IOP Conf. Series: Materials Science and Engineering **322** (2018) 072026 doi:10.1088/1757-899X/322/7/072026

# Research on Control Strategy of the Micro Grid's Hybrid Energy System

**Zi-jun Gao, Yang Li, Yan-ping Wang, Ke-yong Zong, Jing Zhang**

School of Information Science and Engineering, Dalian Polytechnic University, Dalian, China

857529964@qq.com

**Abstract.** This paper study the structure and operating characteristic of the hybrid energy system which is made of super-capacitor and battery. The system is controlled by strategy of bus voltage following. The bus voltage can change the state from swings to stable quickly when load mutation occurs in the micro grid. The transient impact also can be reduced by this way. The passage set up the model of energy system and make an analysis by the software named MATLAB/Simulink. At last, the passage proves the correctness and the effectiveness of the control strategy and draws a conclusion that the transient impact can be inhibited which occurs in the bus voltage of energy system.

## 1. Introduction

In recent years, the defects of traditional power grid such as poor flexibility and accident widely spread become prominent[1]. Therefore, the micro grid technology come into being. Micro grid uses clean energy such as light and wind. It has energy storage structure and the capable of grid connected operation and isolated network operation[2].

But the output power is not stable because micro sources are random and intermittent[3]. The transient impact will directly affect the power quality of the micro grid[4]. However,the energy storage system can solve the problem of transient impact through some control algorithm.

Battery energy storage has the characteristics of high energy density and low power density. Super capacitor has the feature of low energy density and high power density[5]. It's found that battery and super capacitor can complement each other in energy storage[6]. The method that battery and super capacitor used in parallel can increase the power of energy storage system[7].

The paper uses battery and super capacitor which are placed in parallel as the energy storage device. Adopting the voltage following control algorithm to restrain the transient impact caused by sudden change of load. Building simulation model and make analysis with software named MATLAB/Simulink to verify the effectiveness of the method.

## 2. The Structure of Micro Grid

At present the common micro grid system structure is shown in Figure 1.

The photovoltaic array is connected to the DC bus through a unidirectional DC/DC converter. When the radiation is strong, the power generation module operates at the maximum power point tracking mode. When the radiation is weak, it operates in idle mode.

IOP Conf. Series: Materials Science and Engineering **322** (2018) 072026 doi:10.1088/1757-899X/322/7/072026

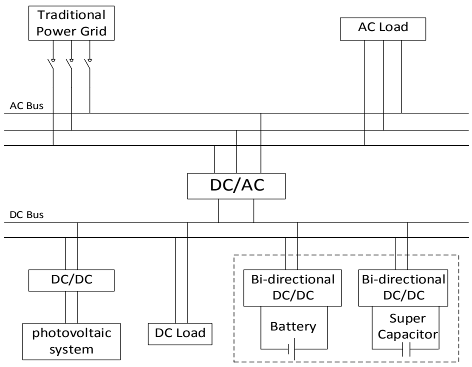

Fig.1 The structure of micro gird

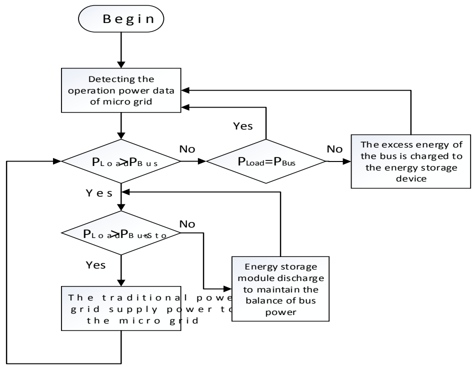

Fig.2 Diagram of system energy management

In the grid connected mode, the micro grid supplies power to traditional power grid when the power output of the micro grid is surplus. But if vacancies happen in micro grid,the traditional power grid will supply power to the micro grid in order to make the network stable. When the traditional power grid break down, the micro grid will separate from the power grid working in the island mode.

## 3. Management of the Energy System

When micro grid operates in isolated island mode, it is necessary to ensure the stability of bus voltage, frequency and amplitude. When it runs in grid connected mode, active and reactive power should be supplied to the bus[8]. The micro grid normal operation flow chart is shown in Figure 2.

When the micro grid is running, it is necessary to detect the power change of the bus, the energy storage module and the load in real time. Then adjusting charge-discharge of the energy storage module and the power transmission between traditional grid and micro grid[9]. The flow relation of the energy system should satisfy the relation.

$$P_s = P_l + P_{bus} + P_{inv} \qquad P_{st} = P_s - P_{pv} \qquad P_{st} = P_{bat} + P_{sc} \qquad P_{bat} = P_{st}\frac{1}{\tau s + 1} \tag{1}$$

In the above equality, $P_S$ is the power sum of generation and energy storage module.PL is the load power consumption. $P_{bus}$ is the power that required to maintain bus stable. $P_{inv}$ is the output power of inverter. $P_{PV}$ is the power of photovoltaic. $P_{st}$ is the output power of energy storage system. $P_{SC}$ is the output power of super capacitor. $P_{bat}$ is the output power of battery. $1/\tau s+1$ is on behalf of the low pass filter.

## 4. Control Strategy for Energy Storage System

In this paper, the hybrid energy storage system consists of batteries and super capacitors which are connected to the DC bus. Battery adopts the three order dynamic equivalent circuit model which can reflect the dynamic process of charging and discharging[10]. The super capacitor adopts RC series equivalent circuit model that could reflect the characteristics of quickly charging and discharging. The structure of the energy storage device adopts a bidirectional half bridge converter circuit. The detailed structure is shown in Figure 3.

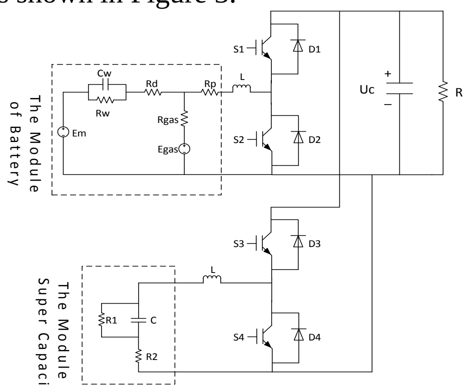

Fig.3 The structure of hybrid energy system

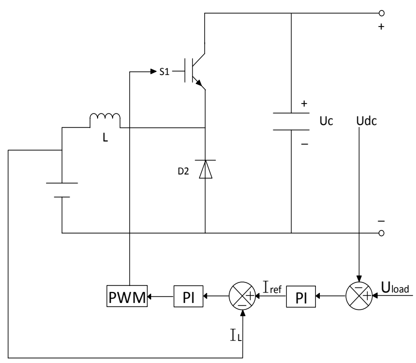

Fig.4 Diagram of charging structure

IOP Conf. Series: Materials Science and Engineering **322** (2018) 072026 doi:10.1088/1757-899X/322/7/072026

Usually, the battery and super capacitor operate at the mode of constant-current charging or discharging. When the energy storage device discharges, the switch S1 and S3 are turned off, and the S2 and S4 are turned on. They construct two boost chopper circuits. When the energy storage device is charged, the switch S1 and S3 are turned on, and the S2 and S4 are closed. They construct two buck chopper circuits. This circuit can control the charging and discharging voltage of energy storage system through changing the switches' duty cycle. When the load power mutation occurs during the operation of micro grid, battery module storage and release low frequency power. The super capacitor module storage and release high frequency power due to its characteristic of short response time. This structure can effectively deal with the problem of bus transient shock caused by load mutations in theory.

In this paper, the battery module and super capacitor module adopt the same control strategy named three stage charging method. The charging control diagram is shown in Figure 4.

Gathering the difference between the bus voltage and the standard voltage. Then converting the difference signal to a current signal via the PI controller. Next sending the signal to the PWM generator to generate PWM waves. The PWM waves are used to control the switching time and duty cycle of the switch. They form the buck chopper circuit to realize the charging of the energy storage device. The transfer function can be obtained by the small signal model of chopper circuit.

$$G_{iu} = \frac{Cs + 2/R}{(1-D)Uc\{1 - Ls/[(1-D)^2 R]\}} \tag{2}$$

$$Gud = \frac{(1-D)Uc\{1 - Ls/[(1-D)^2 R]\}}{LCs^2 + L/Rs + (1-D)^2} \tag{3}$$

$G_{iu}$ represents the function of the bus voltage to the inductor current. $G_{ud}$ represents the transfer function. The diagram of charging control block is shown in figure 5.

Using the charging block diagram of energy storage system, the transfer function can be introduced. The function is shown as follows.

$$G(s) = G_1(s) + G_2(s) + G_3(s)$$

$$\begin{cases} G_1(s) = \dfrac{K_{pIL} * K_{pv1} * G_{ud} * s^2}{D(s)} \\ G_2(s) = \dfrac{(K_{iIL} * K_{pv1} * G_{ud} + K_{iv1} * K_{pIL} * G_{ud}) * s}{D(s)} \\ G_3(s) = \dfrac{K_{iIL} * K_{iv1} * G_{ud}}{D(s)} \\ D(s) = (K_{pIL} * G_{id} * G_{ud} + K_{pIL} * K_{pv1} * G_{ud} + 1) * s^2 + (K_{iIl} * K_{pv1} * G_{ud} + K_{iv1} * K_{pIL} * G_{ud} + K_{iIL} * G_{id} * G_{ud}) * s + K_{iIL} * K_{iv1} * G_{ud} \end{cases} \tag{4}$$

In the upper model, the transfer function of the PWM controller takes the default value of 1 and the voltage feedback coefficient is 1. The structure diagram of discharging system is similar to the charging control. It's shown in Figure 6.

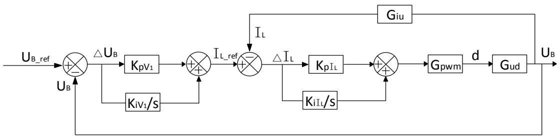


Fig.5 Control diagram of charging

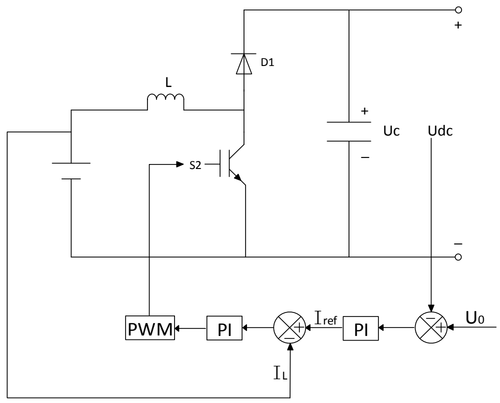


Fig.6 Diagram of discharging structure

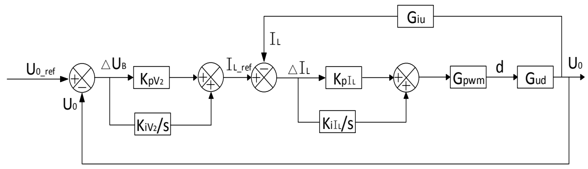


Fig.7 Control diagram of discharging

In the discharge mode, the S1 is switched off and the S2 is switched on to form a boost chopper circuit. The control structure adopts a double closed loop structure.

The structure of discharging circuit is the same as charging circuit. Only the current direction is different. Thus they have similar control block diagram. But there is a slight difference between input and feedback. The charging control block diagram is shown in Figure 7.

The transfer function of the discharge system is the same as the charging system. The discharge control can be realized by changing the scale factor and integral coefficient of the PI controller.

The battery and super capacitor adopt the same charging and discharging control strategy. But the priority issues are involved in the charging and discharging process because of their different power density, energy density and response time. In view of charging and discharging rate of super capacitor is faster, the strategy used in this paper is that super capacitor charge and discharge in priority. The system workflow is shown in Figure 8.

Tab.1 Parameter of simulation mode

| Parameters | Numerical Value |
|---|---|
| Photovoltaic power/W | 2500 |
| Busbar voltage /V | 500 |
| Battery voltage/V | 350 |
| Battery capacity/Ah | 500 |
| Super capacitor/F | 50 |
| Inductance /mH | 8 |
| Filter capacitor/μF | 1000 |
| Load resistance /Ω | 100 |

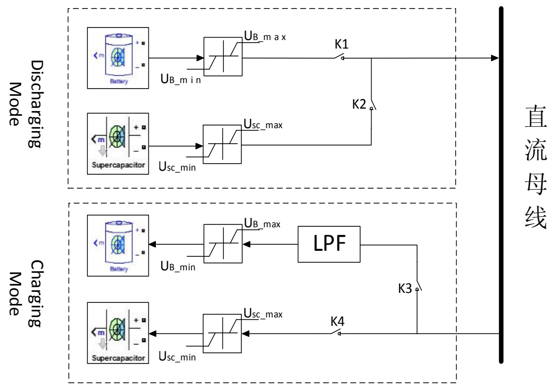


Fig.8 Working diagram of energy system

When the system is in the discharging mode, the super capacitor module discharges preferentially until reach $U_{sc\_min}$ which is the lower limit voltage. The switch K2 is switched off and switch K1 is switched on. When the battery voltage drops to $U_{B\_min}$, the switch K1 is switched off and the discharging mode is ended. When the system in charging mode, the super capacitor module charge first. The battery module is connected to the low pass filter in order to make the high frequency power which is produced by load mutation absorbed by super capacitor.

## 5. System Simulation and Analysis

The paper uses the software named MATLAB/Simulink to build the simulation model of system. The model verifies the effect of hybrid energy storage system and control strategy which is used to solve the problem of transient impact caused by load power mutation. The partial parameters of the model are shown in Table 1.

The simulation model is mainly composed of power generation module, bus module, energy storage module and control module. The generation module adopts constant power output at the value of 2500W. It works in maximum power point tracking mode which adopts the method of incremental conductance. The model of generation system is shown in Figure 9.

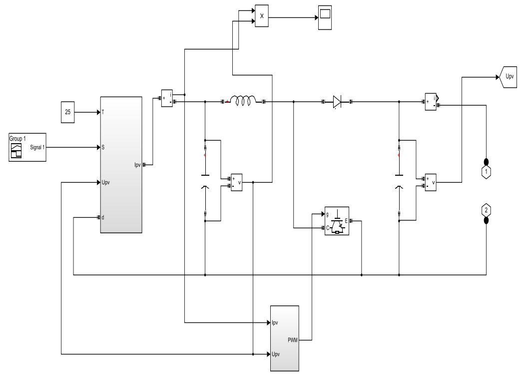

Fig.9 The model of photovoltaic system

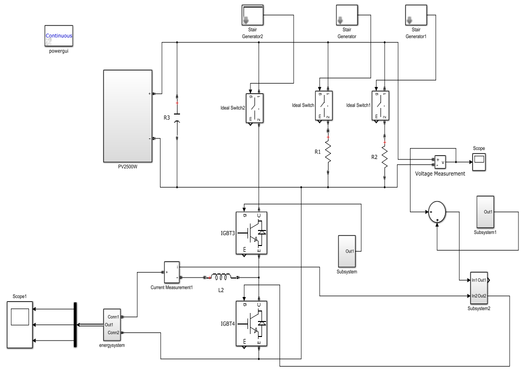

Fig.10 Model diagram of simulation system

When the load resistance has a mutation, it will inevitably affect the stability of the bus. The bus voltage will fluctuate accordingly. If the load change causes the bus voltage to decrease, the part of the power shortage will be supplied by the energy storage device. If the load mutation causes the bus voltage to rise, high frequency power and low frequency power will be charged to the super capacitor and battery respectively. The model of the simulation system is shown in Figure 10.

0-0.3 second, the system begin to work at the mode of maximum power point tracking. The bus voltage maintains 500V. In 0.3s, the load power has a mutation and the bus voltage drops of nearly 20V. At the same time, the energy storage module begin to discharge. It takes 0.1s to make the bus back to a stable state. The change process of bus voltage is shown in Figure 11.

If the mutation of the load power leads to the increase of the bus voltage, the energy storage module will perform charging operation. It will take about 0.5s to make the bus voltage return to be stable. Because the battery is used as the main energy storage unit, and the super capacitor is used as the auxiliary unit. So it costs a longer time. The change of the bus voltage is shown in Figure 12.

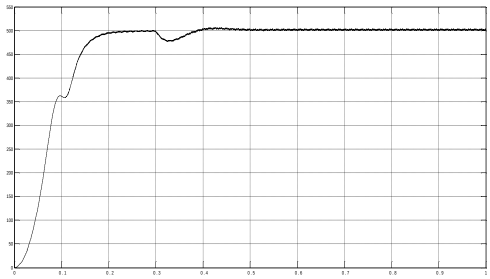

Fig.11 Diagram of bus voltage change

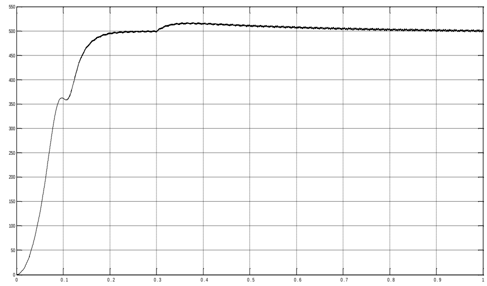

Fig.12 Diagram of bus voltage change

## 6. Conclusion

In this paper, the basic structure of micro grid and the basic process of its work are briefly described firstly. The method of balance management which is used in energy system is clarified. Then taking the module which consist of battery and super capacitor that connected in parallel as the core of the hybrid energy storage system. Proposing the structure of hybrid energy storage module and charging and discharging control algorithm. Finally, building the simulation model of the system and verifying that the structure and the control algorithm have a certain inhibitory effect on the transient impact caused by the sudden change of load on the microgrid bus.

## References

[1] Satoshi Kagami,Tomonobu Kitagawa,Koichi Nishiwaki,Tomomichi Sugihara,Masayuki Inaba,Hirochika Inoue. A Fast Dynamically Equilibrated Walking Trajectory Generation Method

IOP Conf. Series: Materials Science and Engineering **322** (2018) 072026 doi:10.1088/1757-899X/322/7/072026

of Humanoid Robot [J], 2002.
[2] Wang Cheng-shan, Li Peng. Development and challenges of distributed generation, the micro-grid and smart distribution system[J]. Automation of Electric Power Systems, 2010, 34(2):10-14.
[3] Wang Cheng-shan, Microgrid Analysis and Simulation Theory [M].Beijing: Science Press, 2013:1-2.
[4] Yang Xin-fa, Su Jian, ET al .Overview on microgrid technology [J]. Proceedings of the CESS, 2014, 34(1):57-59.
[5] ZHOU Lin, HUANG Yong, ET al. A survey of energy storage technology for micro grid [J]. Power System Protection and Control, 2011, 39(7):148-151.
[6] Zhang Xiao-hong. Research on Low - voltage Micro - grid Control Strategy with New Energy Storage Technology [M].North China Electric Power University, 2013.
[7] Feng Yan-ming. DC Distribution Network with Distributed Power Supply and Energy Storage Planning [M]. North China Electric Power University, 2013.
[8] Cheng Zhi-jiang, Li Yong-dong, ET al. Control strategy for hybrid energy storage of photovoltaic generation microgrid system with super capacitor [J]. Power System Technology, 2015, 39(10):2739-2745.
[9] LI Bin, BAO Hai-long, GUO Li. Strategy of energy storage control for islanded microgrid with photovoltaic and energy storage systems [J]. Automation of Electric Power Systems, 2014, 34(3): 8-15.
[10] Li Jun-hui, Jiao Jian, Yan Gan-gui, ET al. Simulation research of the third-order dynamic model of lead-acid battery [J]. Journal of Northeast Electric Power University,2013, 33(1-2):103-108.