Chinese Energy Internet Construction Promotes Development of Distributed Renewable Energy Mini Grid

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Abstract. Distributed renewable energy Mini grid is a novel power grid architecture which consists of micro power, load, energy storage devices and control devices. In this paper, status quo and existing problems of distributed renewable energy Mini grid in China are analyzed, and then research contents and key technologies are introduced, a typical distributed renewable energy Mini grid demonstration project is introduced finally. Distributed renewable energy Mini grid will fundamentally change response of Chinese traditional power grid to load growth, reduce energy consumption and improve power system reliability and flexibility.

1. Introduction
Electrical power is the backbone of modern industrial society, and is expected to remain so for the foreseeable future [1-3]. Renewable energy is energy which comes from natural resources such as sunlight, wind, rain, tides, and geothermal heat, which are renewable (naturally replenished). In 2018, China's power generation continues to expand, up 7.8 percent year on year in the first seven months of this year. China is vigorously developing new energy such as: Photovoltaic power, wind power etc. As for new energy power, wind, nuclear, and solar power generation increased 24.7 percent, 14.2 percent, 10.9 percent year on year, respectively [4-6].

Figure 1. The 2017 winter storm in Enshi seriously damaged the transmission facilities.

In January 2018, winter storm events that affected high altitude areas of central China. The power system of China was severely affected by the adverse conditions. Widespread power outages were
reported as Fig.1. These widespread power outages deepen State Grid Corporation of China to consider their power supply schemes; they make efforts not only to build Chinese Ultra High Voltage power grid, but also to plan the construction of a Mini grid. There are two operation styles for renewable energy Mini grid: isolated power operation and interconnected power operation. Renewable energy Mini grid can ensure the power supply in some extreme conditions.

At present, United States and some European countries presented their Mini grid concepts and development goals. For example, many European countries have formed theories on Mini grid operation, protection, control, and carried out the relevant verifications [7-10]. In 2018, the International Energy Agency estimated that “to achieve universal access to electricity, 90% of the rural areas that currently lack access will need to be connected using mini-grid or off-grid solar power solutions.”

In this paper, status quo and existing problems of distributed renewable energy Mini grid in China are analyzed, and then research contents and key technologies are introduced, a typical distributed solar energy Mini grid demonstration project is introduced finally.

2. Status quo and existing problems
Distributed renewable energy Mini grid in China is the Mini grid which is combined with Chinese practices; it is a novel power grid architecture which consists of power station, load, energy storage devices and control devices. China is working steadily toward distributed renewable energy Mini grid. The power stations usually include Mini Photovoltaic power station (such as Hubei Shennongjia forest region photovoltaic power station,2018, Fig.2), Mini wind power station (such as wind power station in Dafengba Hebei China, 2018, Fig.3), power storage devices usually are batteries. Distributed renewable energy Mini grid in China can make the Chinese traditional grid more intelligent.

Figure 2. Hubei Shennongjia forest region photovoltaic power station.

Figure 3. Wind power station in Dafengba Hebei China.
There are many benefits of these distributed renewable energy Mini grids: Foster demand side management and response; Reduce power outages, increasing reliability, efficiency, and safety; Reduce carbon footprint and minimize fossil fuel consumption; Provide customers autonomy to manage their electricity needs. However, there are still some problems should be solved: 1) Construction procedures are complicated; 2) Difficult to operate and maintain in time; 3) Difficult to get subsidy and settlement in time; 4) Wind and photovoltaic power are often restricted to transport; 5) Lack of relative Mini grid technology standards; 6) Low level of power electronic technology application and protection and control technology application; 7) Expensive operation and maintenance [11-12].

3. Key technology research

Key technology research on distributed renewable energy Mini grid characteristics includes the following aspects: Distributed solar energy data cloud platform building, energy management system, device R&D and system modeling, control technology, measurement technology research, protection technology research, isolated power operation research, interconnected power operation research.

3.1. Distributed solar energy data cloud platform building

At present, china is promoting the integration of various energy storage and new energy Mini grid, especially distributed photovoltaic. With the help of the Internet technology, credit data, financial service, operation and maintenance resource and innovative advantage of State Grid Corporation, distributed solar energy data cloud platform are developed to provide professional online and offline collaborative services for distributed photovoltaic energy power stations.

3.2. Measure technology research

The measure objects of distributed renewable energy Mini grid are often change in multidimensional and dynamical, such as temperature of solar energy system, cutout switch, switching value of ring main unit (RMU) etc. The measurement uncertainties of these parameters are also often multidimensional and time-varying.

Based on Advance Metering Infrastructure (AMI), we should study new theories and new methods to carry out multidimensional dynamic measurement of Renewable energy Mini grid, evaluate the measurement uncertainties, correct the measurement errors, and to solve the state estimation of Renewable energy Mini grid and so on. For example: Detection based on infrared thermal imaging technology for solar energy system electrical joints. The detection steps can be described as follows: 1) acquiring original infrared thermal image; 2) preprocessing of original infrared thermal image; 3) image denoising; 4) image enhancement; 5) image edge line extraction; 6) infrared thermal image data analysis. All these steps are carried out according to infrared thermal image characteristics.

3.3. Research on isolated power operation, interconnected power operation and protection technology

The contents include following aspects: Analyze Renewable energy Mini grid’s stability in isolated power operation and interconnected power operation respectively; Analyze harmonic problems of the Mini grid; Analyze protection scheme in terms of Mini grid load demands. If there are faults occurred in distribution grid, it is necessary that some important sensitive loads should be isolated by separation device (SD) as quickly as possible. However, once the distribution grid back to normal, the Mini grid should be interconnected by measuring and comparing voltage amplitude and angle on both sides of SD in automatic or manual ways.

3.4. Control Technology and Energy Management System

Improving smart Reactive Power compensation equipments; controlling Active power and Reactive power independently; Correcting voltage dips and system imbalances; adapting to the dynamic load of the Mini grid load demands.
According to the local heat demands, climate conditions, electricity and fuel costs, China is working for the optimal use of the Mini grid’s electricity and heat by Energy Management System (EMS) research.

3.5. Device R&D and system Modeling
Develop devices of power generation, power transmission, power transformation, power distribution, power using, such as novel smart meter, novel Phasor Measurement Unit (PMU), novel intelligent dispatch controller, novel Smart Hybrid Controller, novel automatic connect/disconnected components etc. To study the effects of distributed generation on the Renewable energy Mini grid's safety operation, Mathemetic model should be built to describe the influence of distributed generation on reliability, at the same time, relative economic and reliability factors should be considered.

4. Demonstration project
A large number of renewable energy Mini grid demonstration projects have been built at home and abroad, which has become an important way to solve the technical problems of power supply in remote areas and islands. For example: Hangzhou Henglong park wind-solar-storage Mini grid, using the Internet of Things, advanced communication technology, big data technology, artificial intelligence, block chain and other new technologies, optical storage charging and cloud platform(Fig.4), the platform realizes distributed solar energy, energy storage, energy charging and energy exchange interconnection, provide overall solution, station building, monitoring and control, system operation services for different users.

![Figure 4. State Grid Corporation distributed photovoltaic cloud platform.](image)

State Grid Corporation distributed photovoltaic cloud platform is the largest "technology + service + finance" distributed photovoltaic integrated service cloud platform in China, which is independently researched and developed by State Grid E-Commerce Co., Ltd. with the carrier of State Grid Mall (PC terminal), DianEbao (mobile terminal). Accumulative number of users and installed capacity of photovoltaic cloud platform in 2018 are depicted in Fig.5, Accumulated trading volume and Equipment manufacturers of photovoltaic cloud platform in 2018 are depicted in Fig.6.
Figure 5. Accumulative number of users and installed capacity in 2018.

Figure 6. Accumulated trading volume and Equipment manufacturers in 2018.

Henglong park wind-solar-storage Mini grid and State Grid Corporation distributed photovoltaic cloud platform are very typical, it fits the load demand of Mini grid, ensures safe operation of big grid, share power and optimize power quality. Such distributed renewable energy Mini grid has great potential, not only in commercial and industrial complexes, but also in hospitals, shopping malls, apartments, residential complexes, and educational institutions, remote un-electrified as well as electrified locations to ensure maximum flexibility, reliability, and safety with enhanced efficiency of the overall grid.
5. Conclusion
The research and deployment of emerging distributed renewable energy mini grid in China has demonstrated the benefits. Distributed renewable energy Mini grid in China may be more attractive in Chinese rural areas. It can often be deployed more rapidly than grid solutions, and does not rely on extending grid connected generation ability; moreover, there are often significant local job creation opportunities. Importantly, distributed renewable energy Mini grid in China is also customizable to local contexts and needs.

In the future, distributed renewable energy micro-grid will be developed in the direction of photovoltaic cell integration, electric vehicle access, cloud computing and edge computing fusion.

Distributed renewable energy Mini grid in China will fundamentally change response of Chinese traditional rural power grid to load growth, reduce Chinese rural energy consumption and improve Chinese rural power system reliability and flexibility.

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