Design of Multi-port Direct Current Microgrid Energy Router

Bingyin Lei¹, Lijun Xu¹, Zichi Wang¹, Yongqiang Wang² and Qi Huang²

¹Pinggao Group Co., Ltd, Pingdingshan, China
²Hebei Provincial Key Laboratory of Power Transmission Equipment Security Defense, North China Electric Power University, Baoding, China

Corresponding author’s e-mail: 2192213103@ncepu.edu.cn

Abstract. In order to meet the comprehensive utilization of "source-grid-load-storage" under the condition of new energy and make the power system more economical and flexible, the design and research of multi-port DC micro-grid energy router are carried out in this paper. Firstly, the essential functions of the energy router are analyzed. Secondly, the main components of the energy router are determined, and the topology structure, communication mode and control strategy of the related units are expounded. Finally, the application scenarios of the energy router are listed, which provides new ideas for the diversified application of the energy router. This article has obtained a multi-port energy router suitable for DC microgrid conditions. The energy router is mainly composed of power unit, communication unit, centralized control unit, power distribution unit and internal control unit, which can effectively complete the plug-and-play function, multi-voltage level conversion function, energy management function, human-computer interaction function, electrical isolation and other functions, to ensure the power demand of different voltage levels and safe and stable operation of the microgrid.

1. Introduction

In recent years, with the rapid development of solar-wind-water and other renewable energy and distributed energy, the innovation and application of DC distribution network technology have been accelerated. To overcome the shortcomings of distributed energy and make the power system more economical and flexible under the premise of making full use of distributed energy, the new concept of microgrid was born. The microgrid is a new type of network structure with self-control and self-regulation capabilities. A microgrid system unit is composed of micropower supply, load, energy storage system and control device, and can be divided into DC microgrid, and AC microgrid according to the different bus voltage types. Among them, the DC microgrid is widely used due to its large transmission power capacity, high system controllability, and good power quality.

As the core equipment of the DC microgrid, the energy router came into being and has been extensively studied by experts and scholars at home and abroad. Reference [1] puts forward the functional requirements of energy routers by comparing energy with information routers, and classifies electrical energy routers according to the existing grid structure, and explains the characteristics of various energy routers. Reference [2] conducts equivalent modeling of small hydropower, photovoltaic, and energy storage devices, analyzes and compares the topology of existing energy routers, and develops research on the new topology of energy routers suitable for common distributed power access. Reference [3] provides a reference for the scene application and coordinated...
control of energy routers by analyzing the operating structure, circuit parameters and decentralized control methods of multi-port bidirectional energy routers.

This article first introduces the basic functions of the multi-port DC microgrid energy router, and then, on this basis, describes in detail the main parts of the energy router components to complete the overall design of the multiport DC microgrid energy router. Finally, an example is given to the application scenarios of the energy router.

2. Basic function of multi-port DC microgrid energy router

The main functions of the multi-port DC microgrid energy router include plug-and-play, multi-voltage level conversion, energy management, human-computer interaction, electrical isolation, and fault current limiting, as shown in the dotted line in figure 1. It will be briefly explained below.

Plug and play function: Provide interfaces for all kinds of power equipment, and provide different voltage levels and control methods according to the types of equipment. When the power equipment is connected to the energy router, the energy router port perceives the equipment, quickly recognizes the power equipment type and current status information and then performs energy transmission and control in [4].

Multi-voltage level conversion function: As there are multiple voltage levels in the DC microgrid, the multi-port of the energy router can output different levels of voltage. On the one hand, the user-side DC voltage level can output mainly including 380V for heating systems, air conditioning systems and large-scale electrical equipment and 48V for small household appliances; on the other hand, it can be connected to the output voltage provided by different forms of distributed power sources.

Information interaction function: The energy router has the function of two-way information interaction between energy ports, energy routers and upper-layer management system, and ensures the security and reliability of information interaction. Through reliable and fast communication network, it realizes the sharing of information among all nodes in the network and provides data support for energy path optimization.

Electrical isolation function: There is no direct electrical connection between different DC voltage levels inside the energy router, which can effectively prevent the short circuit formed by the grounding point and other paths of the power distribution system in the directly grounded system, and avoid the short-circuit current generated from coupling to other voltage levels.

Energy management function: The energy router can realize the rapid adjustment of the power flow direction of each line according to the scheduling information, and can target the conversion and optimized configuration of multi-port and multi-type energy. Through the coordinated control of each port, the energy router and DC microgrid can be realized Internal power balance.

3. Multi-port DC microgrid energy router component units

As a highly integrated device with versatility, openness and compatibility, the multi-port DC microgrid energy router consists of five core units: power unit, communication unit, centralized control unit, power distribution unit and internal Control unit, as shown in figure 1.

The power unit is composed of a combination of multi-level power electronic conversion units, with functions such as DC voltage level conversion and plug-and-play electrical isolation. Compared with common single-port isolated DC-DC converters, the bidirectional anti-excitation type has a simple topology and low cost and is suitable for low-power applications, but its power tube is prone to resonance and cause breakdown; the bidirectional push-pull type is compared with the bidirectional anti-excitation type is suitable for occasions with slightly higher power, but its power tube needs to withstand greater voltage and current stress, and is not suitable for places with harsh voltage environments; two-way full-bridge type has flexible control, high compatibility, low voltage and current stress and strong anti-interference ability. Therefore, in order to meet the requirements of the multi-port energy router of the DC microgrid, a bidirectional full-bridge type is selected as its DC-DC converter, and the above-mentioned converters are combined in series and parallel with a common DC bus to realize multi-port expansion.
The communication unit needs to meet the internal and external communication of the equipment to realize the power distribution and electric energy routing function, the information interaction function, the plug and play function, etc. In order to meet the requirements of multi-port energy routers for DC microgrids, the router uses the combination of CAN bus and RS485 protocol to carry out inter-unit communication, and transfers port device information, power conversion information and energy management information; the outside of the router uses the IEC61850 standard in [5]. The communication between devices is to be compatible with the communication protocol between different devices in the power system for the transmission of microgrid parameter information, primary energy parameter information and other information.

![Diagram](image)

**Figure 1. Basic functions and components of a multi-port DC microgrid energy router.**

The centralized control unit mainly finds the optimal energy path and coordinated control strategy according to the information of the communication unit and the information fed back from the power unit, to realize the overall energy balance of the electric energy router and the DC microgrid. In this paper, a DC microgrid energy router coordination control strategy based on virtual synchronous generators is adopted. By improving the inertia of the DC microgrid to suppress the voltage fluctuation of the DC bus, enhance its anti-interference ability, thereby ensuring the power quality and the overall energy balance of the DC microgrid[6]. The centralized control unit also provides a human-computer interaction window to realize the demand-side management function, so that the user can automatically or manually control the operation of the equipment.

The power distribution unit mainly completes the power balance among the internal ports of the multi-port energy router based on the scheduling of the centralized control unit. In this paper, the port energy model of the energy router is established, and the energy conversion relationship between each port energy and the internal passive device storage during the operation of the energy router is calculated based on the power unit information, and the power distribution between the ports is completed to achieve power balance.

The internal control unit is mainly combined with existing protection devices to form a protection system including an energy router. In order to meet the needs of low-voltage DC microgrid, the internal control unit is mainly composed of fault current-limiting modules, which are used to reduce...
the amplitude of DC fault current, reduce the extinguishing pressure of DC circuit breakers, and strive for a longer time for the protection of the system.

4. Applications of multi-port DC microgrid energy router

4.1. Application of energy router in energy internet

In order to solve the problem of local consumption of renewable energy, improve the efficiency of energy use on the energy side, and promote the country's economic and social transformation, the idea of building a global energy Internet came into being. Relying on electricity, the Energy Internet uses energy conversion and storage devices to organically integrate multiple energy systems such as power grids, natural gas networks, and cooling and heating systems, through the integrated use of multiple new energy sources and energy storage devices in the system, to realize the coordinated complementation and cascade utilization of multiple energy sources. In the Energy Internet, the role of each power user is not only a consumer of electric energy but also a supplier of electric energy.

Therefore, the energy router as the core equipment of the DC microgrid can be used in the interconnection and grid connection of distributed energy, as shown in figure 2, to meet the power supply diversity of the Energy Internet, the two-way flow of energy and even the multi-directional flow, and power regulation, greatly promote the construction of the energy Internet.

![Figure 2. Application of Energy Router in Energy Internet](image)

4.2. Application of energy router in urban rail transit

Urban rail transit is an important part of the modern urban transportation system. It plays an increasingly important role in improving the quality and efficiency of urban public transportation supply, alleviating urban traffic congestion, and guiding and optimizing the layout of urban spatial structure. The power supply mode of the urban rail transit traction power supply system adopts DC power supply. There are many DC traction power supply voltage levels in urban rail transit in the world. Our country's national standards stipulate two types of 750V and 1500V. The allowable voltage fluctuation ranges are DC500~900V and DC1000~1800V.

As the country puts forward the concepts of intelligent transportation and green transportation, traditional rail transit substations can no longer meet the development concept of new rail transit, and it is difficult to achieve an accurate analysis of the rational energy use of the system. Therefore, the multi-port DC microgrid Energy routers can be used in the power supply scenarios of urban rail transit traction power supply systems, as shown in figure 3. On the one hand, it can effectively solve the cumbersome multi-level power transformation problem of rail transit substations and distribution stations, and on the other hand, it can effectively solve the energy recovery problem in the braking process of rail transit, to ensure the safe and stable operation of urban rail transit.
4.3. Application of energy routers in the large data center

With the advent of the era of big data, Internet products and services demand is growing, more and more data need to store and handle, the life of people more and more rely on the network and information, including financial, chemical industry, government affairs, communication, scientific research, the power of all walks of life, more and more high to the requirement of data processing, more and more dependent on. The front-end of the transformer and distribution system in large data centers basically adopts AC power transmission and distribution. AC/DC devices need to be configured at the end of the power equipment to convert the mains (including standby UPS) into DC240V, DC24V or DC12V for the use of the core equipment in the data center, which undoubtedly increases the investment cost and power transmission loss. Moreover, the introduction of a variety of AC/DC inverters in large data centers also brings many adverse factors to the operation and maintenance of power supply and distribution system.

Therefore, multi-port DC microgrid energy routers can be applied in large-scale data center power supply scenarios, as shown in figure 4, providing highly reliable power distribution solutions, reducing many power conversion links in the original AC transmission and distribution power supply system, reducing equipment deployment and investment, and ensuring the safe and stable operation of the data centers.

5. Conclusions

This paper proposes a design of a multi-port energy router suitable for DC microgrid conditions. It consists of five core units: power unit, communication unit, centralized control unit, power distribution unit and internal control unit. The function to be completed by the unit carries out the research of topology, communication mode and control strategy. After that, examples of its new application scenarios are given to provide references for the development of energy routers under the conditions of DC microgrid and the promotion of equipment use. The energy router can not only provide various interfaces for new energy power generation equipment and users, but also flexibly control the multi-directional flow and balance of energy, which is of practical significance for improving the power quality, energy utilization rate and system stability of the DC microgrid. Based on the DC microgrid, this paper analyzes and designs a multi-port DC microgrid energy router. The power unit part adopts a two-way full bridge as its DC-DC converter series and parallel combination. The structure is complex and the cost is high. Consider adopting more convenient and reliable topological structure and high-performance power electronic conversion devices to meet the requirements of economy.
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