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The key technologies and analysis of research state of microgrid community

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ABSTRACT

Microgrid (MG) based on renewable energy source (RES) is an important component of the energy development strategy in China. Microgrid community (MGC) is a new product that has resulted from the development of MG and has reached a critical stage. In China, research on MGC currently remains at an early stage. This paper focuses on an analysis of the concept and characteristics of MGC as well as the key technologies involved in it. In addition, this paper discusses the research progress and achievement of the first MGC demonstration project in China—key technologies and a demonstration of the efficient and reliable operation of it. Finally, this paper provides an outlook on the further development and construction of MGC throughout China.

1. Introduction

In recent years, distributed power generation technologies using mainly renewable energy sources (RES) have become an important choice for modern power grids (Wang and Li, 2010). As microgrid (MG) is becoming increasingly popular, more and more MGs will connect to grid. A MG is a small-scale power generation and distribution system consisting of distributed power sources, energy storage devices, energy conversion devices, monitoring and protection devices and local loads (Lasseter and Paigi, 2004). Most of the power sources in MG are distributed power sources with a relatively small capacity (10–100 kW) (Yuen and Oudalov, 2007). An autonomous management mode can be established when a MG operates in island mode (Wang and Li, 2010). When a single MG operates in island mode, the reliability of supplying power to some local users is reduced because of the limitations of the energy storage capacity and the effect of intermittent power sources. Connecting MG s in close geographical proximity can improve their power supply reliability through energy scheduling and reciprocity among these MGs.

The "More Microgrids (MMG)" project supported by the European Union expanded and enhanced the concept of MG, which subsequently developed an early form of the concept of microgrid community (MGC). In the MMG project, low-voltage-level (<400 V) MGs in close geographical proximity and with distributed power sources, energy storage devices and loads were connected to form a MGC. A MGC can not only operate in a grid-connected mode but can also detach from the large grid and operate in island mode (Guerrero et al., 2013). From the perspective of power generation and distribution, MGC increases the permeability of the distributed power sources in the power grid and enhances the operation reliability of the MGs. From the user's perspective, MGC enhances the reliability of supplying power to local users, reduces the losses that occur in the power transmission process, enhances the voltage support within the community, reduces the voltage sag, and improves the power quality while supplying power and heat (Madureira et al., 2011a).

Currently, the studies conducted worldwide on MGC mainly focus on the following areas: the planning and design, the energy management and the technical standards, communication protocols of coordinated control and management (Guerrero et al., 2013). Presently, research on MGC remains at an early stage in China. Zhou et al. (2010) discussed the fault protection or energy management strategies for MMG systems from the perspective of power distribution grids and intelligent power grids consisting of multiple microgrids. Tian Pigen etc. discussed the methods for setting the energy storage capacity of MGC (Peigen et al., 2013). For a relatively long time, the basic concept and characteristics of MGC have not been clearly defined and described. Indeed, the research on MGC has not completely diverged from the scope of research on

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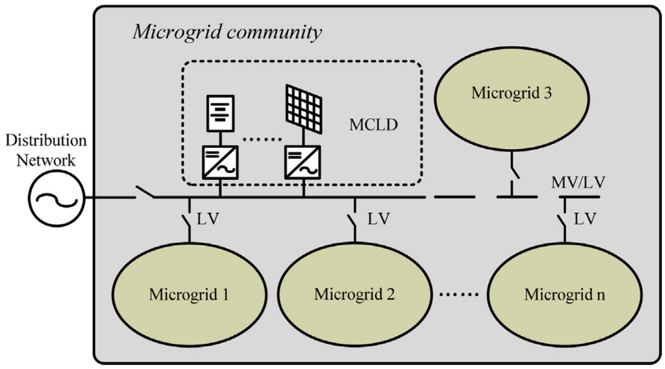

Fig. 1. Schematic of a MGC.

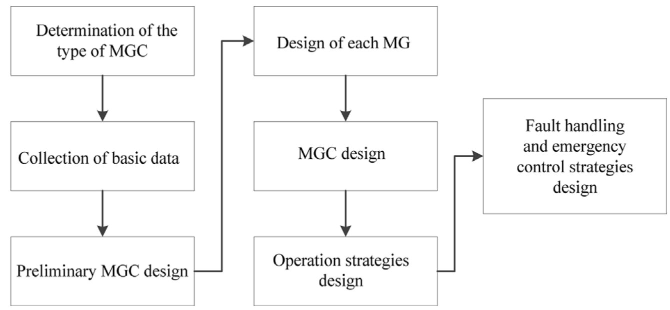

Fig. 2. Flow chart of the 7-step design procedure.

individual MG, and a MGC research framework system has not yet been established.

This paper highlights the research progress of a National 863 Project of China, including key technologies and a demonstration of the efficient and reliable operation, an analysis of the definition, characteristics and key technologies (design, energy management, control, etc.), and a description of the specific design and operation results of the demonstration project. The successful operation of it indicates that China has mastered the key technologies of MGC. Moreover, the demonstration project establishes a solid foundation for the further development and construction of MGC.

2. Basic characteristics of MGC

As shown in Fig. 1, a MGC consists of some MGs and some devices, in which are directly connected to the medium/low-voltage (MV/LV) level on several adjacent feeders (Lopes and Madureira, 2013; Gil and Peas Lopes, 2007). The devices are defined as MGC level device (MCLD). MCLDs include distributed generation (DG) units, load, energy storage system (ESS). These devices have contributed to the management and control of MGC. The MG in MGC is typically at the LV level and is composed of microsource (MS), load and ESS. As a new concept, MGC can be defined by following basic characteristics (Tian et al., 2015; Zhao et al., 2015a):

- The MGC has at least 2 MGs.
- There is a close relationship and interaction among the MGs in MGC.
- The MGs in MGC belong to different owners and have their own operational goals, such as economy, reliability and environment friendliness.
- The operational goals of whole MGC are achieved by coordinating the management and control of the MGs and MCLDs.
- The structure of MGC is variable and this variance may be unknown to the manager of MGC because MG can spontaneously connect or disconnect to MGC for their operational goals.

Compared with MG, MGC integrates more generators and energy storage devices. However, this characteristic does not imply that the MGC is a large-scale MG with greater capacity and more devices, covering a large region. The key difference between MGC and MG involves the topology, control structure and energy management system. In contrast to MG, MGC must consider the design the topology to interconnect its MGs. In addition, the control structure of a MGC includes more levels than that of a MG in order to efficiently control the MGs and MCLDs. Despite the complexity of the control structure, the task and risk of control may be distributed by allowing for improvements in efficiency and effectiveness (Madureira et al., 2011b).

Notably, there are differences between MGC and MG clusters. MG clusters is a gather of some MGs which have the same properties and are in close region. Compared with it, the MGs in MGC can have different properties and are not strictly limited in close region. It is worth noting that a MGC has common control and operation goal by coordinated control and management. And, the other differences are showed in Table 1.

3. Key technologies of MGC

3.1. Planning and design

3.1.1. Basic design process

Reasonable design is vitally important for the construction, operation and management of MGC. Based on the design of MG, it is necessary to consider not only how each MG meets its local load requirements but also how to access and coordinate. Compared with the design of a single MG, as shown in Fig. 2, the basic design process of MGC is more complicated and includes 7 steps.

Step 1: Determination of the type. The types are two options: (1) MGC that operate mainly in the grid-connected mode, MGC that mainly operate off-grid, and MGC that operate in both the grid-connected mode and off-grid; (2) newly constructed MGC and modified MGC. The selection of a specific MGC type has an impact on the focus of the subsequent steps of the planning process. Currently, MGC that primarily operate in the grid-connected mode, and modified MGC remain the most common types.

Step 2: Collection of basic data. The main data include wind, light resources and load characteristics. The data can be further classified into two types: data required for MGC and for the MG.

Step 3: Preliminary MGC design. Based on the data obtained in Step 2, the access points of the MGC, the power distribution grid, and the MGC-level load requirements and distribution are preliminarily determined. In addition, the number, capacity and types of MG, as well as the functions of MGs in the MGC, are determined. Furthermore, the initial grid structure of the MGC and the control mode of the MGC are determined.

Step 4: Design of each MG. The distributed power generation system, grid structure, energy storage system (ESS) and other auxiliary devices within each MG are designed. On this basis, as well as on the basis of the preliminary MGC design scheme formulated previously, the normal operation and emergency control strategies for each MG are designed and verified.

Step 5: MGC design. Based on the results of the previous steps, the MGC design is further refined through validating and adjusting (as needed) the preliminary MGC planning scheme, configuring MCLDs and safety devices, designing

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