

Analysis of the Application and Development of Microgrids in Post-Disaster Emergency Power Supply

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Abstract

This article focuses on the application and development of microgrids in post-disaster emergency power supply. Firstly, the significance and challenges of emergency power supply after disasters are expounded, and then the unique advantages of microgrids as an effective solution are introduced. A detailed analysis was conducted on the specific application models of microgrids in post-disaster emergency power supply, including aspects such as grid-connected to isolated island switching and distributed energy integration. Meanwhile, the constraints at the technical, economic and policy levels that microgrids face during their development process were discussed. Finally, in combination with industry trends and technological innovations, the future development direction of microgrids in the field of post-disaster emergency power supply is prospected, aiming to provide theoretical references and practical guidance for enhancing the capacity of post-disaster power emergency guarantee.

Key words: Microgrid; Emergency power supply after disasters; Distributed energy; Power supply guarantee.

1. Introduction

1.1 Research Background and Significance

Natural disasters are characterized by suddenness and destructiveness. In recent years, the frequency and intensity of natural disasters worldwide have shown an upward trend ^[1]. Earthquakes, typhoons, floods and other disasters often cause severe damage to power infrastructure, leading to large-scale power outages. Electricity, as the fundamental energy source for the operation of modern society, the interruption of power supply after a disaster will seriously affect the progress of rescue work, the basic living of the affected people and social stability ^[2].

The traditional post-disaster emergency power supply methods mainly rely on mobile power equipment such as diesel generators, but these devices have many limitations. For instance, fuel supply is restricted. In the event of traffic disruptions after a disaster, it is difficult to ensure a continuous fuel supply. The operating cost is high. Not only is the fuel cost expensive, but also the maintenance and transportation of the equipment require a large amount of funds. Environmental pollution is severe. Diesel generators emit a large amount of pollutants during operation, causing further damage to the environment after disasters ^[3].

As a new type of power supply mode, microgrid has the advantages of flexibility, reliability and sustainability. It can integrate distributed energy, energy storage devices and loads to achieve autonomous power supply and interaction with the large power grid ^[4]. After a disaster, microgrids can quickly organize power supply, providing strong support for emergency rescue and recovery and reconstruction. The study of the application and development of microgrids in post-disaster emergency power supply holds significant theoretical and practical value for enhancing China's capacity to respond to natural disasters and safeguarding people's lives and property.

1.2 Review of Current Research Status at Home and Abroad

Research on microgrids started earlier and has achieved fruitful results in aspects such as modeling, control and protection of microgrids. A number of microgrid demonstration projects have been built in countries and regions such as the United States, Japan and Europe, and have been put into practical application in post-disaster emergency power supply. For instance, after the "3·11" earthquake, Japan utilized microgrids to provide power support to some affected areas, verifying the feasibility and effectiveness of microgrids in post-disaster emergency power supply ^[5]. The U.S. Department of Energy has also carried out a series of research on the application of microgrids in post-disaster recovery, with a focus on the rapid deployment of microgrids and their integration with existing power systems ^[6].

Europe focuses on the integration of renewable energy and the application of intelligent control technologies in microgrid research. Some European countries have explored the potential of microgrids in improving energy utilization efficiency and reducing carbon emissions by building microgrid demonstration projects [7]. Meanwhile, Europe has also formulated relevant standards and norms, promoting the standardization and regularization of microgrid technology.

Although domestic research on microgrids started relatively late, it has developed rapidly. In recent years, the state has introduced a series of policies to support the development of microgrids, and domestic universities and research institutions have also carried out a large amount of research work. In terms of key technologies of microgrids, China has made certain progress in distributed energy generation technology, energy storage technology, microgrid control and protection technology, etc. [8] Meanwhile, some microgrid demonstration projects have also been built in China, such as the Zhangbei Wind-Solar-Storage-Transmission Demonstration Project, which has accumulated experience for the promotion and application of microgrids [9]. However, at present, domestic research on the application of microgrids in post-disaster emergency power supply is still relatively scarce, and there is a lack of systematic theoretical and practical guidance.

2. The Importance and Challenges of Emergency Power Supply after Disasters

2.1 The Importance of Emergency Power Supply after Disasters

After a disaster occurs, timely rescue operations are crucial for saving lives and reducing losses. Electricity is the fundamental guarantee for rescue operations. Facilities such as lighting, communication, and medical equipment all rely on power supply. Rapid restoration of power supply can provide necessary working conditions for rescue workers, improve rescue efficiency and ensure the smooth progress of rescue operations.

The lives of the affected people after the disaster are confronted with many difficulties. Power supply is an important guarantee to meet their basic living needs. For instance, providing lighting, ensuring the supply of drinking water, and maintaining food refrigeration, etc. A stable power supply can alleviate the anxiety of the affected people and enhance their confidence in overcoming the disaster.

Large-scale power outages can trigger social panic and unstable factors. The restoration of power supply can maintain the normal operation of society and ensure the stability of public order. Meanwhile, electricity is also a crucial support for post-disaster recovery and reconstruction, providing impetus for the restoration of infrastructure and economic recovery.

2.2 Challenges Faced by Emergency Power Supply after Disasters

Natural disasters often cause severe damage to power infrastructure, such as the collapse of transmission lines and damage to substations. This led to the traditional power supply system being unable to operate normally, requiring a great deal of time and resources for repair and reconstruction. Traditional emergency power supply equipment such as diesel generators rely on fuel supply. However, after a disaster, problems like traffic disruptions and insufficient fuel reserves can lead to fuel supply difficulties, affecting the continuous operation of emergency power supply equipment. Post-disaster emergency power supply requires the rapid and reliable restoration of power supply in complex environments to meet the electricity demands of different users. At the same time, the stability and safety of power supply should also be taken into consideration to avoid secondary disasters caused by power failures.

3. Advantages of Microgrids in Post-disaster Emergency Power Supply

3.1 Flexibility and Reliability

Microgrids can operate in two modes: grid-connected and isolated. Under normal circumstances, microgrids operate parallel with large grids to achieve bidirectional power flow. When a failure occurs in the large power grid, the microgrid can quickly switch to island operation mode, independently supplying power to local loads and ensuring the power supply for important users. This flexible operation mode enables microgrids to quickly restore power supply after disasters and enhance the reliability of power supply.

3.2 Distributed Energy Integration Capacity

Microgrids can integrate various distributed energy sources, such as solar energy, wind energy, small hydropower, biomass energy, etc. These distributed energy sources have the advantages of being sourced locally and being clean and environmentally friendly. After disasters, they can quickly organize power supply by utilizing local natural resources and reduce reliance on external fuel supplies. Meanwhile, the decentralized layout of distributed energy has also enhanced the

disaster resistance capacity of microgrids and reduced the power supply risk caused by the interruption of a single energy supply.

3.3 Rapid Deployment and Recovery Capabilities

The modular design and standardized components of microgrids enable them to be deployed and installed rapidly. After a disaster, a microgrid system can be quickly built according to actual needs to provide power support for the affected areas. In addition, the automatic control and management system of microgrids can achieve real-time monitoring and adjustment of power supply, improving the efficiency of power restoration.

3.4 Environmental Friendliness and Sustainability

Compared with traditional diesel generators, the distributed energy sources adopted by microgrids are mostly clean energy, such as solar and wind energy, which do not produce or produce very little pollutant emissions during the power generation process and are environmentally friendly. Meanwhile, the sustainable utilization of distributed energy also conforms to the concept of sustainable development and is conducive to reducing reliance on traditional fossil energy.

4. Application Models of Microgrids in Post-disaster Emergency Power Supply

4.1 Grid-connected - Island Switching Mode

Under normal circumstances, the microgrid operates in parallel with the main power grid and exchanges power with it through a common connection point (PCC). Distributed energy in a microgrid can generate electricity based on the demands of the large grid and its own power generation capacity, achieving an optimal allocation of electricity. When a fault occurs in the main power grid, the microgrid quickly disconnects from the main power grid through a rapid switching device and enters an island operation mode. In the islanding operation mode, the microgrid uses its own distributed energy and energy storage devices to supply power to local critical loads, ensuring the power demands of key users. When the large power grid returns to normal, the microgrid is reconnected to the large power grid through the switching device and resumes the grid-connected operation mode.

4.2 Distributed Energy Complementary Model

Microgrids can integrate various types of distributed energy. For instance, solar and wind energy have the characteristics of intermittency and randomness, while small hydropower and biomass energy have relatively stable power generation features. Through reasonable configuration and coordinated control, complementarity among different distributed energy sources can be achieved. For instance, during the day when there is abundant sunlight, the solar power generation system serves as the primary power supply source. When it is night or cloudy, wind or biomass power generation systems can supplement the power supply. This distributed energy complementary model can enhance the power supply reliability and stability of microgrids and reduce reliance on a single energy source.

4.3 Multi-microgrid Interconnection Mode

In cases where the affected area is large, the power supply capacity of a single microgrid may not be able to meet the demands of all loads. At this point, a multi-microgrid interconnection model can be adopted, connecting multiple microgrids through transmission lines to form a microgrid cluster. The interconnection of multiple microgrids can achieve the sharing and optimal allocation of power resources and enhance the power supply capacity and reliability of the entire system. When a microgrid malfunctions, other microgrids can provide power support to it through interconnected lines, ensuring the power supply in the disaster-stricken area.

4.4 Cooperative Mode with Mobile Power Sources

In the early stage after a disaster, the construction of a microgrid may take some time. At this time, mobile power supply equipment such as diesel generators and mobile energy storage devices can be combined to provide temporary power supply to the disaster-stricken areas. As the construction of microgrids gradually improves, mobile power supply equipment can be gradually phased out or serve as a supplement to microgrids, operating in coordination with them. For instance, mobile energy storage devices can release electrical energy when the microgrid power supply is insufficient, ensuring continuous power supply to important loads. Diesel generators can serve as backup power sources when the distributed energy generation in a microgrid is insufficient, enhancing the reliability of power supply.

5. Constraints on the Development of Microgrids in Post-disaster Emergency Power Supply

5.1 Technical Aspect

The power generation of distributed energy sources such as solar and wind energy is influenced by natural factors like weather and seasons, and it has the characteristics of intermittency and randomness. This poses challenges to the power balance and stable operation of microgrids, and it is necessary to be equipped with advanced energy storage devices and intelligent control systems to achieve real-time power regulation and optimal allocation.

During the grid-connected to islanding switching process of a microgrid, it is necessary to quickly and accurately detect faults and implement protective actions to avoid damage to equipment and personnel. Meanwhile, the distributed energy sources and loads in microgrids are diverse and uncertain, and advanced control technologies need to be adopted to achieve stable operation and optimized control of microgrids. At present, the protection and control technologies of microgrids are not yet mature and require further research and improvement.

Energy storage devices are an important component of microgrids, capable of addressing the intermittency and randomness of distributed energy generation and enhancing the reliability and stability of power supply in microgrids. However, at present, energy storage technology still has problems such as high cost, low energy density and short lifespan, which limit the large-scale application of energy storage devices in microgrids.

5.2 Economic Aspect

The construction of microgrids requires a large amount of investment in the procurement and installation of distributed energy generation equipment, energy storage devices, control systems, etc. Compared with traditional power supply methods, the initial investment cost of microgrids is relatively high, which makes some regions and enterprises less enthusiastic about adopting microgrids in post-disaster emergency power supply.

There are a large number of distributed energy sources and devices in microgrids, making their operation and maintenance rather difficult. Professional technicians are required for management and maintenance. Meanwhile, the replacement and maintenance costs of energy storage devices are also relatively high, increasing the operation and maintenance costs of microgrids.

5.3 Policy and Standard Level

At present, the policies for the development of microgrids in our country are not yet perfect, lacking clear policy guidance and support. In terms of post-disaster emergency power supply, no specific policies and measures for the application of microgrids, such as financial subsidies and tax preferences, have been introduced yet. To some extent, this has restricted the promotion and application of microgrids in post-disaster emergency power supply.

A microgrid is a complex system involving multiple fields, and it is necessary to establish complete technical standards and norms to ensure its safe and reliable operation. However, at present, the standard system of microgrids in our country is still not perfect, lacking unified standards for design, construction, operation and maintenance, which brings certain difficulties to the large-scale application of microgrids.

6. The Future Development Direction of Microgrids in Post-disaster Emergency Power Supply

6.1 Direction of Technological Innovation

With the continuous development of technologies such as artificial intelligence, big data, and the Internet of Things, their application in the control and optimization of microgrids can achieve intelligent operation of microgrids. For instance, by using artificial intelligence algorithms to predict the power generation of distributed energy, optimizing the charging and discharging strategies of energy storage devices, and enhancing the energy utilization efficiency and power supply reliability of microgrids.

Increase the research and development efforts on new energy storage technologies, such as solid-state batteries, flow batteries, and supercapacitors, to enhance the energy density, lifespan and safety of energy storage devices and reduce costs. Meanwhile, explore the combined application of multiple energy storage technologies to achieve complementary advantages and enhance the comprehensive performance of energy storage systems.

Study the collaborative interaction mechanism between microgrids and large power grids to achieve bidirectional power flow and optimal allocation between them. By establishing a reasonable market mechanism and dispatching strategy,

microgrids are encouraged to participate in auxiliary services such as peak shaving and frequency regulation of large power grids, thereby enhancing the overall operational efficiency and reliability of the power system.

6.2 Directions for Business Model Innovation

Introduce the Energy Management Contract (EMC) model, where professional energy service companies sign energy management contracts with disaster-stricken areas or enterprises, and are responsible for the investment, construction, operation and maintenance of microgrids. Energy service companies recover their investment costs and make profits by sharing energy-saving benefits, while disaster-stricken areas or enterprises do not need to bear the initial investment costs, reducing the risks of adopting microgrids.

Combining the concept of the energy Internet, a microgrid energy Internet platform is constructed to achieve information exchange and energy trading between the microgrid and users. Users can independently choose to purchase electricity from microgrids, or large grids based on their own electricity demands and electricity price information, thereby enhancing energy utilization efficiency and user satisfaction.

6.3 Direction for Policy and Standard Improvement

The government should introduce more comprehensive policies to support the application of microgrids in post-disaster emergency power supply, such as providing financial subsidies, tax incentives, and low-interest loans, to reduce the construction and operation costs of microgrids. At the same time, establish an emergency response mechanism for microgrids, clarify the position and role of microgrids in post-disaster emergency power supply, and enhance the emergency support capacity of microgrids.

Accelerate the formulation and improvement of technical standards and norms for microgrids, including those related to design, construction, operation, maintenance, and safety, to ensure the safe and reliable operation of microgrids. At the same time, strengthen the publicity and promotion of standards to enhance the overall level of the microgrid industry.

7. Conclusion

As a new type of power supply mode, microgrid has unique advantages and broad application prospects in post-disaster emergency power supply. With flexible operation modes, distributed energy integration capabilities, rapid deployment and recovery capabilities, as well as environmental friendliness and sustainability, microgrids can provide effective solutions for emergency power supply after disasters. However, at present, the application of microgrids in post-disaster emergency power supply still faces constraints in terms of technology, economy, policy and standards. In the future, efforts should be made in areas such as technological innovation, business model innovation, and improvement of policies and standards to promote the development of microgrids in the field of post-disaster emergency power supply, enhance China's capacity to respond to natural disasters, and ensure the safety of people's lives and property as well as social stability.

REFERENCES

- [1] Change, I. P. O. C. (2001). *Climate change 2007: Impacts, adaptation and vulnerability*. Geneva, Suíça.
- [2] Mohagheghi, S., & Javanbakht, P. (2015, April). Power grid and natural disasters: A framework for vulnerability assessment. In *2015 Seventh Annual IEEE Green Technologies Conference* (pp. 199-205). IEEE.
- [3] Tian, H., Alhaji, A., Long, Z., & Chow, M. Y. (2024, June). Microgrids for post-disaster power restoration application. In *2024 IEEE 33rd International Symposium on Industrial Electronics (ISIE)* (pp. 1-6). IEEE.
- [4] Nikos, H. (2007). Microgrids: an overview of ongoing research, development, and demonstration projects. *IEEE Power & Energy*, 5(4).
- [5] Yu, J., Marnay, C., Jin, M., Yao, C., Liu, X., & Feng, W. (2018). Review of microgrid development in the United States and China and lessons learned for China. *Energy Procedia*, 145, 217-222.
- [6] Hamidieh, M., & Ghassemi, M. (2022). Microgrids and resilience: A review. *IEEE Access*, 10, 106059-106080.
- [7] Yang, F., Feng, X., & Li, Z. (2019). Advanced microgrid energy management system for future sustainable and resilient power grid. *IEEE Transactions on Industry Applications*, 55(6), 7251-7260.
- [8] Xia, J., Xu, F., & Huang, G. (2020). Research on power grid resilience and power supply restoration during disasters-A review. *Flood Impact Mitigation and Resilience Enhancement*.
- [9] Zeng, Z., Zhao, R., Yang, H., & Tang, S. (2014). Policies and demonstrations of micro-grids in China: A review. *Renewable and Sustainable Energy Reviews*, 29, 701-718.