Research on Key Technologies of Campus Microgrid Control

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Abstract. Taking campus microgrid as the research object, combining the characteristics of campus energy use and the development trend of multi-energy complementary microgrid, a typical architecture of microgrid system suitable for campus is proposed. This paper discusses the significance and future development prospect of microgrid to ensure the safety of campus energy consumption.

1. Introduction
Today's society relies heavily on the security of energy supply. People's demand for electricity is everywhere in daily life. Power failure will cause many problems, such as communication interruption, water supply and heating shutdown, mobile payment obstruction. The security and reliability of power supply and distribution have become an increasingly serious challenge. Microgrid is a low-voltage power generation and distribution system composed of distributed energy, energy storage device, energy conversion device and load. It is obvious that the basic characteristics of microgrid are local load, local micro source and intelligent control. It can run in grid or independently. It is an autonomous system with self-control and self-energy management\cite{1}. When the large power grid fails, it can ensure the power supply of local key loads, and the power supply reliability is high.

In recent years, the research on Microgrid at home and abroad has made great progress, and many demonstration projects of microgrid in parks have been implemented. Microgrid project construction for schools and hospitals is gradually spreading out. Among them, Stanford University has reached an agreement with a solar energy company. About half of the electricity required by Stanford University is supplied by solar power plants, and the rest is supplied by campus solar panels or California's power grid. About two-thirds of Stanford's electricity demand comes from renewable energy, and its carbon emissions are down 68\%, equivalent to reducing the carbon emissions of 32,000 vehicles. The enthusiasm of Chinese universities for the construction of microgrid is also increasing day by day. With the continuous development of new energy industry technology, university laboratories and scientific research institutions engaged in microgrid experimental research and theoretical verification personnel are also gradually increasing.

The school is the secondary load, and the hospital is the primary load. The campus, which contains a certain number of students and staff, is equivalent to a micro community with sound functions. The learning, working and living activities of teachers and students in the school are inseparable from the power supply. Therefore, schools and hospitals will set up dual power supply or standby power supply (generator), and the input cost of dual power supply and standby power supply is high. Moreover, the
average number of power outages in urban power supply is not much, which leads to the low utilization rate of dual power supply and standby power supply. Moreover, the campus power load has distinct characteristics, the campus personnel are relatively concentrated, the activities are regular, and the power load is highly predictable. The daily power load curve of a campus is shown in Figure 1.

![Daily load curve of a campus](image)

Figure 1. Daily load curve of a campus

Through wind and solar power generation, battery energy storage, intelligent control and other means, microgrid can effectively solve the problems of power safety and economy faced by schools and hospitals. According to statistics, by 2019, there are 518,800 schools at all levels and various types in China, and 1,007,545 medical and health institutions. It can be seen that microgrid has a broad application market prospect in schools and hospitals.

2. Campus microgrid system

Campus microgrid is a small power generation and distribution system composed of distributed generation, energy storage device and load, which can realize self-control, protection and management. Its scale can be large or small, and its composition can be simple or complex. According to the mode of access to the distribution system, the microgrid can be divided into user level, feeder level and substation level microgrid[1]. The voltage level of the public connection point of the user level microgrid access to the distribution system is 380V, and its operation and management are the responsibility of the user. The campus power supply and distribution system is introduced from the municipal power trunk line to the campus switching station, and then the switching station is introduced into the campus indoor substation or outdoor box type substation. After the transformer reduces the 10KV voltage to 380V, it is introduced into the building distribution room. The scale of distributed power generation in campus is small, for example, photovoltaic array is distributed on the roof of the building, diesel generator is installed in the basement, and wind generator is installed on the top of street lamp or open space. Therefore, the campus microgrid belongs to the user level microgrid, and the AC bus voltage is selected according to the generation capacity of distributed generation.
2.1 Campus microgrid system architecture

The access diagram of campus microgrid system is shown in Figure 2. It uses three-phase AC bus mode to connect wind power, photovoltaic, energy storage, diesel generator, charging pile[2], lighting equipment, power equipment and other microgrid equipment, and connects with campus distribution network side through microgrid metering monitoring device with bidirectional power metering capacity. The operation status and control of microgrid is in the charge of the microgrid measurement monitoring device, which collects the operation data of each microgrid equipment in real time, monitors the voltage, power and power quality, charging and discharging information of energy storage system and load access. According to the internal control strategy of the device, the active power of the power station is regulated, the charging and discharging of the energy storage system are controlled, and the peak load and valley load of the microgrid, the supporting voltage frequency and the power balance are realized. The administrator can realize the remote management of microgrid through the cloud platform. With the help of the operation data uploaded by the microgrid metering and monitoring device, the cloud platform stores and analyzes the data. According to the historical data and meteorological data, the generation output and load change of microgrid can be predicted through the algorithm, and the dispatching plan and operation optimization curve and other commands can be issued to the microgrid metering and monitoring device, so as to realize the remote optimal scheduling of microgrid operation.

2.2 Campus microgrid communication mode

The communication between the microgrid measurement and monitoring device and the cloud platform system can use the campus network resources to realize the up and down communication of data, which is cost-effective, stable and reliable. According to the characteristics and technical requirements of the equipment, RS485 communication, can bus, MODBUS communication, Ethernet communication, optical fiber communication, Lora wireless and other communication modes can be adopted for the data transmission between the microgrid metering monitoring device and the converter equipment in the microgrid. Strive to achieve high-speed communication, fast response.

3. Campus microgrid control technology

The campus microgrid system can operate in the grid mode and off grid mode. The two modes need to be converted to each other, which will involve the problem of parallel off grid mode switching of
microgrid. Under normal circumstances, the campus microgrid operates in the grid connected mode. If there is a sudden power failure in the campus due to the distribution network failure, or the station area where the distribution network outage maintenance plan is issued, the campus microgrid has to switch to the off grid mode; when the distribution network failure is eliminated, the power supply is restored to normal, or the distribution network maintenance plan is completed, the campus microgrid is restored to grid operation. The off grid mode switching scheme can be divided into seamless switching and slotted switching. For the first level load and second level load users with high power consumption requirements, the seamless switching scheme without power outage can be adopted, and the switching time is very short, which can reach millisecond level. At the same time, the scheme has high performance requirements for the equipment and relatively high cost. For the third level load users, the switching process is short. The scheme has low requirements for converter and controller and is easy to realize. The process of grid-connected to off-grid includes four steps: grid-connected, grid-connected shutdown, black start and off-grid. Flow chart of grid-connected to off-grid is shown in Figure 3. The process of off-grid to grid-connected includes four steps: off-grid, off-grid shutdown, grid start-up and grid-connected. Flow chart of off-grid to grid-connected is shown in Figure 4.

Figure 3. Flow chart of grid-connected to off-grid

The above switching process involves a sequential control technology[3] and black start control technology. Cloud platform provides scheduling instructions for microgrid, and optimizes the optimal power configuration of photovoltaic power station, wind power station, diesel power generation, battery energy storage system and load. With the help of cloud platform management system, microgrid can realize group management and control, improve calculate ability and optimal operation.
3.1 *Black start control technology*

The black start control technology[4] is that when the microgrid is completely blackout, the system is in the black state. It does not rely on the help of the distribution network, and provides voltage and frequency support for the microgrid bus with the help of its own energy storage system or diesel generator set, so as to ensure that the power supply equipment without self start ability can resume operation. Firstly, the micro grid system self checks the status of each node equipment to meet the black start condition. The micro grid metering and monitoring device preferentially selects the battery energy storage system as the main power supply of the system and the diesel generator as the alternative main power supply. The VF control strategy is adopted to establish the AC bus voltage and frequency of the micro grid, and then start the wind power converter, photovoltaic converter, energy storage system converter and other auxiliary power supplies, Set the operation mode of the secondary power supply to PQ mode, and then connect the loads one by one to complete the black start of the microgrid.

3.2 *Virtual synchronous machine (VSG) technology*

If the microgrid system needs to achieve seamless switching and adjust the power, voltage and frequency of AC bus more quickly, virtual synchronous machine (VSG) technology can be used to adjust the converter of microgrid and simulate the electrical model, droop frequency regulation and droop voltage regulation characteristics of synchronous generator. The external characteristics of grid connected are similar to those of traditional synchronous generator[5]. It can participate in the primary frequency modulation of the system and increase the damping and inertia of the microgrid system.

3.3 *Frequency partition based on multi-stage fast frequency modulation strategy*

The frequency division of multi-stage fast frequency modulation strategy based on frequency division refers to the frequency division according to the frequency deviation caused by disturbance, and different frequency modulation means are adopted in different sections to coordinate with each other. Multistage frequency regulation is one-stage frequency regulation by energy storage VSG, two-stage frequency regulation by energy storage system, photovoltaic system and wind power system, three-stage frequency regulation by accurately cutting off the unit and load, which can realize coordinated control of different deviations and different time scales, and ensure the stability of system frequency. The multilevel fast frequency regulation strategy based on frequency partition can solve the frequency stability problem of microgrid when it is off grid.
4. Conclusions
Aiming at the control technology of campus microgrid system, this paper takes the campus microgrid as the research object, combined with the development trend of multi energy complementary microgrid and the characteristics of campus energy consumption, puts forward the typical architecture of campus microgrid system, and expounds the parallel and off grid switching sequence control, black start control technology, and seamless switching involved in the operation control process of campus microgrid Virtual synchronous machine (VSG) technology and multi-level fast frequency modulation strategy based on frequency partition are introduced. Microgrid can absorb distributed energy locally, which is an important part of smart grid in the future. With the help of cloud platform management technology, the group control of microgrid will not be a problem. For the campus micro grid, it can be used as a backup power supply for uninterrupted power supply of important loads, and can also be used as the school smart grid control experimental system.

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