Review on operation and maintenance management technology of smart photovoltaic micro grid in plateau cold area

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Abstract. Energy crisis and environmental pollution are more and more concerned. The smart photovoltaic micro grid system is in the stage of rapid development because of its clean solar energy as the power source, which has been strongly supported by national policies. Based on a brief summary of the operation and maintenance management technology characteristics of smart micro grid in the United States, the European Union and China's plateau cold region, this paper analyzes the key parts of smart photovoltaic micro grid system: energy consumption management, system control and system protection. It provides a theoretical reference for the follow-up research.

Keywords: Alpine region of Plateau; Smart micro grid; Photovoltaic power generation technology; Operation and maintenance management technology.

1. Introduction
With the rapid development of social economy, the degree of urban centralization is becoming more and more prominent. Both the industrial production power consumption and the living power consumption of the citizens are rising in a straight line. Especially in the Tibetan farming and pastoral areas, due to the scattered residential areas and high power cost, the power quality in remote areas is poor. Therefore, the scale of traditional centralized high-voltage long-distance transmission system also increases with the increasing demand for electricity. At the same time, because of its high cost of construction, the difficulty of operation and maintenance, the quality of power transmission is difficult to follow up the increasing diversified power demand of users and other shortcomings are becoming increasingly prominent. And with the increasingly prominent energy crisis, environmental pollution is becoming more and more serious. On the basis of making full use of all kinds of clean energy for distributed power generation, smart micro grid system, which combines advanced communication, measurement, sensor and other technologies and advanced control methods, has become the focus of experts and scholars at home and abroad. The smart micro grid system mainly uses renewable energy (solar energy, wind energy, geothermal energy, tidal energy, etc.) as far as possible, supplemented by fossil energy (natural gas, etc.) which is easily accessible locally, and distributed nearby the user side, so the smart micro grid system improves the reliability of power supply at the user side and can achieve the purpose of energy ladder use. At the same time, it has low power consumption in the power supply network, so it has the advantages of high energy utilization rate, convenient maintenance and so on, which has gradually attracted the attention of all countries in the world.
This paper mainly summarizes the concept and characteristics of smart micro grid, and gives the current situation of operation and maintenance management of smart micro grid in the world, and analyzes the three key parts of smart distributed photovoltaic micro grid system (energy management, system control and system protection).

2. Characteristics of smart micro grid

2.1. The concept of smart micro grid
Due to the different definitions of micro grid in the world, experts and scholars all over the world have different definitions of smart distributed micro grid. Galvin Electric Initiative believes that smart distributed micro grid system is the embodiment of miniaturization, modernization and intelligence of traditional centralized and large-scale power supply system. It can not only meet the diversified power demand of users as much as possible, but also ensure the reliability and safety of power supply quality, make the most of renewable energy and promote the continuous innovation of power grid technology[1]. Value Energy believes that smart distributed micro grid system should be able to use multiple energy sources (including renewable energy and non-renewable energy) for coupling power generation, intelligent control and management through the end-user side, and achieve the goal of sustainable development while maximizing economic benefits[2]. Experts and scholars in China think that smart distributed micro grid system is the micro grid system, which shows intelligence. It relies on small and decentralized resources, combines distributed generation technology with end-user side energy management technology and energy cascade utilization technology, so as to form a decentralized small modular power transmission network, and through advanced communication, measurement, monitoring and Control and other technologies enable the microgrid to meet the higher demand for future power quality, environmental benefits and economic development[3].

Although there are different definitions of smart distributed micro grid system in the world, the basic consensus for smart distributed micro grid system is that smart distributed micro grid system mainly consists of various distributed power sources, power storage units, loads, protection equipment, intelligent monitoring and intelligent control. It has the characteristics of flexible and adjustable, intelligent monitoring, intelligent control, and has two operation modes of grid connected operation and off grid operation. At the same time, according to the actual situation of electricity consumption, the installed capacity of the whole micro grid system generally varies from several kilowatts to several megawatts[1]. The intelligent distributed micro grid system can not only supply power for the nearby area, but also supply heat or refrigeration for the nearby area under certain conditions, and it has a parallel relationship with the traditional municipal power grid. In Table 1, the development objectives of the smart distributed micro grid system in the United States, the European Union and China’s plateau cold region are given.

| Objective                                      | U.S.A | European Union | China (plateau cold area) |
|-----------------------------------------------|-------|----------------|--------------------------|
| Reliability of power supply                   | ✓     | ✓              | ✓                        |
| Reduce the emission of environmental pollutants (CO2, dust, etc.) |       | ✓              |                          |
| Reduce construction cost                       | ✓     | ✓              |                          |
| Improve energy efficiency                      | ✓     | ✓              | ✓                        |
| Capable of grid connection and off grid operation |       |                | ✓                        |
2.2. Structure of smart micro grid

2.2.1. The structure of smart micro grid in the United States. The basic structure of smart distributed microgrid proposed by CERTS is shown in Figure 1. In cooperation with American electric power company, it has established a large-scale intelligent distributed microgrid system platform in Dolan technology center, which integrates monitoring, control, protection equipment and power management[4]. The smart micro grid system is mainly composed of three feeders: one of them is still connected with the municipal grid system. When the static switch on the feeder is closed but does not send power to the municipal grid system, the feeder can still send the power generated by the distributed power supply to the load end. The other two feeders are connected to DG unit and can operate in off grid mode. The intelligent distributed microgrid system proposed by CERTS consists of two core components: controllable micro power supply and static switch.

Fig.1 The structure of smart distributed microgrid in USA

2.2.2. The structure of smart micro grid in EU. Led by Athens National University and in cooperation with Siemens, ABB, SMA, ZIV, I-Power and other companies, EU framework 6 (2002-2006) project: "Advanced Architectures and Control Concepts for More Microgrids", with a total investment of 8.5 million euros[2]. The main research direction of the project is intelligent monitoring, intelligent control strategy, coordination management method of the whole system, protection scheme of the system, and the influence of the system on the municipal power grid system, etc. The basic structure of the smart distributed microgrid system in the EU is shown in Figure 2. The core of the whole smart micro grid is the central controller (MGCC) connected with the distributed power and load. MGCC provides signals to the distributed power controller (MC) and load controller (LC) through the set initial values, so as to achieve the purpose of controlling the distributed power and load matching operation.

Fig.2 The structure of smart distributed microgrid in EU
2.2.3. The structure of smart micro grid in Plateau and cold area of China. The development of smart micro grid system research in China is mainly based on the basic concept of CERTS. The research direction is mainly aimed at the grid connected operation and off grid operation mode of smart micro grid system, the degree of intelligent control of the system and the impact of the system on the municipal power grid system. The national government has also given great support to the research work of smart distributed micro grid, for example, in the national "863" and "973" plans, the research of smart distributed micro grid system has been supported[5]. Figure 3 is the structure diagram of intelligent distributed photovoltaic micro grid system for office building power supply constructed by Tibet energy research and demonstration center. The system is mainly composed of five parts: 255Wp polysilicon photovoltaic module, 240kWh energy storage battery, 58kW energy storage converter, distribution cabinet and intelligent communication cabinet. The intelligent distributed photovoltaic micro grid system mainly uses a hierarchical control system, which is mainly composed of the system center general controller (communication cabinet) and two remote controllers (energy storage converter and distribution cabinet). The energy storage system is mainly composed of battery pack, battery management system, PCS, power distribution system, etc., with a design capacity of 60kW / 240kwh. As shown in Figure 4, the energy storage battery system is composed of a battery rack energy storage unit, each battery rack energy storage unit is composed of a battery string, with a capacity of 80kWh, a total of three cell battery racks, with a total capacity of 240kWh. Together with a 58kW energy storage converter, a 60kW / 240kWh energy storage system is formed. At the same time, in order to ensure the safe and reliable operation of the energy storage system, a set of fire fighting system, air conditioning system, BMS, etc. are also equipped inside the system to ensure the safe and reliable operation of the energy storage system.

Fig.3 The structure of intelligent distributed micro grid in Plateau and cold area of China

Fig.4 Composition diagram of battery cabinet
2.3. Advantages of smart micro grid

2.3.1. Compared with municipal grid system, smart micro grid system has the following advantages. (a) The smart micro grid system can use different kinds of decentralized energy (solar energy, wind energy, tidal energy, natural gas, etc.) for coupling power generation, so it realizes the complementary advantages of multiple energy sources, improves the energy utilization rate of decentralized energy, and reduces the impact of the instability of single decentralized energy generation quality on the municipal power grid;

(b) Because smart micro grid system adopts the principle of nearby power generation, it not only reduces the transmission loss in the circuit network, but also reduces the construction cost caused by the upgrading of municipal power grid system;

(c) Due to the regional centralized power transmission characteristics of smart micro grid system, it reduces the reserve power demand of municipal power grid system and the high peak power consumption of municipal power grid.

2.3.2. Compared with the user side, smart micro grid system has the following advantages. (a) The smart micro grid system has flexible operation mode, so it can meet the diversified demand of users;

(b) The smart micro grid system realizes the user side power autonomy, improves the ability of regional power grid to resist natural disasters, and ensures the reliability of regional power supply;

(c) The user side can provide higher quality power for itself through intelligent control;

(d) The smart micro grid system can provide power distribution network for areas without power, and realize the goal of power supply for villages;

(e) Because most of smart micro grid systems choose renewable energy as the source of power generation, it ensures the sustainable use of energy, energy conservation and environmental protection.

3. Key parts of smart micro grid system

3.1. Energy management

As the core part of smart micro grid system, energy management unit should have the following five functions: man-machine communication, data monitoring, information analysis, information prediction and control optimization[4]. Through the use of advanced data monitoring and data acquisition equipment, the energy consumption management unit can obtain the real-time electricity demand and real-time electricity price fluctuation information on the user side, and predict and analyze the operation conditions of the intelligent distributed photovoltaic micro grid system according to these information, and finally formulate the implementation scheme with the highest economic benefit and the best system operation. Figure 5 shows the BMS communication topology of the energy research and demonstration center of Tibet Autonomous Region.

The energy consumption management unit of smart micro grid system is different from that of traditional municipal grid system in the following three aspects:

(a) The energy management unit of smart micro grid system not only has the electric energy management unit, but also includes the thermal energy management unit (heating in winter, or cooling in summer in hot areas). The electric energy and thermal energy management units in the energy management unit need to coordinate with each other;

(b) The energy consumption management unit of smart micro grid system can realize the energy exchange with the municipal grid system (i.e., it can realize the grid connection, off grid operation and surplus power on grid);

(c) The energy consumption management unit of smart micro grid system can realize the hierarchical power supply at the user side. For example, under the condition of off grid operation and insufficient light, the production power of the system is not enough to meet the demand of the whole user side, so the unimportant load can be cut off and the power supply of the important load can be guaranteed in priority.
Future development goals of smart micro grid system:
(a) Improve the centralized control ability of the system, so that the user side can control the whole system more conveniently;
(b) Improve the quick response ability of the system, so that the system can reflect the electricity price in real time;
(c) Improve the monitoring and acquisition ability of the system, so that the system can efficiently and accurately locate faults and handle various information;
Improve the decision-making and scheduling ability of the system, so that the system can provide the best operation scheme.

Fig. 5 BMS communication topology of Tibet energy research and demonstration center

3.2. System control
The operation mode of smart micro grid system mainly includes grid connected operation and off grid operation.
(a) Grid connected operation status: When the smart micro grid system is in the state of grid connected operation, its photovoltaic power supply adopts the constant power control mode, that is, by coupling the active power and reactive power, using the voltage space vector control technology to adjust the output voltage of the converter, and then adjust the size of the line current, and finally achieve the purpose of constant power[6]. In grid connected operation mode, active power and reactive power are set as reference values, so the output power of photovoltaic power supply maintains its reference value to output.
(b) Off grid operation status: When the smart micro grid system is in off grid operation state, its photovoltaic power supply generally adopts droop control or constant voltage and constant frequency control mode. The droop control is to define the initial setting value of the active power or reactive power as the reference value of the control, and then according to the linear relationship between the active power and the frequency and the linear relationship between the reactive power and the output voltage, the droop control is used to calculate the output frequency and the output voltage of the converter (similar to the primary frequency modulation of the generator)[7]. Constant voltage and constant frequency control is to control the output voltage and frequency to keep them within the reference range, so as to achieve the purpose of control and regulation (similar to the secondary frequency modulation of generator)[7].

3.3. System protection
Smart micro grid system is a regional active network which uses solar energy as power source, so there is a huge difference between its system protection and municipal grid system:(a) The internal current flow of the smart photovoltaic micro grid system is bidirectional, so it must be installed with anti reverse...
current equipment to prevent the internal current from reverse flow to the photovoltaic modules;(b) Because the short-circuit current of the smart photovoltaic micro grid system varies greatly in the state of grid connected operation and off grid operation, the current protection value should be set separately to prevent the system short-circuit. The protection setting value of smart micro grid system shall be able to make efficient and accurate judgment on the faults in the whole system according to the real-time information, so as to meet the requirements of the municipal grid protection system: rapidity, sensitivity and reliability[8]. And the protection system can be applied to both grid connected operation and off grid operation, that is, when the parallel / off grid switching occurs, the protection system will not fail.

4. Conclusion
The smart micro grid system not only realizes the purpose of energy conservation and emission reduction, but also realizes the purpose of power grid system intellectualization because it makes full use of Distributed Renewable Energy and adopts advanced monitoring, control, communication and computer technology, so it has been highly valued by the state. However, with the increase of the ratio of smart micro grid system in the whole distribution system, how to improve the human-computer communication ability, real-time data monitoring ability, analysis and prediction ability, fault accurate positioning ability, group control ability, multi energy coordination ability and other aspects of smart micro grid system will become the next research focus. With the increase of the number of smart micro grid system construction, there may be some problems such as the construction division of regional virtual power stations, unified power grid, etc., which need the unified management and coordination of the state. Even though China's smart micro grid system starts late compared with foreign countries, and its technology is relatively backward, with the continuous support of national policies, China's smart distributed micro grid technology will be in a rapid development stage.

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