International Journal of Research in Engineering and Science (IJRES)
ISSN (Online): 2320-9364, ISSN (Print): 2320-9356
www.ijres.org Volume 5 Issue 5 ǁ May. 2017 ǁ PP. 42-45

Research on Micro-grid Stability Based on Data Center and Battery Array

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ABSTRACT: At present, the number of distributed energy in the micro-grid shows a gradually increasing trend. In order to absorb and use distributed energy greatly, and to achieve stable control of the micro-grid, this paper adjusts the load power and distributed energy to match the demand response, and then make the micro-grid stable. Through the adjustable load to reduce the peak and fill the valley in themicro-grid, and use the energy storage device to achieve the excess output and load demand. By using the data center and the battery array to control the micro-grid, the data center load is adjustable and the battery array is to absorb the energy release. The intermittent fluctuations of the distributed energy in the micro-grid has been suppressed, and this two devices achieve stable control of the micro-grid in two different ways.
Keywords: micro-grid; distributed energy; data center; battery array

I. INTRODUCTION

For the micro-grid system with renewable energy, the power is intermittent, volatile and random, generally equipped with energy storage device. Energy storage devices often use batteries and supercapacitors. The high-density characteristics of the supercapacitor can achieve the absorption or release of the instantaneous power, but cannot provide power for a long time. The battery array can provide power for a long time, but it has the shortcomings of low cycle life and low power density. At present, the hybrid energy storage system has become a research hotspot [1]. In this system, the lead-acid battery energy density is large, can be used as the system long-term energy storage equipment, but supercapacitor's power density is high, can be used as short-term energy storage equipment to adjust the system's instantaneous change power. The characteristics of the supercapacitor and the lead-acid battery make the intermittent and randomness of the output power of the micro-grid be improved. In order to ensure the reliability and stability of the system power supply, combining battery with high energy density and supercapacitor with high power density to form a hybrid energy storage system, and then applied to photovoltaic micro-grid. This idea has become a research hotspot. Hybrid energy storage system can quickly balance the system's instantaneous power, optimize the system running,and ensure the reliability of power supply.

Data center load adjustable features, related to demand response technology, can be applied to the user side of the micro-grid energy management. Among them, the adjustable load is the entry point of intelligent electricity, and the physical basis of the user side of the micro-grid energy management; demand response is the direction of intelligent electricity. It belongs to application part of the user side of the micro-grid energy management. The emergence of the data center provides a new way for the stability of micro-grids by adjusting the load consumption to match the renewable energy output. The adjustable load has the ability to increase the distributed energy consumption capacity, participate in the demand response and reduce the user's electricity cost, but this has put forward higher requirements for its specific control. The traditional manual control is completely dependent on personal wishes and use experience, and it is difficult to achieve real-time, remote, intelligent control [2]. So fully play the active load adjustment capacity must rely on modern intelligent power technology. The data center itself can change the use of energy according to the mode of operation, and has real-time response in the face of distributed energy fluctuations.

II. BATTERY ARRAY STABILITY STRATEGY

2.1 COMPOSITE ENERGY STORAGE

Through the power conversion device, energy storage device can achieve the power of the four quadrant flexible adjustment, achieve micro-grid active and reactive power instantaneous balance, and improve system stability. Due to the role of energy storage system, micro-grid can realize the decoupling of two groups of unrelated random variables, which can effectively weaken the influence of intermittent energy such as wind power and photovoltaic power generation on micro-grid. In addition, energy storage is also the physical basis of micro-grid custom power technology, which can meet a variety of requirements, such as user's power quality, power supply reliability and security. Limited by the development of energy storage technology, there is not yet a single form of energy storage, which has mature technology, acceptable cost, and can meet the energy and

power requirements. Taking into account the characteristics of different energy storage, it should develop multiple composite energy storage technology to complement each other, and maximize the performance of energy storage technology. At present, the composite energy storage is mainly composed of energy storage (take battery type mainly) and power type energy storage (such as supercapacitor, flywheel energy storage, etc.) with fast response characteristics. Now there are composite energy storages formed by supercapacitors and batteries used in micro-grid.

The control of the composite energy storage in the micro-grid should take the limitation of the energy storage state, the maximum power limit of the energy storage and the instantaneous power balance into account, so as to ensure the rationality of the storage capacity optimization [3].

1) Energy storage state requirements

In order to prevent damage caused by overcharging and over discharging on the battery cycle life, the battery should be under the guidance of the battery management system in the use of the process, and strictly control the upper and lower limits of its state of charge.

2) Energy constraint

In the premise that the energy storage device can guarantee enough output power, the maximum output energy of the storage energy should also be able to meet the load demand.

3) Maximum power requirements

In order to prevent the sudden power loss when load power, such as power quality drop caused by large motor starting, the composite energy storage device must be able to quickly output large power to support the system, namely the total power of the composite energy storage device must not be less than the maximum instantaneous power loss.

2.2Stable mode

The structure of the micro-grid system [4] based on energy storage is shown in Fig.1. The system consists of uncontrollable power (photovoltaic and fan), controllable power (battery) and AC load. It uses photovoltaic power generation and wind power generation as the main source of supply. Wind power generation use rectifier converter into a DC source, and then use Boost circuit boost access; photovoltaic power generation includes MPPT maximum power control and boost circuit. The battery connects the DC bus through bidirectional DC/DC, and control the battery's charging and discharging. 220 V AC load connect the DC micro-grid through the DC / AC inverter.

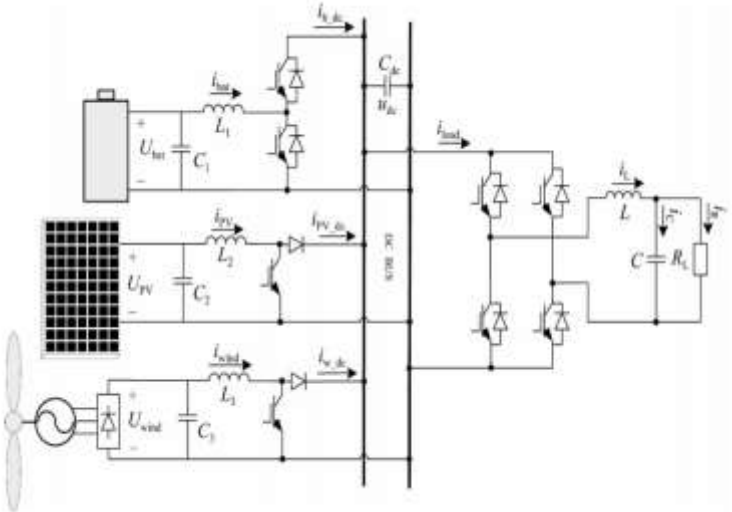

Fig.1:the structure of the micro-grid system

The battery connect to the micro-grid DC bus through a bidirectional DC/DC converter, which controlthe battery charge and discharge to make the two-way flow and maintain the DC bus voltage stability. The bi-directional DC/DC converter adopts the independent PWM control method. When the bridge is off, the circuit works in the boost mode, the controller outputs the PWM signal to modulate the lower arm of the IGBT module, so that the battery discharge, andtransmit the power to the DC bus; When the lower arm is turned off, the circuit operates in buck mode, the controller outputs the PWM signal to modulate the upper arm of the IGBT module to charge the battery and absorb the power from the DC bus. The DC side bus voltage of the converter is always the control target of the bidirectional DC/DC converter. The converter adopts the double closed-loop control method with the DC bus voltage as the outer loop feedback and the battery inductance current as the

inner loop feedback. The structure shown in Figure 2.In figure 2, u_{dc}^{*} and u_{dc} are the given voltage and feedback voltage value of the DC side, the DC side of the voltage error signal $e_{dc}(e_{dc}=u_{dc}^{*}-u_{dc})$ generate current referencesignal i_{bat}^{*} of the energy storage inductor through the voltage PI regulator on the DC side:

$$i_{bat}^{*}=k_{dep}e_{dc}+k_{dci}\int e_{dc}dt \quad , (1)$$

Where,

k_{dcp} : Proportional coefficients of the DC side voltage PI regulator.

k_{dci} : Integral coefficients of the DC side voltage PI regulator.

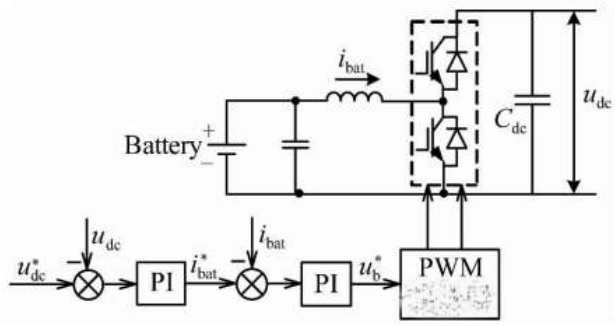

Fig.2: the structure of the DC/DC converter

Energy storage inductor current error signal $e_b(e_b=i_{bat}^{*}-i_{bat})$ generate modulated wave signal u_b^{*} through energy storage inductor current PI regulator:

$$u_b^{*}=k_{bp}e_b+k_{bi}\int e_b dt \quad , (2)$$

Where,

k_{bp} : Energy inductor current proportional regulator of PI regulator.

k_{bi} : Energy inductor current integral regulator of PI regulator.

The PWM generator receives modulated wave signal for SPWM modulation, and outputs two PWM pulses drive the bi-directional DC/DC converter to achieve step-up and step-down function. The system detects the DC bus voltage change when the renewable energy output fluctuates and the load changes, and carries on the charge and discharge control to the battery through the rapid reaction of the bidirectional DC / DC, realizes the real-time transient stability of the DC bus voltage. The system detects the DC bus voltage change when the renewable energy output fluctuates and the load changes, and carries on the charge and discharge control to the battery through the rapid reaction of the bidirectional DC / DC, thus realizes the real-time transient stability of the DC bus voltage.

III. DATA CENTER MICRO-GRID STABILITY CONTROL

3.1 Adjustable Load and Demand Response

The difference between data center and battery for demand response is the control of the load. Unlike traditional demand-side management, demand response is an important development form in demand-side management in a competitive electricity market, and requires the open power market to a certain extent. From the implementation point of view, traditional demand-side management is more of a load management tool used to improve energy efficiency. The general measure is to actively cut off the power supply in part of the system at the appropriate time, thereby reducing part of the electricity demand during the peak load or transferring some of the power to the low load period. But the subject of demand response is more biased towards power users, the user can independently adjust the load demand or power mode, according to the market, especially the price signal. And thus it can strengthen the market stability and reliability of power grid to a certain extent.

The concept of adjustable load in the data center comes from the residents' electricity consumption [5]. In the past, the demand response was adopted for residents' electricity control. The load of residents is mainly from household HVAC equipment (including heating, ventilation and air conditioning), refrigerators, water heaters, lighting, entertainment, kitchen and other living appliances. According to the difference between electricity

mode and user demand, the general electricity load can be divided into the baseline load, transfer load and adjustable load. Among them, the baseline load changes in accordance with the natural needs of life and work decisions, and has a lot of mandatory and random, thereby cannot participate in demand response. However, the residents' electricity consumption contains the residents' power consumption intention, and cannot bring about actual effects. Now, the strategy of adjustable load is applied to the data center to realize the stability control of the micro-grid.

3.2 Data Center Control Mode

After running the load control information, the user side of the micro-grid can control the residential electricity and run load and power transfer between micro-grid and distributed energy transactions. In order to obtain better stability of the micro grid, with the goal of minimizing the energy supply difference of the user side micro grid, the energy balance and the maximum utilization of distributed energy are taken as the constraint conditions, so as to achieve the stable and optimal operation of the system. The specific process of adjusting load operation is not too much attention, but is more concerned about whether the requirements within the time to complete a task, so the user side, micro grid energy maximization as the goal, considering the conditions of the operation of the system of constraints, the optimal control, so as to achieve a stable optimal operation of the whole system.

IV. DATA CENTER AND BATTERY COORDINATED CONTROL

By combining the data center with the storage battery to change the distributed energy absorptive capacity in the micro-grid, the disturbance of the distributed energy to the micro-grid mainly lies in unpredictable energy fluctuations. In order to reduce the impact of energy fluctuations in the micro-grid, generally it uses the battery to absorb excess energy, but the battery itself in the micro-grid construction operating costs are too high, and only the battery cannot absorb fluctuations. A unit with load adjustable characteristic is introduced to control the micro-grid at the same time through the data center, and the load of the data center is adjusted by the opportunity forecasting control to realize the stability in the micro-grid. The key of load control between data center and battery is the prediction and matching of distributed energy, data center and storage location of the battery also play a role in micro-grid stability. Through the control strategy of data center oriented and battery auxiliary, the whole operation of micro-grid is controlled, and the effective unification of energy use and energy storage is realized.

V. CONCLUSION

In the case of more frequent use of renewable energy, in order to better absorb and eliminate fluctuations in the output, maintain micro-grid stable operation, the emergence of energy storage equipment and adjustable load equipment undoubtedly gives the possibility of micro-grid stability. In the future, the location and control strategy of the storage battery and data center in the micro-grid must be considered when more distributed energy sources are introduced into the micro-grid. The current approach is to place data centers near large distributed energy sources, with batteries placed in residential areas. The data center is the main control for micro-grid stability, and the storage battery is a stable power supply for the load. This stable mode can also be applied to the multi distributed micro grid system.

ACKNOWLEDGEMENTS

This work was financially supported by The Innovation Foundation of SUES under Grant NO. E3-0903-17-01221.

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