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Literature Review of DC Microgrid Operation Control

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Abstract

In recent years, DC microgrid has attracted widespread attention as a technology to improve the stability and reliability of renewable energy access to the grid. DC microgrid can control the DC power generated by new energy through power electronic converters and intelligent algorithms. To supply power to the load or integrate into the large power grid, new energy power generation can utilize natural resources and reduce the pollution of fossil energy to the environment. Therefore, the DC microgrid will occupy an increasingly important position in the future power grid development. This paper analyzes the topological structure of DC microgrid, introduces the technical difficulties of DC microgrid operation control and existing control technologies, including topology, island detection, droop control, hierarchical control, peer-to-peer control, energy management, power control, And finally look forward to the follow-up research.

Keywords

DC Microgrid; Island Detection; Droop Control; Energy Management.

1. Introduction

With the development of society, the rapid and healthy development of our country's national economy and the progress of science and technology, people's awareness of environmental protection has gradually increased, and today's fossil energy problems and environmental pollution problems have gradually increased. Therefore, current research is developing in the direction of green and environmental protection. Especially the development and utilization of renewable energy such as wind energy, solar energy, tidal energy, etc. Therefore many researchers actively devote themselves to the research in this field. In recent years, photovoltaic power generation, as a new energy generation, has attracted the attention of the majority of researchers. Photovoltaic power generation is connected to the grid or supplies power to loads after being controlled by power electronic converters and intelligent algorithms. Therefore, many researchers have devoted themselves to the research of this field. Due to the different terrain factors in various regions of our country, the electricity consumption and the degree of access to the grid are different in different places, the microgrid can be divided into distributed power generation and centralized power generation. Because distributed installation is flexible, low cost, and can be directly connected to a large power grid, distributed applications are more extensive. Due to the intermittent and fluctuating characteristics of renewable energy such as wind, solar, and tidal energy, this poses a new challenge to the stable operation and control of the microgrid. Therefore, the microgrid technology shows a strong technical advantage in the operation and control of the renewable energy access to the large power grid. Therefore, the microgrid technology has attracted the attention of a wide range of researchers as soon as it was proposed. Microgrid can be divided into DC microgrid, AC microgrid, and AC/DC hybrid microgrid. Because DC microgrid does not need to consider frequency and reactive power problem and the line loss during transmission is small, DC microgrid has aroused the research of many scholars.

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2. Technical difficulties in DC microgrid operation control

2.1 The diversified structure of DC microgrid makes it difficult to unify the control problem

As shown in Figure 1, the DC microgrid consists of two new energies, photovoltaic and wind energy, energy storage devices, and two loads. The DC microgrid connects the new energy generation, load, and the large power grid though the DC bus and various power electronic converters. The DC microgrid can be connected to a large power grid and work in grid-connected mode, or it can work in off-grid mode without being connected to the large power grid.

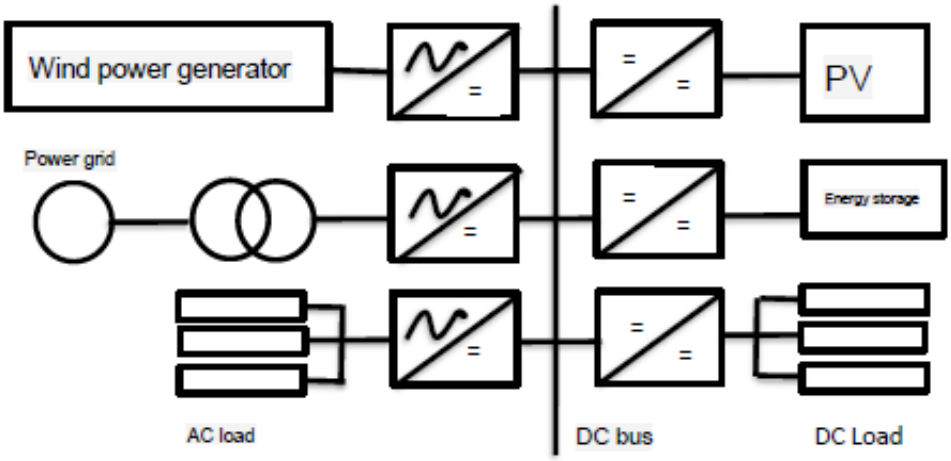

Figure 1. DC microgrid structure diagram

The off-grid operation of the DC microgrid, as shown in Figure 2, the energy storage system is an indispensable part of the off-grid operation of the DC grid, and the energy storage system has a certain inhibitory effect on the volatility caused by the access of renewable energy, So as to stabilize the voltage of the DC bus, thereby improving the quality of power supply.

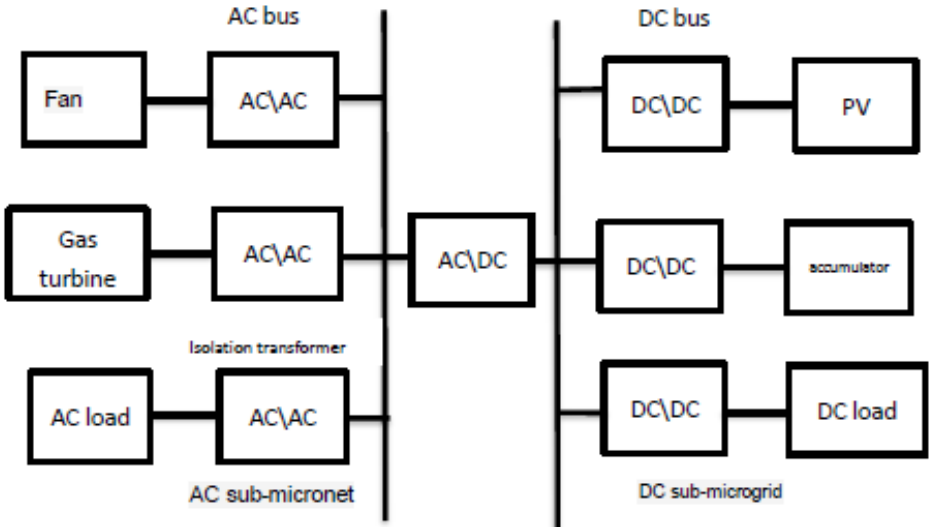

Figure 2. Off-grid operation mode of DC microgrid

The DC microgrid works in grid-connected mode, as shown in Figure 3. The difficulty of its control is the design and operation control of the microgrid's grid-connected and off-grid mechanism to avoid power fluctuations caused by the conversion between modes, and the problem between parallel and off-grid Smooth switching is a major difficulty in grid-connected operation research, so efficient and

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reliable control algorithms are necessary. Due to the complex and non-uniform structure of the microgrid, the focus and difficulty of microgrid operation control are different, which leads to the different operation control schemes of the current microgrid, which makes it difficult to have a unified control method for the microgrid.

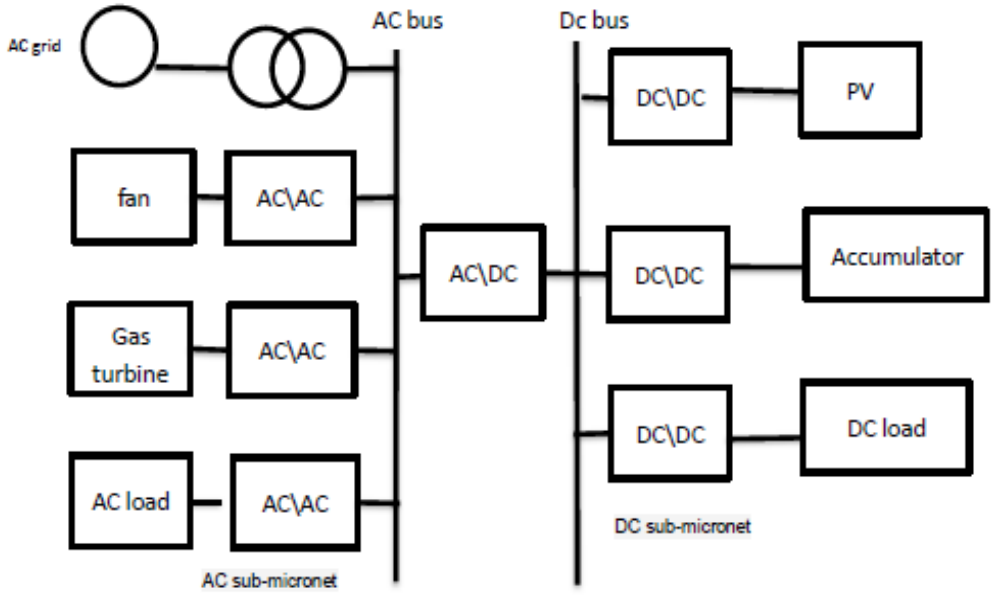

Figure 3. Grid-connected operation mode of DC microgrid

2.2 Island detection in microgrid

When the large power grid is out of power due to faults, power outages or other human factors, each distributed power source does not detect the cause of the fault and leaves the large power grid to continue to supply power to the surrounding loads. The island phenomenon of autonomous power supply is called the island effect. The methods of island detection include active detection and passive detection. Passive detection is mainly to detect electrical parameters such as voltage, phase, frequency, and harmonics of the grid-connected points to determine whether island occurs. Active detection is mainly to inject disturbance signals into the power grid system to disrupt the electrical balance of the system, and then inject small disturbance signals into current, frequency, phase, etc., in the grid-connected mode, limited by the large power grid, the disturbance signal will not produce the system Large influence, but in the island mode, the disturbance signal has an obvious effect to determine whether island occurs. Active detection methods mainly include active frequency shifting method, sliding mode frequency shifting method, Sandia frequency shifting method, etc. Literature [1] proposed an improved sliding mode frequency shift algorithm based on the tan function on the basis of the traditional sliding mode frequency shift method, and built a model on the simulation platform to verify its accuracy. This algorithm improved the detection speed, Reduce the influence of disturbance on power quality. For the current island effect research, most of the active detection methods are used to determine whether the system is island.

3. Several key points of DC microgrid operation control

3.1 Energy Management

In the DC microgrid, an optimal energy management strategy can improve the utilization of renewable energy, reduce the number of charging and discharging of the energy storage system, and is helpful to maintain the stability of the system. Energy storage systems that are widely used in microgrid systems mainly include batteries, super capacitors, and so on. In the grid-connected mode, when the energy in the DC microgrid is insufficient, the power electronic converter can be used to

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obtain energy from the large grid to supplement the energy of the microgrid. When the large grid fails to supply energy, it can also be obtained from the microgrid to absorb energy in the process to alleviate the problem of electricity tension. When the microgrid is operated off-grid, not only the balance of supply and demand must be considered, but also the energy flow between renewable energy and energy storage system must be considered. This requires an efficient, reliable and optimal energy management control strategy. For example, literature [2] proposed a hybrid energy storage structure of supercapacitors and batteries suitable for DC microgrid. The small signal analysis method is used to derive the stability conditions of the energy storage system. Under the premise that the microgrid can operate normally, not only It can increase the service life of the energy storage system, as well as its practicability and flexibility.

3.2 Power conversion control technology

Power converters with high efficiency, high reliability and simple structure, as well as advanced, reliable and precise control algorithms and strategies are particularly important in DC microgrids. In the DC microgrid, according to the operation mode, it can be divided into off-grid operation (also known as island operation mode) and grid-connected operation. In the grid-connected operation, it mainly involves the conversion between AC and DC, so it is equivalent to the study of AC and DC microgrid. It is necessary to realize the smooth switching of operation modes between the microgrid and the distribution network to ensure the stability of power and the reliability and controllability of the system. Power conversion technology is mainly focused on the research of PET (power electronic converter), connecting new energy sources, such as wind energy, solar energy and other renewable energy through power electronic converters to the large power grid, and connecting DC microgrids, AC power grids and large power grids. The power grid is organically combined, and power electronics needs to achieve precise control of power conversion in this. The most extensive research in the AC/DC microgrid is the study of PET, which mainly focuses on the structure and control method. For example, the literature [5] improves on the basis of traditional control methods, and aims at the problem of uneven power distribution and for microgrids operating in island mode, a control method is proposed that combines droop control and average power to solve the above problems. This control method is suitable for microgrids operating in low-voltage island operation mode, but it does not consider whether this control method can achieve the same effect during grid-connected operation. The literature [6] mainly aims at the AC/DC hybrid microgrid. It is suitable for smooth switching between off-grid and grid-connected and the power can be balanced. In order to improve the quality of power supply, this paper proposes a unitized processing The droop control method of the AC/DC hybrid microgrid, which normalizes the voltage of the DC microgrid and the frequency of the AC microgrid to realize the unification of the output power of the microgrid, but does not take into account the large number of power electronic devices Whether the power is balanced after being connected to the microgrid. For the off-grid operation mode of the DC microgrid, the stability of the DC bus voltage is the only criterion to measure whether the system power is balanced. This method is to divide the DC bus voltage into several intervals, but each interval can ensure independent operation. For DC microgrid power control, there are mainly bus voltage signal (DBS) control technology and virtual impedance control technology. The DBS method divides the DC bus voltage into different levels, and determines the working modes of distributed power generation, energy storage systems, loads, and grid-connected converters in the DC microgrid system according to different voltage levels, so as to realize the coordination of various energy equipment and loads run. For example, literature [7] proposed a control strategy for the coordinated control of distributed power generation units based on bus voltage signals. The control strategy divides the DC bus voltage into four levels, so that each level corresponds to a working mode, and Different working modes use different control strategies. This control method not only improves the energy utilization rate but also maintains the stability of the bus voltage, but this method is only suitable for small and medium-sized DC micro-grids, and the application range is not wide, and it cannot be widely used in major industries. AC and DC microgrid.

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4. Existing control technology

4.1 Droop control

In the DC microgrid, the problem of reactive power and frequency do not need to be considered too much. Only the bus voltage and active power need to be considered. The stability of the DC bus voltage is the only indicator to measure whether the system power is balanced, so the operation control is a easier than the operation control the operation of the AC microgrid. The bus voltage of the DC microgrid can directly reflect whether the power is balanced, so when the droop control method is applied to the DC microgrid, the relationship between the bus voltage and the active power can be directly obtained without considering the decoupling of reactive power and active power, that is, the formula P =UI. The DC microgrid bus voltage can most directly reflect whether the power is balanced, as shown in Figure 4, it is the droop control curve of the DC microgrid off-grid operation system with energy storage device, according to the formula Uref=U1-iRd, where Uref is the bus reference voltage, Rd is the droop coefficient of droop control (that is, the slope of the straight line in the figure is the droop coefficient), which can be equivalent to the output virtual impedance of the converter in the system. The energy storage system is connected to the DC bus through a bidirectional converter. When the actual microgrid voltage is lower than the bus voltage, it indicates that the load consumption increases, and the energy storage system increases the output current according to the droop curve to maintain the balance of the bus voltage; when the actual voltage provided is higher than the bus voltage, it indicates that the system has excess energy. The energy storage system charges and stores energy according to the droop curve, absorbs excess energy, and maintains a stable bus voltage.

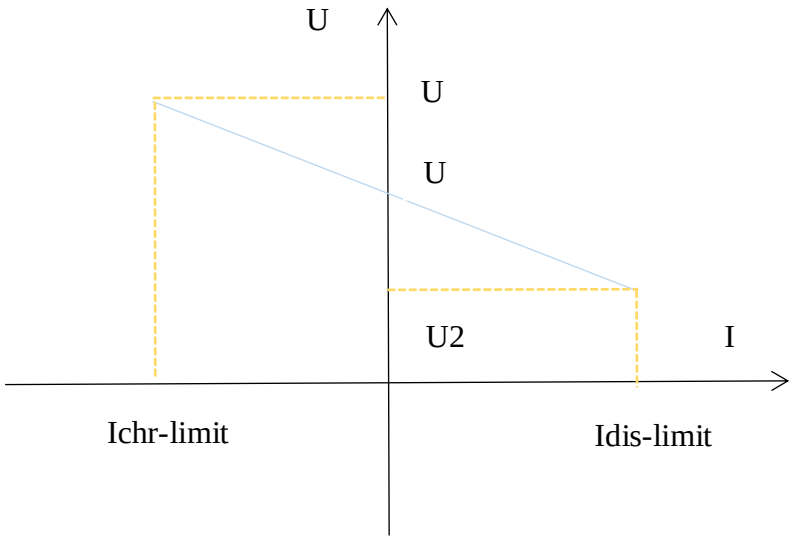

Figure 4. Droop control curve

4.2 Hierarchical control

Different control methods proposed according to different control objects are called hierarchical control. Hierarchical control can generally be divided into three layers: the first layer is the inverter control layer, the second layer is the energy management layer, and the third layer is the power management layer. Hierarchical control can process system information more flexibly, improve the coordinated operation of the DC microgrid, and enable the microgrid to switch smoothly and coordinate and stabilize the operation in both off-grid and grid-connected working modes. At present, the research on hierarchical control mainly focuses on improving the communication of hierarchical control and improving power quality. For example, in reference [8], according to the control requirements of the island-type DC microgrid to maintain the DC bus voltage stability, the DC microgrid hierarchical control strategy is divided into two levels: system-level control strategy and

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converter-level control strategy. The control method of power generation unit, photovoltaic power generation unit, energy storage unit and load unit is designed. Establish a DC microgrid dynamic simulation model on the PSCAD/EMTDC simulation software platform and set the simulation parameters for experiments to observe the sudden change of the output power of the micro source in the system, the sudden change of the load power, and the fluctuation of the bus voltage under the three working conditions when the two change at the same time.

4.3 Peer control

The plug-and-play function can improve the practicality and flexibility of the new energy DC microgrid. Peer-to-peer control solves the plug-and-play problem through mutually equal and compatible control strategies, and the communication is convenient and the cost is relatively low. Therefore, peer-to-peer control has become an important research direction of operation control. When adopting peer-to-peer control, each distributed power supply adopts local control, which improves the flexibility and practicability of the microgrid. At present, the actual application of peer-to-peer control is still relatively small, and the control method is mostly studied from the aspects of stability and improvement of traditional peer-to-peer control.

5. Summary and Outlook

From a review point of view, domestic and foreign research on DC microgrids has achieved certain results, and the focus of research in this research field needs to focus on the following points:

(1) There are a large number of renewable energy accesses in the DC microgrid, which reduces the stability and reliability of the system. Therefore, it is necessary to propose a new energy-energy storage coordinated control method to improve the stability and reliability of the system.

(2) There will be many power electronic conversion devices connected to the DC bus in the DC microgrid. The functions and power of these converters are not the same. A control method should be proposed to distinguish different controls and improve the coordinated operation of the system.

(3) The protection of DC microgrid is also a research hotspot. When a microgrid fails, how to find and remove the fault is also a hotspot worthy of attention. For recent research, researchers have proposed combining artificial intelligence and deep learning methods with traditional detection methods are combined to detect and remove faults, but this problem is still worthy of attention.

(4) The development of artificial intelligence is now in full swing. Combining artificial intelligence and microgrid to improve the coordinated control ability of microgrid is also a hot research topic.

With the increase of people's awareness of environmental protection and the vigorous development of new energy, photovoltaic power generation will occupy an increasingly important position in the future distribution network. This paper analyzes the technical difficulties and existing control aspects in the operation and control of DC microgrid, summarizes and looks forward to the development of DC microgrid in the future, hoping to provide some reference for the research of DC microgrid.

References

[1] Dandan Hu, Qian Zhao, Hao Xu, Zheran Zhu, Jie Long, Liyao Zhu.Research on island detection algorithm based on improved sliding mode frequency shift method [J]. Electric Drive, 2021, 51(02): 69-74.

[2] Guoju Zhang, Xisheng Tang, Zhiping Qi. Application of hybrid energy storage system of supercapacitor and battery in microgrid [J]. Automation of Electric Power Systems, 201034(12):85-89.

[3] M0HAMED A, MOHAMMED O. Power flow control in DC distribution systems [C]// 2010 North American Power Symposium,Arlington,TX ,USA, 2010,1-7.

[4] Chunyang Gu, Zedong Zheng, Lie Xu, et al. Modeling and Control of a Multiport Power Electronic Transformer (PET) for Electric Traction Applications[J]. IEEE Transactions on Power Electronics, 2016, 31(2):915-927.

[5] Xubin Wang, Peng Li, Pengchong Dou, Zeyuan Zhou. A new power control method for island operation of microgrid[J]. Electric Power Automation Equipment, 2014,34(06):122-128+134.

ISSN: 2414-1895 DOI: 10.6919/ICJE.202106_7(6).0022

[6] Wenchao Xie, Yongqiang Zhu, Shaofei Du, Ruihua Xia. Power control of interconnected converters in AC/DC hybrid microgrid[J]. Electric Power Construction, 2016, 37(10): 9-15.

[7] Zhongtian Zhao. Research on DC microgrid bus voltage control technology[D]. Shandong University of Technology, 2018.

[8] Yaoyi Ren. Research on the control strategy of island-type DC microgrid[D].Shenyang University of Technology, 2018.

[9] Cintuglu M H, Youssef T, Mohammed O A. Development and application of a real-time testbed for multiagent system nteroperability: A case study on hierarchical microgrid control[J]. IEEE Transactions on Smart Grid, 2018,9(3):1759-1768.

[10] Werth A, André A, Kawamoto D, et al. Peer-to-peer control system for DC microgrids[J]. IEEE Transactions on Smart Grid,2018,9(4):3667-3675.

[11] Azuka Affam, Yonis M. Buswig, Al-Khalid Bin Hj Othman, Norhuzaimin Bin Julai, Ohirul Qays. A review of multiple input DC-DC converter topologies linked with hybrid electric vehicles and renewable energy systems[J]. Renewable and Sustainable Energy Reviews, 2021,135.

[12] Engineering; Study Results from Tianjin University Broaden Understanding of Engineering (A Bidirectional Llcl Resonant Dc-dc Converter With Reduced Resonant Tank Currents and Reduced Voltage Stress of the Resonant Capacitor)[J]. Journal of Engineering, 2020.

[13] Engineering; Researchers at Macau University of Science & Technology Have Reported New Data on Engineering (Unified Boundary Control With Phase Shift Compensation for Dual Bridge Series Resonant Dc-dc Converter)[J]. Journal of Engineering, 2020.

[14] Peng Y, Shuai Z, Liu X, et al. Modeling and stability analysis of inverter-based microgrid under harmonic conditions[J]. IEEE Transactions on Smart Grid, 2020,11(2):1330-1342.

[15] Ziang Tong, Jianwen Wu, Suliang Ma, et al. A DC microgrid load current sharing control strategy based on active voltage disturbance [J]. Transactions of the China Electrotechnical Society, 2019, 34(24): 5199-5208.

[16] Xiangshan Li, Xiaodong Yang, Youbing Zhang, etc. DC Microgrid Coordinated Control with Bus Voltage Compensation and Load Power Dynamic Distribution [J]. Electric Power Automation Equipment, 2020, 40(1):198-204.

[17] Jun Shen, Wei Liu, Hucheng Li, etc. Distributed secondary optimization control of multi-microgrid based on reinforcement learning [J]. Automation of Electric Power Systems, 2020, 44(5): 198-206, 275-278.

[18] Xu Q, Vafamand N, Chen L, et al. Review on advanced control technologies for bidirectional DC/DC converters in DC microgrids[J]. IEEE Journal of Emerging and Selected Topics in Power Electronics [2020-03-05]. DOI:10.1109/JESTPE.2020.2978064.

[19] Choi J, Khalsa A, Klapp D A, et al. Survivability of prime-mover powered inverter-based distributed energy resources during microgrid islanding[J]. IEEE Transactions on Industry Applications, 2019, 55(2): 1214-1224.

[20] Bayati N, Hajizadeh A, Soltani M. Protection in DC microgrids: A comparative review[J]. IET Smart Grid, 2018, 1(3):66-75.

[21] Zhang L, Tai N, Huang W,et al. A review on protection of DC microgrids[J]. Journal of Modern Power Systems and Clean Energy,2018,6(6):1113-1127.

[22] Kabalan M, Singh P, Niebur D. A design and optimization tool for inverter-based microgrids using large-signal nonlinear analysis[J]. IEEE Transactions on Smart Grid,2019,10(4):4566-4576.

[23] Hui Zhang, Haiming Yan, Na Zhi, etc.DC microgrid grid-connected converter control strategy based on bus voltage differential feedforward [J]. Automation of Electric Power Systems, 2019, 43(15): 166-175.

[24] Jingrong Shi, Yong Li, Piao He, et al. A comprehensive inertia control method for improving the dynamic characteristics of AC/DC hybrid microgrid[J]. Transactions of the Chinese Society of Electrical Engineering, 2020, 35(2): 337-345.

[25] Ziwen Liu, Shihong Miao, Zhihua Fan, et al. Power precision distribution and voltage unbiased control strategy for isolated DC microgrid based on adaptive droop characteristics [J]. Transactions of China Electrotechnical Society, 2019, 34(4): 795-806.

ISSN: 2414-1895 DOI: 10.6919/ICJE.202106_7(6).0022

[26] Meiqin Mao, Rui Xu. Economic dispatching method for island microgrid based on distributed control[J]. Proceedings of the Chinese Society of Electrical Engineering, 2018, 13(9): 8-13.

[27] Meng L, Luna A, Díaz E R, et al. Flexible system integration and advanced hierarchical control architectures in the microgrid research laboratory of aalborg university[J]. IEEE Transactions on Industry Applications, 2016, 52(2):1736-1749.

[28] Fuxing Zhang, Tao Zhang, Rui Wang, et al. Energy management of energy local area network system considering multi-source-charge-storage collaborative optimization [J]. Power System Technology, 2017, 41(12): 3942-3950.

[29] Sarfi V,Livani H. An economic-reliability security-constrained optimal dispatch for microgrids[J]. IEEE Transactions on Power Systems, 2018,33(6):6777-6786.

[30] Yi Wang, Ming Yu, Yonggang Li. Wind power DC microgrid distributed control based on model predictive control method[J]. Transactions of the Chinese Society of Electrical Engineering, 2016, 31(21): 57-66.

[31] Chengshan Wang, Bingqi Jiao, Li Guo, et al. Overview of microgrid planning and design methods[J]. Electric Power Construction, 2015, 36(1): 38-45.

[32] Hu J, Wang B, Wang W, et al. Small signal dynamics of DFIG-based wind turbines during riding through symmetrical faults in weak AC grid[J]. IEEE Tran. Energy Convers. 2017,32(2):720-730.