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Study on the control strategy of PV-Energy storage microgrid working in islanded mode

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Abstract. This paper mainly discussed the control strategy of PV-energy storage microgrid that run in islanded mode , the PV inverter and the energy storage inverter use constant power control and constant voltage and constant frequency control respectively,with such a control strategy to ensure the microgrid in islanded mode supply the load stably. To verify the proposed theory,built the simulation model on the Simulink platform.In order to facilitate the parameters modification and improve the speed of the simulation,PQ controller was programmed by C language and embedded in the Simulink platform.Through the analysis of the simulation results,proved that the correctness and validity of the control strategy.

Introduction

Energy is an important material basis for social and economic development,as a clean and convenient energy form,energy is the lifeline of the national economy[1].Power grid safe, economical and stable operation not only directly related to people's lives, also an important issue related to the social stability and national security.In recent years, under the leadership of the China State Grid Corp, the power system has developed into a large-scale interconnected system,a system with large capacity unit centralized power, ultra transmission characteristics of high voltage long distance; at the same time, the development of power grid is also faced with multiple pressure shortage, environmental protection, operation safety and reliability.In this environment, many countries in the world have started looking for both environmental protection and high efficiency, flexible way of generating -- DG(Distributed Generation).Distributed generation has the advantage of dispersed, flexible power generation, without the need for long-distance transmission, etc. It can very well adapted to the needs of users and the disperse character of resources,so it can delay the upgrading process of the distribution network . Distributed generation also have the advantage that less pollution, high energy utilization rate, flexible installation,etc[2].

Comparing with the traditional power grid,the distributed generation has a variety of advantages, its development still exist many problems, in order to solve these problems, fully tap the distributed power generation for grid and user benefits, promote the integration and application of large scale DG better, at the beginning of this century, some Western scholars put forward the concept of MicroGrid[3]. Micro grid is a small electric power system,including distributed power, energy storage, energy conversion device, load, control and protection devices.It can realize the self control, management and protection, this distribution system can not only with large grid connected operation, also can be run in island mode.When the main grid failure or maintenance, Microgrid need divorce from it, namely the Microgrid need to operate the way island.when the Microgrid is in island mode, power supply fluctuations may cause imbalance of the output of the Microgrid or a substantial offset of the frequency.If this imbalance or offset beyond the range of the threshold value, it may cause the micro grid instability.Therefore, in the microgrid islanded operation mode, looking for an effective and flexible control strategy is very important[4].

In this article,according to the microgrid islanded operation mode,put forward the constant power control (PQ control) and constant voltage constant frequency control method(V/f control) . The energy storage system for V/f control, is used to determine the voltage and frequency of power grid

needs;PQ control for photovoltaic system,is used to provide power to the load of the Microgrid.At the same time, in the photovoltaic output can not satisfy the load, the energy storage system were added; when the photovoltaic output redundancy, redundant portion to the storage battery charging, so as to realize power economic utilization[5,6].In the simulation analysis of this article, the photovoltaic system PQ controller is programmed by C language, and the program is integrated cure to Simulink simulation system, which not only facilitates rapid adjustment of parameters, and also can save simulation time of Microgrid system for long time scale.

System structure

In this paper, the islanding operation using energy storage system and photovoltaic system for parallel operation mode, and the energy storage system using V/f control, PQ control for photovoltaic system. As shown in Figure.1, the PV system and energy storage system adopts three-phase voltage type inverter circuit, photovoltaic system using L filter,energy storage system using LC filter, and the two systems in parallel to the load side[7].

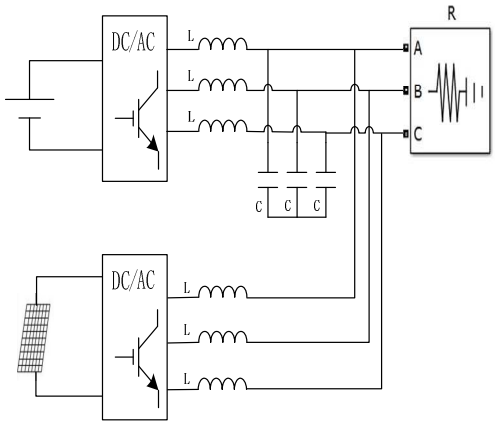

Fig.1 Microgrid islanding system architecture

Operation control method

PQ control. The main purpose of photovoltaic system using PQ control is to make the PV system output reference the output specified power and reactive power, i.e. when the frequency and the voltage of the load side bus changes within a certain range, the active power and the reactive power output of photovoltaic system maintain constant.Figure.2.1 is the actual generation power curve of a photovoltaic system, we can see from the chart, the active power output of photovoltaic system has serious fluctuation,in the simulation photovoltaic system need to reproduce the volatility, and guaranteed the output of the whole system together with the energy storage system.

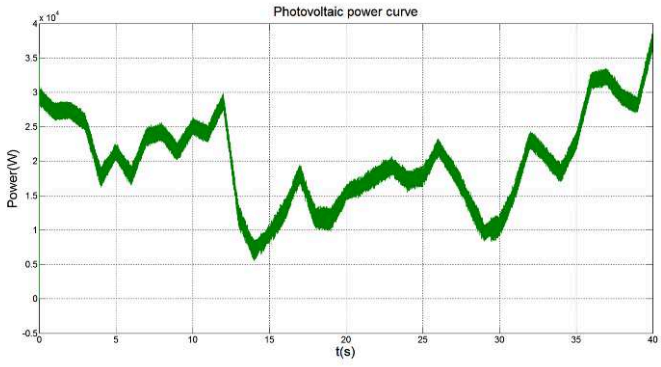

Fig.2.1 Photovoltaic power curve

The photovoltaic system main circuit of the Microgrid choose three-phase full bridge circuit, the inverter output filter, using L. The control part by sampling the output voltage and current, the sampling result is transmitted to the C language program,the program include power measurement module, PQ control module, and the SVPWM modulation module.The power measurement module

calculate active power (P) and reactive power (Q)by sampling the voltage and current of the inverter output; the PQ control module generate a modulated signal to SVPWM modulation module, the modulation module generates a trigger pulse output from the program.

Figure.2.2 digital integrated power measuring module, PQ control module, and the SVPWM modulation module. By compiling C language program to realize the above functions in digital.

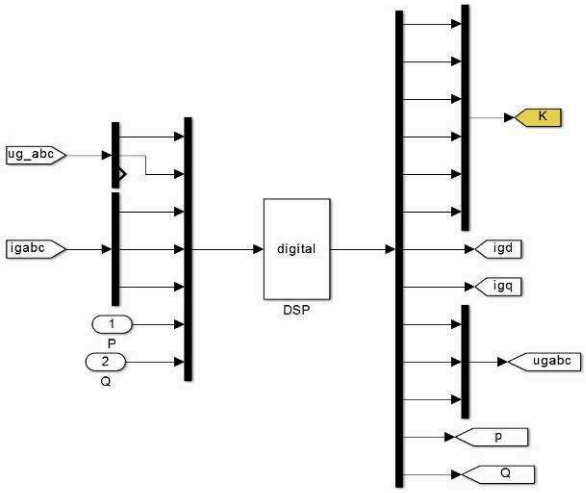

Fig.2.2 Controller model

Figure.2.3,the PQ control module structure, including two parts,power control and current control. P and Q are obtained from the power measurement module,P and Q compared with the reference power Pref and Qref, and the errors are used to PI controller, the PI controller's output as the reference of current loop controller,idref and iqref; three-phase current through CLARK and PARK transformed obtain id and iq, id and iq compared with idref and iqref respectively,and the errors are used to PI controller,in the end, according to the circuit principle generate the modulated signal to adjust the modulation module for SVPWM.

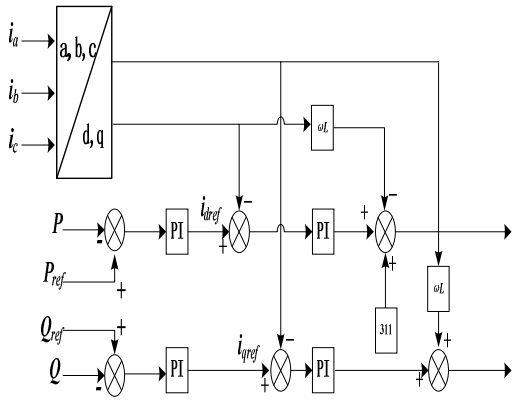

Fig.2.3 PQ control block diagram

According to the structure of PQ controller, the control strategy of PQ is through decoupling the control of active power current and reactive power current, realize the system output active and reactive power decoupling control. Its essence is a kind of current control.

In the construction of Microgrid,we can find the output power of photovoltaic and wind is influence by weather greatly, which leads to the electricity has obvious fluctuation and intermittence, if we need such distributed generation can adjust its generating capacity according to the load , appropriate capacity of energy storage system is necessary.And, in the island mode, not only the need to equipment the energy storage device, also need to select a appropriate controller according to the characteristics of the islanding operation[8].

V/f control. Constant voltage constant frequency control strategy is designed to ensure that: regardless of inverter output active power and reactive power how to change, the amplitude and frequency of the output voltage is constant or controlled within the acceptable range.This control

strategy can provide strongly voltage support and frequency support for the Microgrid in the islanded mode, also ensure that the system has certain ability to follow the load power.

The inverter circuit use V/f control is shown in Figure.2.4. The main circuit of three-phase full bridge inverter circuit, inverter with LC filter.In the control loop, voltage loop is the outer loop, current loop is the inner loop.

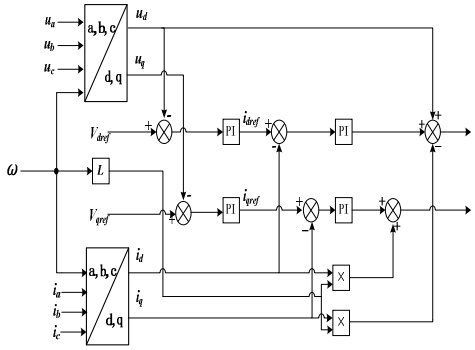

Fig.2.4 V/f control block diagram

In the figure, f_{ref} is the reference frequency of the inverter output voltage,multiply it with 2π,after an integral link, can obtain the reference phase θ of the output voltage, reference phase mainly used for voltage PARK change and inverse PARK transform; V_{ref} is the reference amplitude of the output voltage.

The inverter output voltage V_{abc}, by PARK transform get V_d and V_q,compared with the reference voltage V_{ref} and 0 respectively, the errors are used to PI regulator, PI regulator's output as the given inner current control reference, then the actual current compared with the given value and the result to PI controller, through the controller's output we can obtain the modulation signal and trigger pulse.In the Microgrid system, battery energy storage device can regulating output power of its own according to the load, so often as a microgrid islanded mode voltage source, to maintain the power balance of power system. In the microgrid islanded mode, V/f control strategy is suitable for battery energy storage system[9,10,11].

Simulation and Analysis of the results

Simulation use the Simulink module of Matlab to verify the proposed theory, and analyzes the simulation results.The structure of main simulation circuit is shown in Figure.3.1,among them, the energy storage system with LC filter,L1=0.003H,C=1500μF;PV system choose L filter, the filter inductance L2=2mH;the load is the constant power type.The whole process of simulation assumes that the battery energy storage system capacity is large enough, there is no charge and discharge limits.

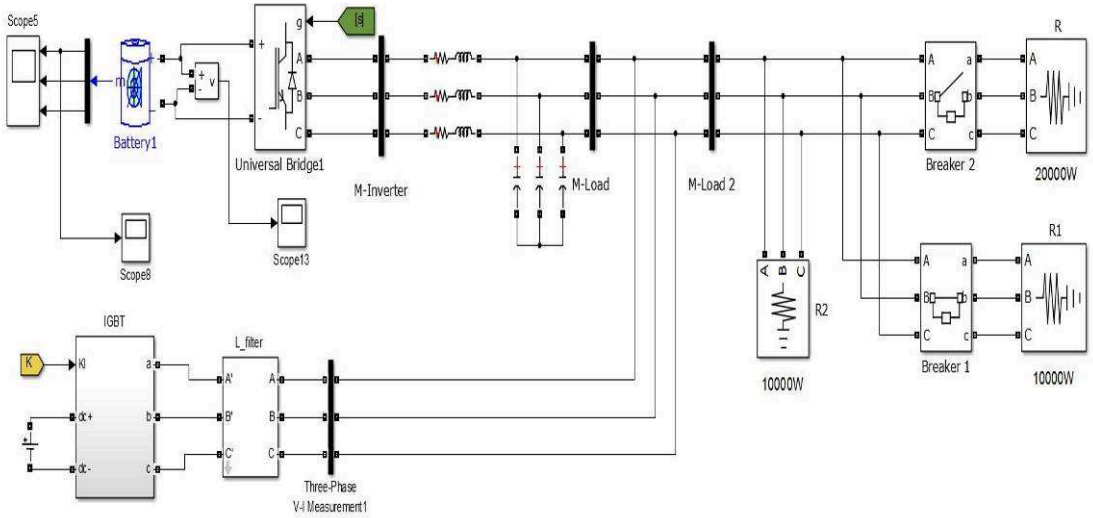

Fig.3.1 Micro-grid island circuit simulation

In the 40s simulation,the initial load of Microgrid is 20kW, in 10s the load fell to 10kW from 20kW ; in 25s the load increased from 10kW to 30kW and run to the end.The simulation results are shown in figure 3.2:

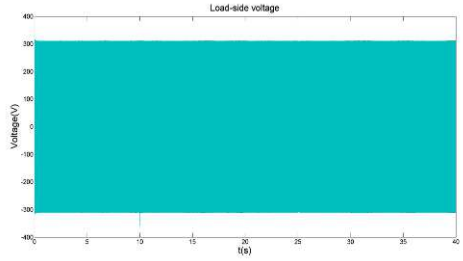

Fig.(a) Load-side voltage

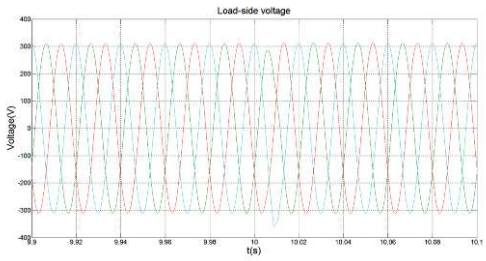

Fig.(b) Local voltage of load

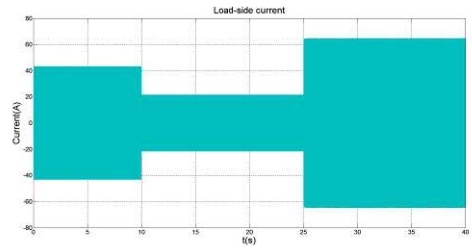

Fig.(c) Load-side current

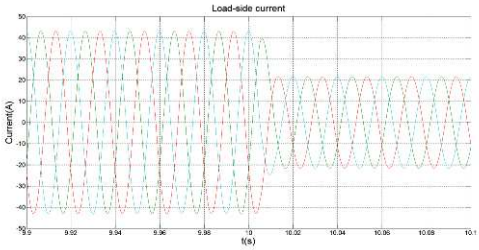

Fig.(d) Local current of load side

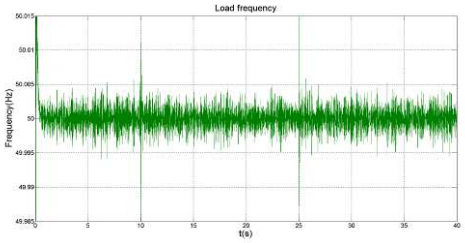

Fig.(e) Load frequency

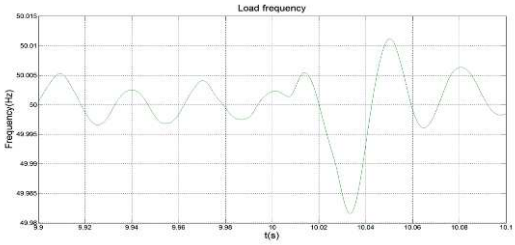

Fig.(f) Local frequency of load side

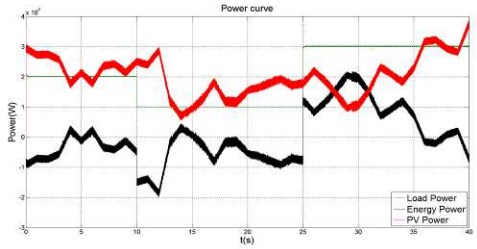

Fig.(g) Power Curve

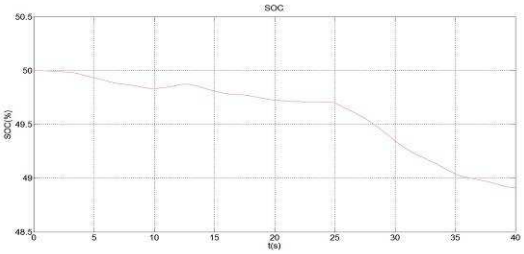

Fig.(h) State of charge

Fig3.2 Simulation curve

We can see from Figure.3.2 (a), in the whole process of simulation,the bus voltage produced no large fluctuations, and always maintain the standard voltage, and by the load side local voltage Figure.3.2 (b) can be seen, even the load is steep, voltage waveform can be quickly restored to standard mode, meet the demand of power supply; Figure.3.2 (c) and 3.2 (d) respectively busbar current curve of the whole simulation process and the load side partial current curve,through Figure. 3.2 (c) we can find, in the whole process of simulation, the load current can better tracking the load change , from Figure.3.2 (d) we can find, in the load steep moment, based on voltage stability, the current can quickly track the load changes, and get better waveform; Figure.3.2 (e) and 3.2 (f) are the load frequency curve and the load side partial frequency curve respectively,through the curve we can find, the load frequency control in the vicinity of 50Hz more accurately, Figure.3.2 (f) shows that, even in the process of abrupt change of load ,the controller can still call for rapid and accurate control to maintain load side bus frequency, to ensure the stable operation of the Microgrid; Figure.3.2 (g) is the power curve of the load side, Figure.3.2 (h) is the SOC curve of battery energy storage system, Figure.3.2 (g) ,the power curve, in the photovoltaic system output is greater than the load demand, energy storage system stores excess capacity, at this time, the battery energy storage system SOC

Line up, when the photovoltaic system output is less than the load demand, energy storage system discharge, ensure stable operation of microgrid system, SOC curve decline, in the whole power change process, Microgrid system load voltage and frequency of the bus are all in the acceptable range by the V/f controller , guarantee the whole system stability.

Table 1 Photovoltaic energy storage operation data

		0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0	PV	–	29,198.12	28,067.73	27,351.00	21,979.45	18,611.22	20,445.92	19,885.28	23,972.16	22,425.44
	Storag	–	-9,077.62	-7,962.76	-7,225.12	-1,912.76	1,483.94	-361.70	236.24	-3,869.86	-2,378.87
1	PV	22,800.43	25,341.91	24,969.83	23,221.44	11,360.36	7,970.56	11,104.49	14,121.00	16,425.85	11,947.79
	Storag	-2,706.02	-15,307.70	-14,930.37	-13,202.94	-1,315.11	2,073.82	-1,051.52	-4,069.71	-6,372.20	-1,902.22
2	PV	13,156.41	16,891.89	15,869.00	17,944.76	18,373.66	16,994.45	18,055.46	22,293.66	17,792.29	12,840.81
	Storag	-3,090.04	-6,845.31	-5,812.61	-7,902.40	-8,322.62	-6,943.86	11,979.19	7,882.82	12,298.66	17,248.85
3	PV	9,815.33	10,915.21	16,223.83	23,266.21	20,373.45	19,184.68	23,618.33	31,662.93	32,195.51	28,437.84
	Storag	20,292.38	19,202.91	13,964.99	6,894.20	9,756.10	10,943.35	6,532.15	-1,586.01	-2,027.75	1,712.18
The power unit is [W], unit of time is [s]											

By comparing the simulation results and the actual operation data in Table 1, the load side voltage maintained at a given value about 311V, and defines the range of voltage fluctuations in the national standard of not more than 5%; frequency of the Microgrid load side maintained at a given value about 50Hz, and defines the range in the frequency fluctuation of not more than 1% ;The whole energy storage system can quickly track and added the power difference between photovoltaic side and load side , when mutated happened, voltage, current and frequency can rapidly change according to the load ,ensure the whole system stable. According to the power curve can be seen,when the load side power mutated, energy storage system can adjust its output rapidly according to the photovoltaic system, and when photovoltaic system can fully meet the load demand, the storage battery charging to ensure the rational use of energy.Through observing the SOC curve of the energy storage system, it is more intuitive to observe the charging and discharging process.

Conclusion

This paper mainly discusses the control strategy of microgrid in islanding mode, selecting the constant power control for PV system to transmit power to the load side,according to the output characteristic,easily affected by the weather,of photovoltaic system, the energy storage system is selected to supply the lack capacity, at the same time,the energy storage can absorb the excess part.The energy storage system using V/f control,ensure the voltage and frequency of the load side stable.Through the analysis of simulation results and graphics, demonstrate that the control strategy is feasible and correct in the islanded Microgrid.

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