance. These technologies not only theoretically provide methods for quickly restoring system operation but also have proven their effectiveness in practice, significantly reducing power outage time and economic losses [20]. The research results of this paper indicate that by comprehensively applying these technologies, the reliability of inverter systems can be greatly enhanced.

Future development directions focus on intelligence, automation, integration, and environmental protection. The combination of intelligent and automated technologies will achieve more precise fault prediction and diagnosis through big data and artificial intelligence, reducing manual intervention and improving repair efficiency. Integrated design will deeply embed fault management functions into power systems, enhancing the overall system reliability. Environmental friendliness will reduce environmental impact and enhance system sustainability by adopting green materials and technologies.

Overall, establishing a robust fault detection and repair system is crucial for improving the reliability of inverter systems. The combination of multiple technical means can provide strong support for the stable operation of power systems and lay a foundation for a safe and stable power supply in the future. With the continuous advancement of technology, this field will usher in broader development prospects, providing continuous support for the efficient and safe operation of power systems. Meanwhile, this paper not only provides a comprehensive analysis and innovative ideas on fault detection and repair technologies for inverter systems to the academic community but also offers feasible technical routes and solutions for practical applications. These research results lay a solid foundation for the safe and stable operation of power systems and provide important references for future technological advancements.

Conflicts of Interest

The authors declare no conflicts of interest.

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