Proceedings of the 2nd International Conference on Machine Learning and Automation
DOI: 10.54254/2755-2721/93/20240930

Research on the status and prospect of microgrid technology

Tianxiong Shi

Ulink College of Shanghai, Shanghai, 201615, China

shi2362837@gmail.com

Abstract. With the increasing demand for electrical energy and the appeal of environmental protection, the world has started to pay attention to the application of microgrids. A microgrid is a grid with many advantages, such as independence, effectiveness in working, and environmental friendliness, and can solve both energy and environmental problems. The paper reviews the microgrid system: how it functions, how it has advantages in energy and environmental aspects, and the prospects of microgrid in the future using a literature review. Microgrid has a flexible operation since it can find the optimum solution for generation, transmission, and distribution by shifting smoothly between island mode (which generates electricity by itself and directly transmits it to the supply side) and grid-connected mode (which connects to macrogrid and is dependent on its power supply). It also has energy reliability for its control system and energy storage system to coordinate the output power, which enhances the utility of energy resources. Microgrid has great potential for solving energy problems in remote or poverty-stricken areas and has unlimited prospects in industry, residential communities, and utilities and energy providers.

Keywords: microgrid, operation mode, energy storage system control system, carbon emission.

1. Introduction

A microgrid is composed of the generator, energy storage, load, and control unit, which greatly utilizes renewable energy as a generator to solve energy problems and also decreases the distribution cost. Pollution of the environment in generations has become a problem. Since microgrids can make full use of wind power generation and photovoltaic power generation, promote large-scale distributed power access to the low-voltage distribution grid, and reduce pollution emissions caused by fossil energy power generation such as oil and coal, the microgrid is in line with the trend of new energy development of The Times. It has become an important part of today's power technology field [1]. With the system's short construction period and high reliability, the microgrid can quickly improve the development of rural areas and provide a power guarantee for local economic development. At the same time, with the development of the power grid in the future, it can also be connected to the unified dispatching of the power grid to improve the system's availability, so it has been widely used in recent years [2]. Microgrid can work independently without the connection of the microgrid by generating power itself. What's more, it can operate independently Plus, it can alter its distribution of electricity when at peak or trough, which decreases the energy losses and stabilizes its energy output. This paper will additionally focus on how to improve microgrids by cutting down its carbon emissions.

A literature review is used to research MG technology: operation mode, the generation part, and systems, in addition to the enhancement in daily engineering. This paper introduces the current situation

DOI: 10.54254/2755-2721/93/20240930

of MG and its prospects for future utilization. It can help the reader understand the reason for promoting MG and give instructive advice for future improvement.

2. Microgrid technology

MG is a small power distribution system consisting of a distributive power supply (solar panel, wind generator) or micropower supply, energy storage, energy converter, load, control system, and safety device [3]. It has flexible operation and schedulable properties which can make MG switch between grid-connected operation and isolated island operation. In addition, with the cooperation between the control systems, MG can simultaneously provide users with electricity and heat.

2.1. Island Mode operation Formatting the title

Island mode operation happens when the power supply system of the major power grid is unstable or malfunctions, causing MG to disconnect from the major power grid, and the output power is only transmitted to an operator of the plant power supply. That means there is no power transmission between the MG and the major power grid, all power demand from loads is provided by distributed power supply and energy storage in MG. Self-sufficient energy is very crucial for island mode operation, which implies the importance of generation. Wind generation and solar photovoltaic generation are part of it.

2.1.1. Model of Wind Generation Probability. Wind energy is a renewable energy, A wind generator converts its kinetic energy into mechanical energy in the turbine, then transforms it to electricity and is connected to MG. However, the wind power output is determined by factors such as meteorological factors,wind speed due to the seasons, or the period in a day. The probability density function of wind speed can be expressed as:

$$f_w(v) = (k/\gamma)(v/\gamma)\text{^}(k-1)\ \exp\left[-(v\ /\ (\gamma)\text{^}k\right] \tag{1}$$

Among the functions:
v: actual wind speed/ m/s
k: form factor
γ: scale coefficient
While the relation between wind power output PWT(v) and actual wind speed v can be expressed as:

$$P^{WT}(v) = \begin{cases} 0 & v < v_{in}, v > v_{out} \\ \frac{v-v_{in}}{v_*-v_{in}} P_* & v_{in} \le v < v_* \\ P_* & v_* \le v < v_{out} \end{cases} \tag{2}$$

Among the functions:
P*: rated output power of wind generator/ kW
Vin: cut-in wind speed, the minimum wind speed required to start generation/ m/s
vout: cut-out wind speed, the maximum wind speed for protecting devices/ m/s
v*: rated wind speed/ m/s

The function shows that when the actual wind speed is lower than the cut-in or greater than the cut-out wind speed, the output power is 0. When the actual wind speed is between the cut-in and rated wind speed, the output power is rated output power multiplied by the ratio of v-vin and v* - vin. As v is between the rated and cut-out wind speed, output power equals to rated output power.

After modeling the wind power generation, the derived probability density function of wind generator output power can be expressed as:

$$f_w(P^W) = \begin{cases} (khv_{in}/\gamma P^*)\left[\left(\left(1 + hP^{WT}/P^*\right)v_{in}\right)/\gamma\right]^{k-1} \times \\ \qquad \exp\left\{-\left[\left(\left(1 + hP^{WT}/P^*\right)v_{in}\right)/\gamma\right]^k\right\}, \quad P^{WT} \in [0,\ P^*] \\ 0, \text{otherwise} \end{cases} \tag{3}$$

Among the functions:
PWT: the output power of wind generator/ kW
h: (v* / vin)-1

2.1.2. solar photovoltaic generation. Photovoltaic generation is a process of converting light energy (mainly from the sun) directly into electricity using solar panels. A PV system consists of solar panels, a controller, an inverter, a storage battery, and a load. As the figure.4 illustrates that a photovoltaic generator can directly provide direct current for loads and needs an inverter to change into alternating current or excess electricity can be contained in batteries.

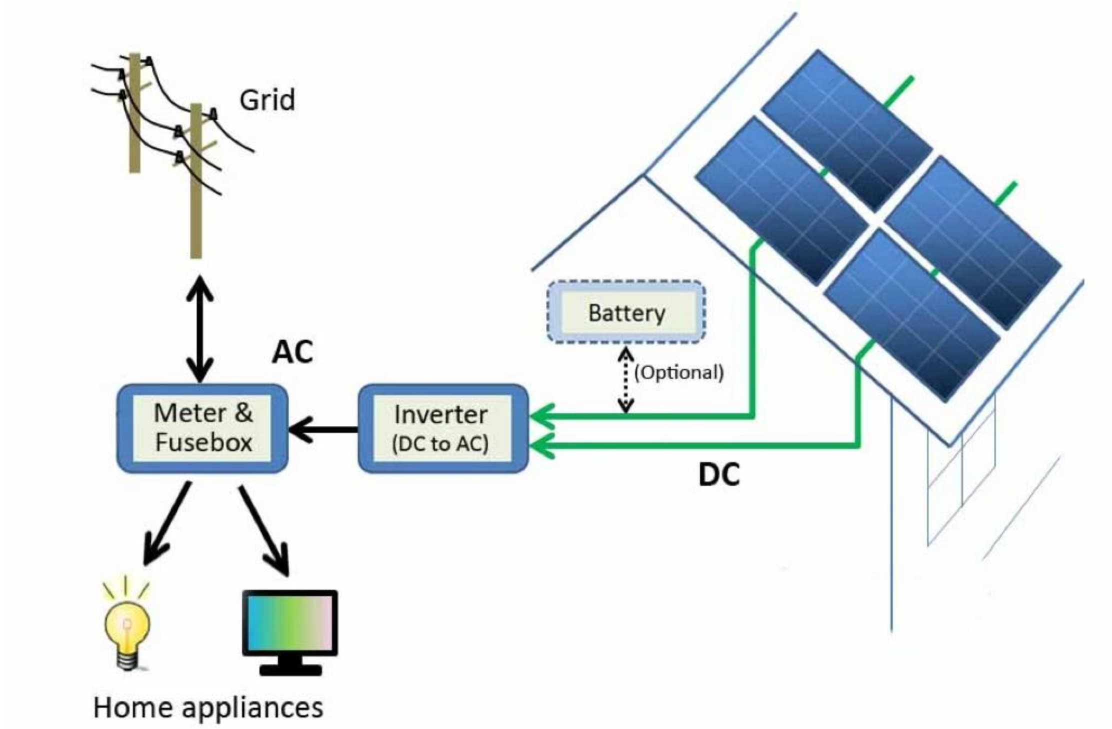

Figure 1. Typical grid-connected PV solar system [4].

The output power of PV generation is affected by meteorology, the material of solar panel, radiation intensity, climate change and the location of generator applied. The output power of PV generation can be expressed as:

$$P_{pv} = Y_{pv} f_{pv} \left(\frac{G_T}{G_{T,STC}}\right) \left[1 + \alpha_p \left(T_c - T_{c,STC}\right)\right] \quad (4)$$

Among the formulas:
Ypv : Rated capacity of the photovoltaic array under standard test conditions
fpv : PV derating factor, mainly related to the surface condition of photovoltaic array
GT: Current solar radiation intensity received by photovoltaic arrays/ KW/m2
GT, STC.: Incident light intensity under standard test conditions, constant (1KW/m2.)
Tc: The surface temperature of the current photovoltaic array (°C)
Tc, STC.: Photovoltaic array surface temperature under standard test conditions(°C)
αp: Temperature correction coefficient, related to the photovoltaic array material
The calculation consists of two parts: 1. The solar radiation intensity of the current photovoltaic array and 2. The surface temperature of the current photovoltaic array

DOI: 10.54254/2755-2721/93/20240930

2.2. *Grid-connected operation*

Grid-connected operation connects the generator with the grid or connects the grid with electric equipment for users. In grid-connected operation, the microgrid's generation and consumption are typically unrestricted, except when the microgrid sends specific generation or consumption orders to the microgrid via power exchange control. [5]. Although MG is not directly connected to generators, it still needs to balance between generation and consumption. We tend to control generation in a stable output, however, there is a fluctuation of electricity consumption during the day (crest and trough), making generator to provide optimum electricity. The grid-connected operation has a distribution network, automatic voltage, and reactive power control, as well as forecasts of intermittent DG output, loads, and power exchange to make economic and optimal dispatch, central dispatch possible [5]. MG can be distributed to excess electricity using energy storage.

2.2.1. Energy Storage System. Energy storage technology (ESS) can improve the efficiency of energy utility by storing energy in it. It can store energy when consumption is low and give out electricity when in high demand for energy consumption. ESS can therefore reach the goal for peak shaving of electricity and a relatively constant generation. Mechanical energy storage, electrical energy storage, electrochemical energy storage, thermal energy storage, and chemical energy storage are the five main categories of existing energy storage systems. ESS has adaptable bidirectional power guideline abilities and has given a viable means to address the difficulties of high-extent sustainable power integration [6]. Nevertheless, ESS still has several issues. It has a high cost of production that few consumers can afford. And since ESS and other storages like Distributed Energy Storage (DES) are limited to utilization due to high cost and intermittent consumption, Cloud Energy Storage (CES) with promising prospects is proposed. CES is a technology for sharing energy storage that lets users use shared energy storage resources made up of centralized or distributed energy storage facilities whenever and wherever they want [6]. CES can greatly enhance the utility rate of energy, lower the cost of energy consumption, and satisfy the demand for energy through sharing energy with individual consumers.

2.2.2. Control technology. Due to the aim for the balance between generation and consumption, MG needs a control system to dispatch the multiple distributive power supply and the ESS to reach a main stable power output. The distributed power supply can be divided into synchronous power supply and inverter power supply because of the difference in the grid-connection mode. At present, the application of parallel grid control technology in small synchronous generators is more mature, but most inverter power supplies often use grid-connected control, constant power control, or constant voltage constant frequency control [7].

Another aim for MG is to maintain the voltage frequency under small disturbances caused by power generation and load changes and smoothly switch the running state under the large disturbance of off-grid switching. With the help of the characteristic of a power grid or ESS by providing unlimited power in a certain period, the control system can achieve the power balance between generation and use, and absorb the imbalance during off-grid switching or power fluctuations. Currently, the common methods of microgrid system coordination control include peer-to-peer control, hierarchical control, and master-slave control. Among them, the master-slave control predicts the load and power of the distributed power supply according to the central controller, makes the operation plan, and then adjusts the plan according to the detection system to maintain the power balance of the system. The principle is simple easy to implement and widely used [7].

3. Prospects

Carbon dioxide emissions have become a global issue that has destroyed the environment in recent years, and the electricity supply sector accounts for a great proportion of them. MG should aim to reduce carbon emissions as well. Currently, it is crucial to measure carbon emissions and thus find a solution to lower them. An important direction for the development of direct carbon emissions measurement is the direct measurement approach, which is based on direct observations and allows for continuous and accurate monitoring of carbon emissions [8]. There could be advanced carbon emissions monitoring technology for more accurate measurements, like flow rate detectors, reducing the cost of production.

However, indirect fossil fuel byproduct accounting is likely to be impacted by different variables like trading behavior and actual alternation. In this manner, there is a requirement for examination into power framework indirect fossil fuel byproducts accounting approaches that consider power exchange conduct, successfully and actually recognizing the fossil fuel byproducts obligation contrasts of exchanged power, non-exchanged power, and helper administrations in the grid [9].

Investigating application situations in light of an exact estimation system for the power system can improve the efficiency of optimization and guidance role of measurement mechanisms advancing carbon decrease in the power business while driving the low-carbon change of other related aspects [9].MG is promising for its potential in the aggregation of distributive energy supply. With the development of grid technology and the huge demand for energy supply and environmental protection, future MG will be advanced in terms of greater utility of renewable energy, better control of carbon emissions, and a cheaper cost of production.

4. Conclusion

MG technology has already drawn great attention all over the world for its flexibility in converting operation modes and its energy reliability for control and energy storage systems to dispatch distributive energy supplies. MG also has the great potential to utilize renewable energy sources like wind and photovoltaic energy using energy storage systems to maintain a stable output and increase the utility rate for energy supply. MG plays an important role for individual consumers, especially in rural areas. MG is also applied in fields like factories, military bases, and house development. It is worthwhile to do deeper research, thus improving the development of those areas. However, MG still needs several improvements.

Here is some advice: Research on clean energy generation to make it more effective and efficient in production. Energy transmission should improve to have less energy lost. Energy storage systems should be greatly developed, especially cloud energy storage. The development of controls for carbon emissions is required to make the environment less polluted. The cost of production needs to be lowered for wider field use.

This paper mainly reviews the basic knowledge of MG technology. The review starts with the classification of the operation mode and then is split into specific parts: renewable energy generation, energy storage systems, and control systems. It then introduces the prospects of carbon emissions for MG. In the research, the function of MG is not well-rounded, and it focuses on the theory part too much, which may have less effect on practical aspects. The paper still needs enhancement on the practical parts, like its application.

References

[1] Chen Xiaohua, Wang Zhiping, Wu Jiekang, et al. Micro grid technology research review [J]. Journal of heilongjiang electric power, 2023, (6) : 471-480 + 506. DOI: 10.13625 / j.carol carroll nki hljep. 2023.06.001.

[2] Liu Guangcan, Xiong Haitao. Case analysis of microgrid technology application [J]. Electronic Technology,2022,51(09):180-181. (in Chinese)

[3] Microgrid(2024).https://baike.baidu.com/item/%E5%BE%AE%E7%94%B5%E7%BD%91/568036?fr=ge_ala.

[4] Kiran Daware, Solar Power System - How Does It Work? https://www.electricaleasy.com/2015/12/solar-power-system-how-does-it-work.html

[5] Li Fusheng, Li Ruisheng, Zhou Fengquan, Microgrid Technology and Engineering Application, Academic Press, 2016, 91-113

[6] Shixu Zhang, Yaowang Li, Ershun Du, Chuan Fan, Zhenlong Wu, Yong Yao, Lurao Liu, Ning Zhang, A review and outlook on cloud energy storage: An aggregated and shared utilizing

method of energy storage system, Renewable and Sustainable Energy Reviews, Volume 185, 2023, 113606,
[7] Zhao Jiaqi, Li Rui. Research progress of microgrid technology [J]. Shanxi Electric Power,2022,(05):10-13.
[8] Yaowang Li, Xuxin Yang, Ershun Du, Yuliang Liu, Shixu Zhang, Chen Yang, Ning Zhang, Chang Liu, A review on carbon emission accounting approaches for the electricity power industry Applied Energy 359,2024,122681
[9] Y. Li et al., A review on carbon emission accounting approaches for the electricity power industry, Applied Energy,359,2024,122681