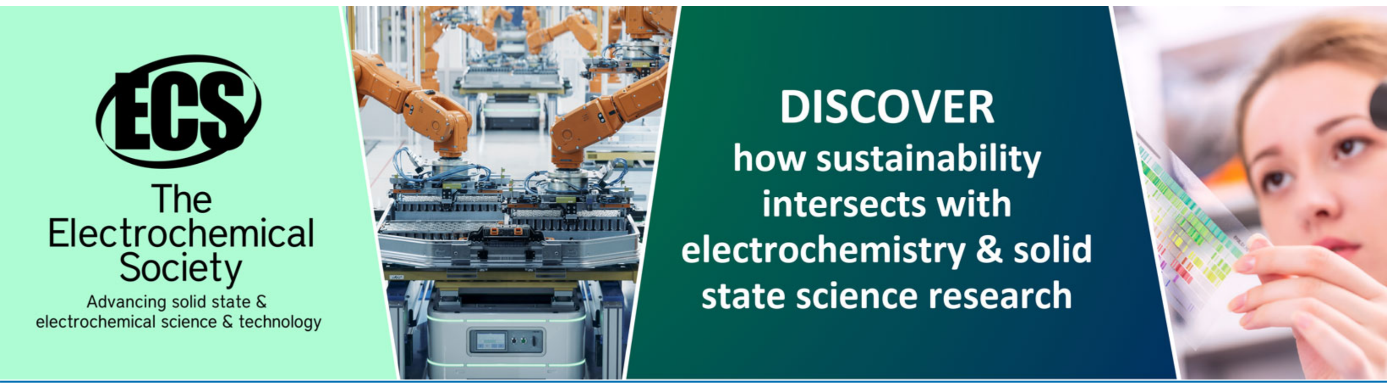
IOP Conference Series: Earth and Environmental Science

Research on hierarchical energy management control strategy based on DC microgrid



IOP Conf. Series: Earth and Environmental Science **170** (2018) 042150 doi:10.1088/1755-1315/170/4/042150

Research on hierarchical energy management control strategy based on DC microgrid

Deren Zhao[1], Peng Ji[1], Fei Xia[1], Zongze Xia[1], Xiaobo Huang[1], Peixian Cong[1], Zhixiong Yang[2, a], Zhuo Di[1], Li Song[1]

[1]State Grid Liaoyang Electric Power Supply Company, Liaoyang 111000, China
[2]Kunming Institute of Physics, Kunming 650223, China

[a]xiongmaoer39@126.com

Abstract. The demand for power supply system is getting higher and higher in the development of modern society. Due to the rise of renewable energy, a large number of distributed generation units will be incorporated into the power grid, which has a negative impact on the safe operation of the power grid. Micro grid technology eliminates this effect, and DC micro grid is more suitable for distributed power access. Based on the research of DC micro grid droop control and voltage recovery control strategy, we use energy stratification method to control the operation of microgrid. It also points out the importance of the battery group in the operation process of the DC microgrid network. Finally, the effectiveness of the control strategy is verified by simulation.

1. Introduction

Modern human society is facing two major problems of energy shortage and environmental pollution, to coordinate the two problems and realize the sustainable development of human society, more and more renewable energy use, these renewable energy tend to be small, usually in the form of grid connected distributed generation. The large-scale use of distributed generation can effectively alleviate the energy shortage and environmental protection. However, due to the fact that distributed generation is mostly small, it is easy to be influenced by the surrounding environment in practice, such as solar power generation and small-scale wind power generation.[1] A large number of use of distributed generation will have a great impact on the security of the power grid. In this context, the concept of smart grid has been put forward by all countries in the world, [2] and the smart grid in China has also entered the stage of the demonstration project.

As one of the key technologies in the smart grid, microgrid technology can effectively improve the stability and reliability of the power grid. And it can adapt to the access of all kinds of renewable energy, so that the power grid can make full use of renewable energy. Because most of the renewable energy is DC power generation, [3] such as photovoltaic power generation, fuel cell and small power wind power generation, if we use the traditional AC power grid, we need to add a set of inverter devices, which increases the system cost and reduces the efficiency of the system. And when the DC transmission is used, the inductance and reactance of the wire are not required to be calculated when the power grid is running in the steady state. The electrical wire has only the resistance parameters. In addition to the AC motor from the load side, most of the load is used in DC power supply. [4]

Therefore, the DC micro grid has a greater advantage than the AC microgrid, and is more conducive to the access of distributed generation.

2. The composition and operation mode of DC microgrid

The DC microgrid is usually composed of four parts: distributed power supply, energy storage unit, static switch (bidirectional AC / DC converter) and load. Distributed generation generally adopts new energy generation mode (such as photovoltaic power generation, wind power generation, etc.), which is generally susceptible to external environment, and the output power cannot be stable. In the process of operation, appropriate operation strategies need to be adopted. This kind of operation strategy generally consists of two kinds, one is to maximize the use of clean energy, such power generally operates in the maximum power point tracking state (MPPT), and the other is constant voltage operation mode. [5] The energy storage component is a very important part of DC micro grid, it can load switching or is due to external factors lead to the output power of distributed power supply system changes lead to fluctuations in the DC micro grid, by changing their charging and discharging operation to maintain the balance of power system, the stable operation of DC micro grid. The static switch (bidirectional AC / DC converter) is the interface between the DC microgrid and the large power grid, [6] making the energy between the DC microgrid and the large power grid achieve two-way flow.

DC / DC converters or DC / AC converters are connected to DC microgrid for various loads in DC microgrid. And the load priority classification should be carried out according to the different load. The structure of the DC microgrid is shown in Figure 1.

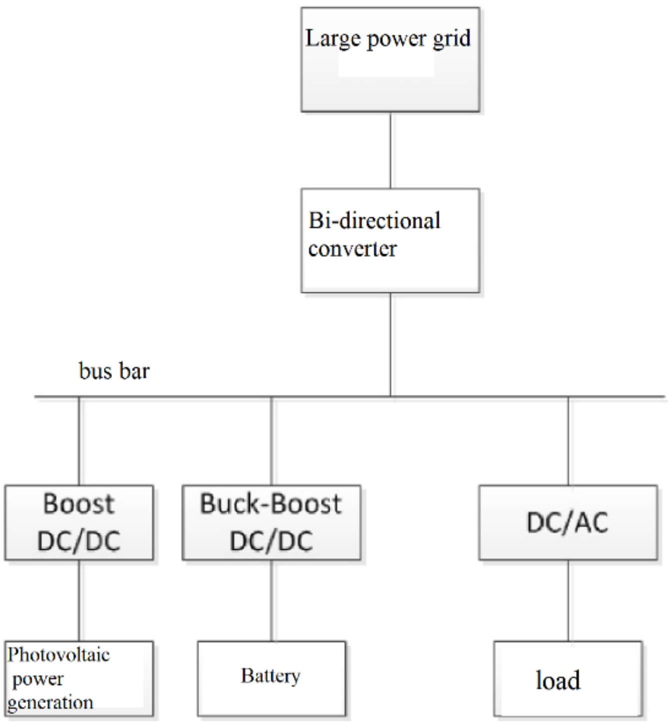


Figure 1. DC microgrid structure

Under the condition of network operation, the DC micro electric network is connected with the large power grid through the static switch, obtaining energy from the large power grid or sending excess energy to the large power grid. When a large power grid fails, the static switch is disconnected, and the DC microgrid is separated from the large power grid into the island operation mode. The microgrid needs to control the load and power generation unit in the grid, so as to achieve the power balance between the power and load in the microgrid. The main control goal is to maintain the bus voltage of the DC microgrid in a certain range. In the running state of isolated island mode, there are two kinds of control methods commonly used. One is the master slave control method. The master slave control method divides all the modules in the microgrid into two main modules: the main module and the slave module, and realizes the coordinated operation of each module through the communication between modules [14]. This control method is less reliable because of the need for complex and large range communication networks. The other way is to control the droop characteristics similar to synchronous generators. This way can distribute the distributed power in the grid automatically to the load within the grid in proportion, and do not need extra communication lines.

3. Voltage recovery control of DC microgrid

Droop control has many advantages, but in fact, the bus voltage of the microgrid has deviated. Therefore, it is necessary to automatically restore the voltage of the DC microgrid on the basis of droop control. Considering a DC microgrid, such as the above, it contains 1 photovoltaic units and a battery unit and a set of pure resistance loads. The power in the system should be balanced when the system runs, so there are:

$$P_{pv} + P_B = P_L \tag{1}$$

In the whole system, the storage battery unit is droop control, there are:

$$V_{dc} = V_{dc}^* - kI_B \tag{2}$$

The V_{dc} is the current bus voltage, the $V*_{dc}$ is the voltage setting value of the DC bus DC bus, the K is the droop coefficient, and the I_B is the current of the battery group. The output power of the battery is as follows:

$$P_B = \frac{V_{dc} \times (d_{dc}^* - V_{dc})}{k} \tag{3}$$

The (3) type is brought into (1) type, and the equation can be obtained after finishing.

$$\left(\frac{1}{R} + \frac{1}{k}\right) V_{dc}^2 - \frac{V_{dc}^*}{k} V_{dc} - P_{pv} = 0 \tag{4}$$

The bus voltage Vdc is equal to the voltage setting value of the DC bus line of the microgrid Vdc. At the time, you can get the following:

$$P_{pv} = \frac{V_{dc}^2}{R} \tag{5}$$

It can be seen from the above formula that if the output power of photovoltaic power generation P_{pv} is a fixed value, the size of load resistance R must match with it, so that the bus voltage of DC microgrid will be constant. However, in the actual situation, the output power of photovoltaic power generation and the size of the load cannot be a quantitative. There is a deviation between the actual bus voltage and the set value of the bus voltage. Let $V_{dc} = V_{dc}^{*} + \Delta V$ be brought into the (4) form:

$$\Delta V = \frac{kV_{dc}^{*}}{R} - \frac{kP_{pv}}{V_{dc}^{*}} \tag{6}$$

In the DC microgrid, there are battery units, so the battery unit can match the power of photovoltaic generation, so that the bus voltage is stable when the external conditions are changed or the load is switched. But the power of the match must be less than the output limit of the battery. The voltage control controller with voltage recovery is shown in Figure 2.

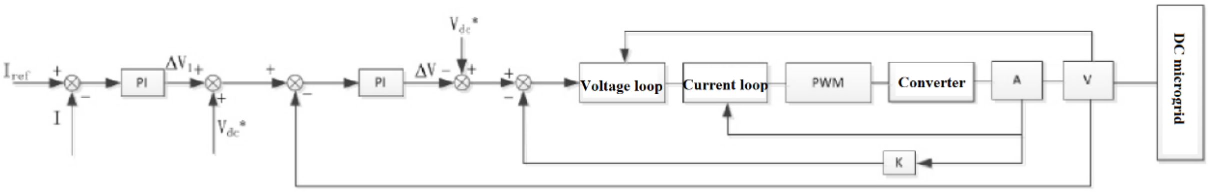


Figure 2. Microgrid control structure map with network control strategy

The 1 * in the figure is the set value of the output current of the DC microgrid, and the 1 is the actual value of the output current of the DC microgrid. At this time there are:

$$\Delta V = k_p(\Delta V_1 + V_{dc}^{*} - V_{dc}) + k_i\int(\Delta V_1 + V_{dc}^{*} - V_{dc})\,dt \tag{7}$$

From the type can be seen, a new voltage increment the reference voltage of DC micro grid network to bus recovery, new bus voltage voltage increment will affect the size of DC micro grid, so the ΔV1 needs to be limited, the DC voltage of the micro grid in a certain range.

4. Simulation and result analysis

A photovoltaic power generation model is set up under Matlab / Simulink, as shown in Figure 3 to figure 4, and the DC microgrid is built.

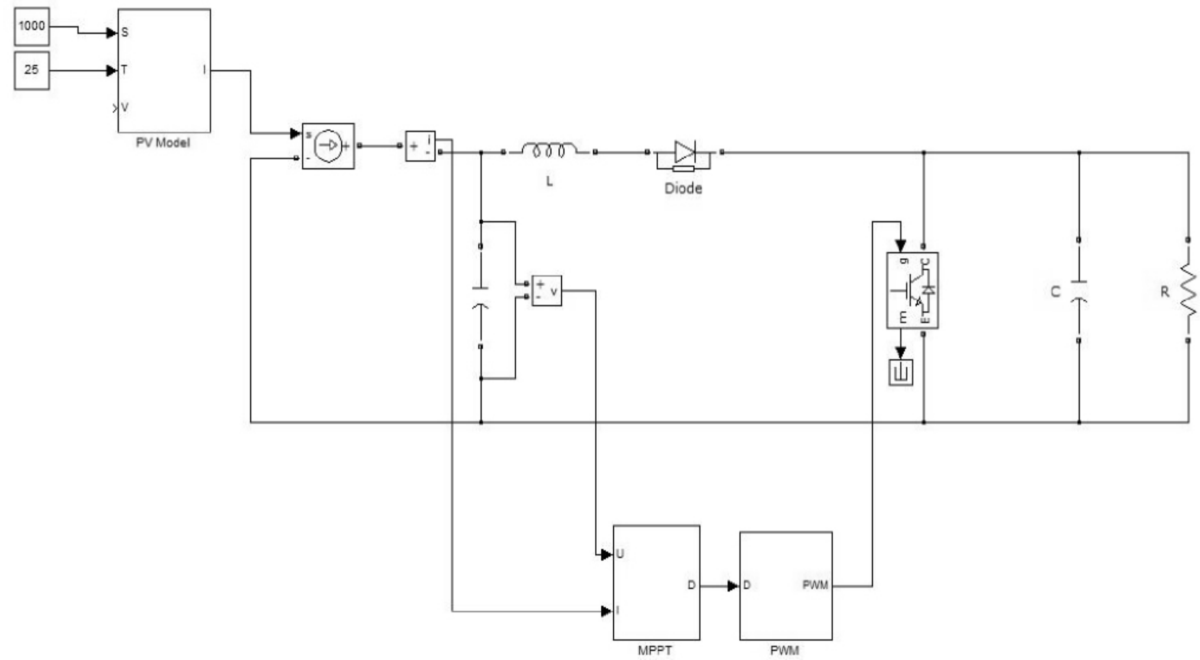


Figure 3. Model of photovoltaic power system

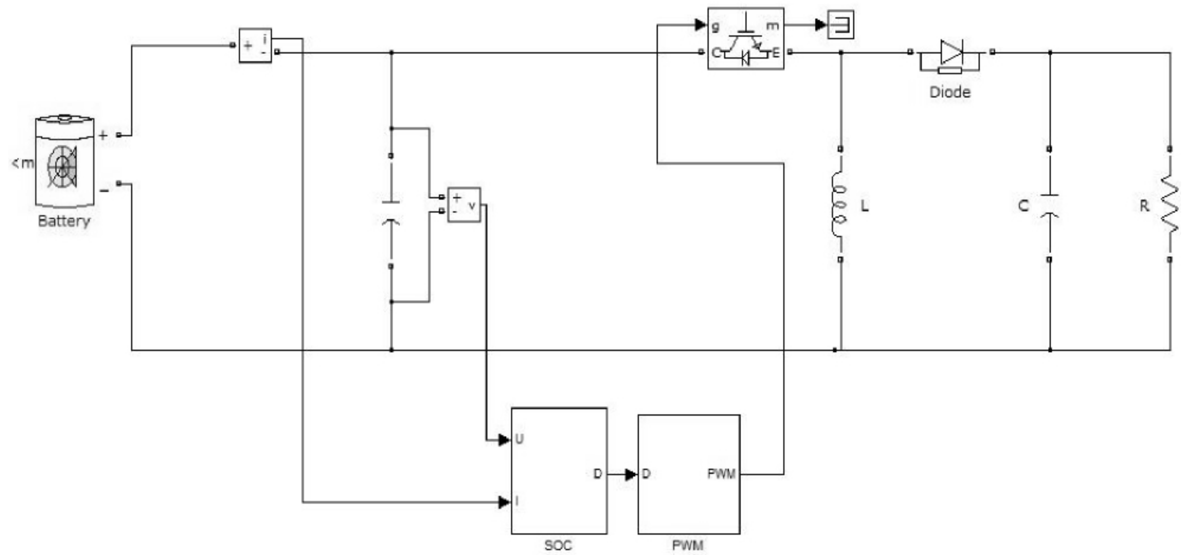


Figure 4. Model of battery system

The parameters and working modes of each component in the DC microgrid are set as shown in Table 1.

Table 1. Threshold of different operating states of each component in DC microgrid

Element	Parameter	Condition	Running state
Battery	Rated voltage 300V capacity 60Ah, maximum power 15KW	V>1. 02pu	Charging
		V<0. 98pu	discharge
Photovoltaic power generation	Maximum power 20KW	V>1. 08pu	Change from MPPT (maximum power point tracking) mode to constant pressure operation mode
Load	Rated voltage 400V	V<0. 93pu	Excision load

The results of the simulation run are shown in Figure 5 to figure 10.

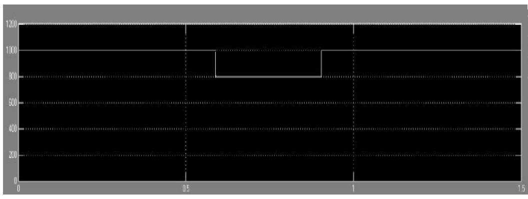


Figure 5. Light intensity (unit: w/m2)

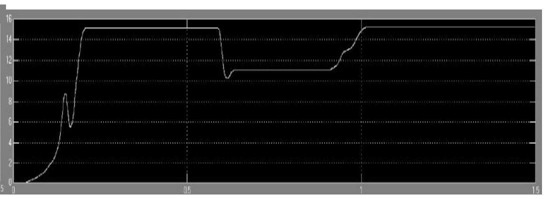


Figure 6. Photovoltaic power (unit: kW)

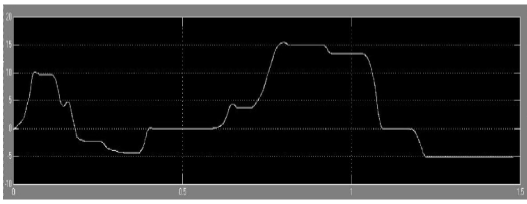


Figure 7. The output power of the battery unit (unit: kW)

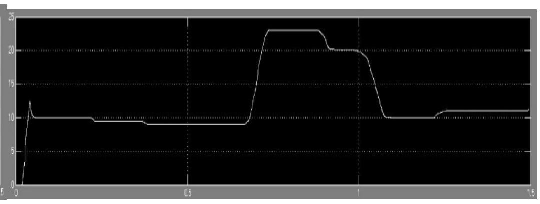


Figure 8. Load power (unit: kW)

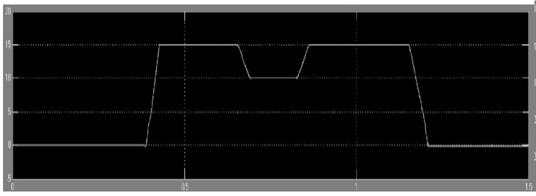


Figure 9. Microgrid output current (unit: A)

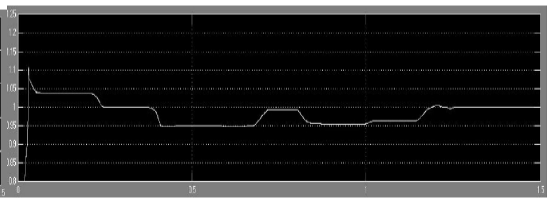


Figure 10. Bus voltage (unit: pu)

The 1 * in the figure is the set value of the output current of the DC microgrid, and the 1 is the actual value of the output current of the DC microgrid. At this time there are:

From the type can be seen, a new voltage increment the reference voltage of DC micro grid network to bus recovery, new bus voltage increment will affect the size of DC micro grid, so the V1 needs to be limited, the DC voltage of the micro grid in a certain range.

At the beginning of 0. 25s, the bus voltage gradually returned to the rated value. When 0. 4S, the network control strategy started, the 15A output of the microgrid and the bus voltage dropped to 0. 95pu. at 0. 58s, the light decreased, the output power of the battery increased and the bus voltage remained stable. At 0. 7S, the load is up to 25kW. At this time the output power of the photovoltaic power is about 11kW. At this point, due to the power limit of the battery unit, the microgrid cannot be output with the 15A current, so the output current is down to 10A. At this point the bus voltage rises to 0.97 PU. At 0. 85s, due to the increase of photovoltaic power output, even though the output of 15A current, the battery will not output at maximum power. Therefore, the output current of the microgrid

IOP Conf. Series: Earth and Environmental Science **170** (2018) 042150 doi:10.1088/1755-1315/170/4/042150

will change to 15A again, and the bus voltage will also fall again. At 1. 15s, the network control ends and the bus voltage is back to the rated value again.

5. concluding remarks

This paper adopts energy management to control the DC microgrid, and analyzes the influence of droop theory, voltage recovery principle and hierarchical network control on DC microgrid. The validity of this method is proved by simulation. It is of certain reference significance to further research in the future.

References

[1] Li Xialin, Guo Li, Wang Chengshan, Li Yunwei. Summary of key technology research of DC microgrid [J]. China Journal of electrical engineering, 2016, (01): 2 - 17.
[2] Wang Panbao, Wang Wei, Mengnina, Wu Yan. The DC micro grid operation from the network and grid unified control strategy J. China Motor Engineering Journal, 2015, (17): 4388 - 4396.
[3] Wen Bo, Qin Wenping, Han Xiaoqing, Wang Peng, Liu Jia win. Based on voltage droop method, the control strategy of DC microgrid hybrid energy storage system [J]. Power grid technology, 2015, (04): 892 898.
[4] Na, Zhang Hui DC microgrid improved hierarchical control strategy study [J]. High voltage technology, 2016, (04). 1316 – 1325.
[5] Zhang Huiqiang, Wang Yutuo, Wang Linchuan. Coordinated control of DC microgrid based on DC bus voltage signal [J]. China electric power, 2015, (11): 110 - 116.
[6] Meng Runquan, Liu Jiaying, Wen Bo, et al. DC microgrid hybrid energy storage control and hierarchical coordinated control strategy [J]. High voltage technology, 2015, (07): 2186 - 2193.