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The Design of Distributed Micro Grid Energy Storage System

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Abstract. Distributed micro-grid runs in island mode, the energy storage system is the core to maintain the micro-grid stable operation. For the problems that it is poor to adjust at work and easy to cause the volatility of micro-grid caused by the existing energy storage structure of fixed connection. In this paper, an array type energy storage structure is proposed, and the array type energy storage system structure and working principle are analyzed. Finally, the array type energy storage structure model is established based on MATLAB, the simulation results show that the array type energy storage system has great flexibility, which can maximize the utilization of energy storage system, guarantee the reliable operation of distributed micro-grid and achieve the function of peak clipping and valley filling.

1. Introduction

With the continuous development of non-renewable resources such as coal and oil, the environmental pollution is becoming more and more serious. The global energy crisis is becoming more and more prominent. The renewable energy sources such as wind energy and solar energy have developed rapidly. Using the energy-saving and environmental friendly resources such as wind energy and solar energy to build a distributed smart micro-grid has become the development trend of the future power industry [1]. Micro-grid is a small hair, change, transport, distribution and utilization system made up of distributed power, energy storage device, power conversion device, protection device and load device [2] [3]. Micro-grid can run parallel operation mode or island working mode. In the mode of parallel operation, through the control of the grid connection device we can establish a connection with the large power grid, achieve the energy transfer between them, reduce the fluctuation to the distribution network caused by distributed power supply randomness, load intermittent and other factors, maximize the utilization of distributed power supply, protect the power quality, and maintain the stable operation of the micro grid. In the mode of island mode, the energy storage system is the center of micro-grid energy transfer. Guaranteeing the stable operation of micro-grid relies mainly on micro-grid operation control technology and energy management technology. How to use energy storage device efficiently and reliably is the core of the island-type micro-grid [4]. Common energy storage methods can be divided into: electrochemical energy storage, electromagnetic energy storage, mechanical energy storage, in which electrochemical energy storage is most commonly used.

At present, most of the research on domestic energy storage system is aimed at electric vehicles. Its function and structure are relatively simple. The characteristics of distributed power supply determine
the complexity of micro-grid, which makes the structure, management, operation and control mechanism of traditional energy storage system can't meet the development needs of micro-grid [5] [6] [7]. An efficient micro-grid energy storage system should be coordinated with the distributed power supply to provide the reliable power for the load and protect the life of the energy storage device.

In this paper, an array energy storage battery pack is proposed for the micro-grid in the island mode. Depending on its flexibility and adjustability, the seamless connection between the energy storage system and the micro-grid bus can be realized.

2. Structural Framework

The storage system is the key guarantee of stable operation of micro grid distributed intelligence, according to the distributed micro-grid scale energy storage system, which can be composed of dozens or even hundreds of batteries and generally use a fixed storage structure. The structure of the system is shown in Figure 1. The fixed energy storage structure consists of the batteries string and parallel. After the installation, the connection between the battery packs cannot be changed, the system flexibility is low, the working mode is single, and battery packs of the system must be put into work during normal operation. Power is not adjustable.

Relative to the fixed energy storage structure, the array of energy storage structure is more complex and the basic structure is shown in Figure 2. Compared with the fixed type, the array energy storage structure is the biggest difference is that there are multiple control switches between the battery pack, these control switches form an array, so that array switch is the core of the array of energy storage. According to the operation of the micro-grid, the energy storage management system controls the various states of the array switch, and can recombine the connection between the battery packs. The advantage is that the connection mode of the array type battery can be adjusted freely according to the working state of the power supply, and the battery pack works according to the on state of the array switch, Only a battery pack that is on the line can be put into operation, while the battery that is not on the line is in the period of rest, which makes the output power of energy storage system adjusted and greatly improves the system's flexibility.
3. **Working Principle**

Above the array type energy storage structure, each battery is connected by 4 switches and another battery, and 2 switches are connected with the DC bus. The battery pack working mode can be selected by controlling the array switches and bus switches, when the switch S1 and S4 are connected and the S2 and S3 are switched off, the battery is in a parallel state, and the output voltage of the system is $U$, and the current is as follows:

$$I = I_1 + I_2$$  \hspace{1cm} (1)

When the switch S2 and S3 are connected and the S1 and S4 are switched off, the battery is in series operation state, the current of the system is $I$, and the output voltage is:

$$U = U_1 + U_2$$  \hspace{1cm} (2)

When the switches S1, S2, S3 and S4 are all disconnected, the DC bus switches is connected, the energy storage system presents distributed energy storage.

4. **Simulation Results**

In order to verify the superiority of the array energy storage system, this paper uses MTALAB software to model fixed structure energy storage system and array energy storage system respectively, and collect the distributed power data and load data for a period of time. The data and the energy storage system itself as the control factors of the energy storage management system, the energy storage management system output connected to the array switch driver. Under the same conditions, the two energy storage structures are simulated, and the simulation results are shown in Figure 3 to Figure 4.
Figure 3 shows the simulation results of the fixed energy storage system and the array energy storage system. From the simulation results, it can be seen that the output power of the fixed energy storage structure is single, which is mainly affected by the charge state of the battery packs. While the array structure of the energy storage system output power changes greatly, this is due to the selectivity of the array switch, some batteries have not been put into operation. The simulation results show that the array energy storage structure has strong adjustability and high flexibility.

Figure 4 shows the results of the online power simulation of the distributed micro-grid under the fixed energy storage structure and the array energy storage structure. If the on-line power of the micro-grid is $P$, then:

$$ P = P_{source} + \lambda P_{battery} + \mu P_{fuel} - P_{load} $$

(3)

In the type: $P_{source}$ is the distributed power supply; $P_{battery}$ is the energy storage system power; $P_{fuel}$ is the fuel power; $P_{load}$ is the load power; $\lambda$ is the battery discharge factor; $\mu$ is the fuel factor.

The range of values for $\lambda$ is:

$$ -1 \leq \lambda \leq 1 $$

(4)

When $\lambda \leq 0$, it shows that the energy storage system absorbs the active power. When $\lambda > 0$, it shows that the energy storage system releases the active power.

The fuel injection machine is used as the backup protection of the distributed micro-grid, to prevent the micro-grid fault caused by the output power of the distributed power supply and the energy storage system which cannot meet the load requirements;

The range of values for $\mu$ is:

$$ 0 \leq \mu \leq 1 $$

(5)

It represents the fuel system with a power of $\mu$ times the rated power.
Fig. 4 The diagram of on-line power simulation results

The simulation results show that the array storage structure can be effectively reduced to the fluctuation of the micro-grid, and the variation of the micro-grid on-line power is from 0 ~ 4Kw to 0 ~ 1Kw, which greatly improves the stability of the micro-grid. Those prove the superiority of array energy storage structure for distributed micro-grid.

5. Conclusion

For the distributed micro-grid energy storage system of single structure, poor adjustability, low flexibility, easy to cause micro power fluctuations and other issues, this paper puts forward a kind of array storage system structure, and models using MATLAB. The simulation results show that the array energy storage structure has a strong flexibility, which can improve the fault tolerance of the energy storage system in the distributed micro-grid and reduce the fluctuation of the distributed micro-grid.

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