Distributed Electric System Control Strategy Optimization

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Abstract. With the increasing energy crisis and environmental pollution, this paper concentrates on the energy management and power control of DC microgrid due to its advantage in the utilization of renewable energy resources (RES). However, the traditional centralized control relies heavily on communication since the distribution of most RES is scattered, and the communication failures may cause serious control error, therefore, a distributed and cooperative control strategy without communication is proposed for DC microgrid in this paper. The proposed strategy not only maintains the bus voltage and power balance in a cooperative way through the regulation of each micro-sources, but also solves the imbalance problem between ESUs, meanwhile, this method is suitable for DC microgrid with multiple PVs and ESUs since the communication is not necessary, which is benefit for the plug and in of micro-sources. Finally, some simulation models are built on Matlab/Simulink platform, and the performance of suggested solution is verified through a set of simulation experiments, the result turns out to be good and confirms our expectation.

1. Introduction

With the continuous development of the national economy, the traditional large power grid has been rapidly developed as a major power supply channel for a long period of time. However, in response to the increasing demand for electricity, with the increasing scale of the power grid, the cost of centralized large-scale power grids has gradually increased, the operation difficulty has increased, and the control system has become more complicated, so that the reliability of power consumption of diverse users has been challenged [1-8]. In particular, some large-scale power outages that have occurred in recent years have exposed the shortcomings of large power grids in terms of safety and reliability, such as the large-scale long-term power outage caused by the southern ice disaster in 2008, 7.30 in India in 2012. Large power outages, etc., not only caused economic losses, but also affected social stability. In addition, with the continuous advancement of industrial production, traditional non-renewable energy sources such as coal, oil and natural gas have been over-exploited, and with the increasing demand for load, human beings will inevitably face the crisis of energy shortage in the long run. At the same time, traditional fossils Excessive use of fuel not only causes irreparable pollution to the natural environment, changes the global climate, but also damages human health and endangers human survival. Therefore, renewable new energy sources with abundant reserves, clean and pollution-free advantages, such as solar energy, wind energy, and ocean energy, have received extensive attention, and have become the development trend of future energy utilization. Compared with traditional firepower and hydropower generation, renewable energy such as solar energy and wind energy has the characteristics of small
environmental pollution, flexibility and never exhaustion. Therefore, improving the penetration rate of renewable energy in the power grid is one of the important signs of power grid progress [9].

In view of the advantages of microgrid in the use of new energy, some researchers believe that microgrid will be an important part of the next generation of smart grid [10]. At present, the microgrid structure studied at home and abroad includes AC microgrid, DC microgrid and AC/DC hybrid microgrid. Since the traditional large grid mainly exists in the form of communication, the AC microgrid is still the main form of microgrid. Research on the exchange of microgrids has also received extensive attention.

Compared with AC microgrid, DC microgrid has many advantages, which can be summarized as follows [9]:

1. The DC power supply in the DC microgrid can be connected to the DC bus through a DC/DC converter, and only one DC/AC converter is needed for energy exchange between the DC microgrid and the large grid, effectively reducing the converter [11]. The number of them reduces the difficulty and cost of microgrid control;

2. Since the DC microgrid [12] does not need to consider frequency, phase, reactive power and other issues with respect to the AC microgrid, it mainly involves the control of active power, so the bus voltage becomes the unique identifier of the system power balance in the DC microgrid [13]. As long as the bus voltage is stabilized, the power balance of each unit in the DC microgrid system [14] can be realized, and the control is simple and reliable, and the power flow and energy scheduling can be realized quickly.

3. DC conversion can significantly reduce the distortion and clutter that often occur in AC/DC conversion process, so DC microgrid can significantly improve the quality of power supply. In addition, the presence of the grid-connected inverter effectively separates the DC microgrid [15] from the large grid, so that the DC microgrid can be used as an independent whole, which can quickly disengage from the faulty large grid and operate on an island, and implement self-sufficiency. And can be re-integrated into the large grid in time to operate together, which improves the reliability of the power supply and the flexibility of the system.

4. DC microgrid has the advantages of simple design, low cost and high efficiency in practical engineering. Under the traditional large power grid pattern of AC transmission, the DC microgrid [16] shows good adaptability on the micro-power source that uses distributed power generation, especially in the form of DC output and avoids AC transmission by means of DC transmission [17]. DC microgrid has a very broad prospect in the development of new energy and smart grid. At present, the research on the basic theory and practical technology of DC microgrid is still in the preliminary stage, and the actual application has not yet begun. In order to give full play to the advantages of DC microgrid, it is necessary to carry out more in-depth research.

2. Related Research

DC microgrid has attracted extensive attention from researchers because of its own advantages. Research on DC microgrid has become one of the hot research areas of power systems in recent years, including many in the US, Japan, Europe, and China. A large amount of research has been invested in countries and regions. Scholars from various countries have put forward a lot of ideas on the basic theory of DC microgrid and the basic theory of micro-power supply. At the same time, they have made many contributions in the research direction of the structure and operation mode of DC microgrid, and initially established various distributed Energy, micro-grid mathematical models and corresponding simulation analysis tools, and different control methods for different DC microgrid models. In addition, the researchers conducted a large number of experimental tests and built a number of experimental demonstration projects, such as the US Mandrecht microgrid and the Zhejiang Zhoushan Polar Island microgrid project to verify the correctness of the theoretical research and technical aspects and The feasibility of the economic level makes the DC microgrid more practical and has made a huge breakthrough.

At present, research on DC microgrid at home and abroad mainly focuses on model establishment and simulation of microgrid, control strategy of microgrid, energy management and reliability evaluation of microgrid. This paper takes DC microgrid with multiple photovoltaic cells, wind power
generation and energy storage system as the research object, first analyzes the principle and operation characteristics of these micro-sources, and then studies the DC micro-grid in networking and island operation without communication. The distributed coordinated control in the mode ensures that the power balance between the micro power supply, the load and the energy storage system in the DC microgrid [18] can be stabilized, the bus voltage can be stabilized at the rated value, and the energy storage unit is passed through the energy storage system. The power distribution realizes the energy storage balance between the energy storage units. The specific research content can be divided into the following three parts:

1) By analyzing the working principle of two kinds of micro-power sources, such as photovoltaic cells, batteries and their respective power electronic interface devices, the mathematical model is established, and the simulation model is built based on Matlab/Simulink platform to study output. The characteristics lay the foundation for subsequent controller research and overall strategy research on microgrid power balance.

2) Studying how multiple photovoltaic power sources and multiple energy storage units in a DC microgrid coordinate control the DC bus voltage. In the absence of a communication connection, each micro power supply is based on the different states of the DC bus voltage and their respective local information. Adjust its control strategy to achieve voltage distributed control of the system during network and island operation and smooth switching between various working modes.

3) Based on the maintenance of the bus voltage at the rated value, the coordinated control strategy of the energy storage system based on local information is studied. By properly distributing the power, the energy storage balance between the energy storage units is realized, and some energy storage in the system is prevented. The unit is in an over- or over-charge condition.

The development trend of renewable energy sources such as photovoltaics and wind power in the future energy structure and the positive role played by microgrids in the use of distributed energy are introduced. The advantages and disadvantages of DC and AC microgrids are described. After comparison, the DC microgrid [19] composed of photovoltaic and energy storage is determined as the research scope of this paper. In addition, the domestic and international research status of DC microgrid is introduced, which involves microgrid modeling and control technology. Finally, the research content of this paper is briefly introduced.

3. Photovoltaic Power Generation System Control Strategy

According to different operating modes of the DC microgrid, the photovoltaic power generation system can be divided into maximum power point tracking (MPPT) and power reduction (off-MPPT) control. In order to lift off the energy utilization rate of the photovoltaic cell, when the output power of the system is less than or equal to the power required for the equivalent load, such as the photovoltaic start-up phase, the illumination blessing is weak, and the load is large, that is, the . At the time, the light supply system operates in the MPPT mode; when the photovoltaic power generation system is redundant in power generation. That is, when the photovoltaic operation is in the power reduction control mode, and the time load and the energy storage unit are both "charge" nodes. For two different control requirements of photovoltaic systems, corresponding control strategies should be designed to ensure stable operation under different working conditions.

4. MPPT Control of Photovoltaic Power Generation System

In addition to its internal characteristics, the energy efficiency of photovoltaic cells is also affected by factors such as light amplitude, temperature and load. According to the PV output characteristics shown in Figures 2.4 to 2.7, the output power of photovoltaic cells is different. Under the conditions of illumination amplitude and humidity, different nonlinear characteristics are presented. Under different external conditions, the photovoltaic cell can operate at different and unique maximum power points, and the output curve is a single peak function with the maximum power point as the extreme value. According to the circuit principle, when the output impedance of the photovoltaic cell and the load impedance are equal, the photochemical battery obtains the maximum output power. It can be seen that the actinic MPPT process is actually the process of matching the output impedance and the load impedance. Since the output impedance is affected by environmental factors, the load impedance needs
to be adjusted in real time through the control method to track the output impedance and realize MPPT control. The MPPT control for actinic is achieved by controlling the duty cycle of the Boost converter and adjusting the equivalent load impedance.

5. Several common MPPT methods

According to the intelligence and complexity of the control method, it can be roughly divided into three categories.

5.1. Open-loop MPPT Method Based on Output Characteristic Curve

The constant voltage tracking method and the short circuit current proportional coefficient method are two commonly used open-loop MPPT methods. When the humidity is constant, even if the illumination amplitude changes, the open circuit voltage of the photovoltaic cell is almost unchanged. Based on this characteristic, the constant voltage tracking method is based on the maximum power point voltage of the actinic battery. The approximate linear relationship between $V$ is approximated. When the illumination amplitude is constant, the short circuit current $I$ of the photovoltaic cell is basically unchanged with the change of temperature. Based on this characteristic, the short circuit current proportional coefficient law is approximated according to the approximate linear relationship between the maximum power point current and the current. The two methods are simple and easy to implement, but because they are based on an approximate linear relationship, the photovoltaic cell does not work at the true maximum power point, and the load needs to be disconnected during the measurement, which causes power loss, and the measurement is complicated. Class methods are not practical.

5.2 Self-optimizing MPPT method

Disturbance observation method and conductance increment method are commonly used self-optimization methods for MPPT. Based on the $P-U$ unimodality of the curve, there is a maximum power point, $dP_{pv} / dU_{pv} = 0$ and $dP_{pv} / dU_{pv}$ the symbols at the maximum power point are different. By disturbing the output voltage (or current) of the photochemical cell, the disturbance observation method and the conductance increment method respectively observe the photovoltaic cell output. The sign of the change $\Delta P_{pv}$ in power, $\Delta P_{pv}$ and $dP_{pv}/dU_{pv}$ then according to the sign of and the sum to determine the direction and step size of the next clever (or current) disturbance, and then repeat, and finally make the battery work in the MPPT state. In essence, the difference between the work and the voltage of the photovoltaic cell output voltage $dP_{pv} / dU_{pv} = 0$ is found, and the working point $U_{pv}$ (or $I_{pv}$) is found. The main difference between the two is the calculation of the power difference. These two methods are simple and have few parameters $\Delta P_{pv}$, which are independent of the characteristics and parameters of the photovoltaic cell. When the external environment changes, the system can track its changes smoothly, but the tracking accuracy and speed are affected by the initial voltage value and the disturbance step.

5.3 Intelligent MPPT Method

The intelligent control methods such as fuzzy control and neural network are applied to the MPPT control of the unknown and nonlinear photovoltaic system. The system can respond quickly to changes in the external environment and obtain good robustness and adaptability. However, the performance of fuzzy control is very dependent on the selection of the rules, which is greatly influenced by the designer's experience [20]. The intelligent algorithms such as neural networks need to process a large number of data samples, which boils down to the optimal control path, and the learning time is longer. It may not achieve the purpose of learning. In general, the good control performance of intelligent algorithms relies on long control cycles, strong hardware facilities and designer experience, so it is difficult to obtain practical applications in modern industrial control.
6. Disturbance Observation Method with Variable Step Size

Based on the above discussion, the MPPT method of photovoltaic power generation system is still dominated by the classical control theory. The control block diagram of the photovoltaic power generation system is shown. The control signal output by the MPPT algorithm and the PV output voltage obtained by feedback are used as double closed loop. The input signal of the voltage outer loop is controlled to adjust the change of the non-station tracking signal. The disturbance observation method has been widely used because of its simple algorithm and easy implementation. However, it is greatly affected by the disturbance step. If the disturbance step is large, it can ensure fast system tracking speed, but it is easy to be near the maximum power point. A certain amplitude of oscillation; while the disturbance step is too small, although it can reduce the amplitude of the oscillation, it will reduce the tracking speed of the system and cannot adapt to the rapidly changing environment. The MPPT algorithm in this paper adopts a variable step size perturbation observation method, and the step size is set to be proportional to , that is, the step size of the disturbance voltage is automatically changed according to the slope of the curve of the photovoltaic cell, so that the work is performed. When the point is far from the maximum power point, the voltage changes in a large step ensure the rapidity of the MPPT. When the working point is close to the maximum power point, the voltage step becomes smaller, and the oscillation near the maximum power point can be suppressed. As shown in Figure 4.2, where indicates the direction of change of the step size, and the photovoltaic output voltage at the next moment is calculated by the following formula:

\[ U_{pv}(k+1) = U_{pv}(k) + N*K * \]

(1)

7. Conclusion

In this paper, a photovoltaic power generation system model is built on Simulink. Under the premise of stable bus voltage control, changing the illumination and temperature conditions is as shown above. From the change of photovoltaic cell output voltage and power, it can be seen that when using the variable step disturbance observation method. Through the voltage disturbance, the maximum operating point of the photovoltaic cell can be quickly and accurately searched, and the tracking speed and accuracy can be transported.

Acknowledgment

This work was supported by the Young Scientists Fund of the National Natural Science Foundation of China under Grant No. 61703412, the China Postdoctoral Science Foundation under Grant No. 2016M602996.

8. References

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