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Research on Inverter Control Technique for off grid Wind Power Generation System

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***Abstract*:** The paper studied the typical off grid wind power generation system. And then, the paper researched on the control strategy of the single phase inverter, especially studied the PID control and double closed-loop control. At last, the paper simulated the control effect of PID control and double closed-loop control with MATLAB software. In particular, the double closed-loop control system has been tested again and again to obtain a set of ideal parameters. In order to simulate the sudden increase and decrease of user load in power generation system, we suddenly add the disturbance in the simulation system. The results show that the double closed-loop control system has better steady precision and has strong robustness to load disturbance.

Index terms: *inverter, PID control, double closed-loop control, wind power generation system.*

I. INTRODUCTION

With the global energy crisis and environmental issues become increasingly prominent, the development of wind energy as one of the most commercial renewable energy has attracted much attention. The United States, Europe and India are the main drivers of the global wind power industry, wind power industry not only can bring significant economic and social benefits, but also ease the shortage of resources to some extent[1]. But the cost of the small wind power generation system is high in China, the stability is poor and the output waveform quality is generally low [2].Therefore, it is important to improve the quality and efficiency of the output voltage of the rectifier inverter with a reliable and reasonable control system and an effective control algorithm. With the rapid development of digital control technology, there has a variety of control algorithm of the inverter of the off grid wind power generation system, such as single closed-loop PID control , double closed-loop control, deadbeat control, variable structure control with sliding mode(VSS), fuzzy control and repetitive control which has rapidly developed in recent years.

PID control has simple structure and easy to master, but can't achieve no static-error tracing. Double closed-loop control has good dynamic performance and steady state accuracy, but if the selection of the parameters is not good, especially when there is a disturbance, the control effect is also biased. Deadbeat control is a kind of PWM scheme based on discrete mathematics model, the control process has no overshoot and good dynamic performance, because the transient response of deadbeat control is fast, and the system is very suitable for the application of this control algorithm in the system which is easy to be influenced by the external environment [3]. Repetitive control is based on the internal model principle in control theory. The internal model principle essentially constitutes a feedback control system through implants the dynamic model of the system external signal in the controller, so that the system can track the input signal [4]. Variable structure control with sliding mode (VSS) has good performance and strong robustness, but the system is not ideal, the sliding mode surface is difficult to choose. Fuzzy control theory can approximate the nonlinear function with arbitrary precision, but because of the influence of the current technology level and people's experience, the split file of fuzzy variable, the selection of rules and the determination of membership functions are lack of uniform design method and theory [5].

In this paper, the MATLAB software is used to carry out many experiments on the double closed loop control system, and a set of ideal parameters are selected. By using this set of parameters, the wind power system has good dynamic and static performance.

II. OFF GRID WIND POWER GENERATION SYSTEM

Small off grid wind power generation system is composed of wind turbine, generator, electric energy conversion device (rectifier, DC voltage regulator, inverter), controller, discharging load, battery, brake device and user load. The operation process of the wind power generation system is as follows, first wind energy is transformed into mechanical energy by wind turbine, then variable voltage and variable frequency AC produced by the generator is rectified into unstable DC current, after the regulator and inverter circuit it becomes constant frequency and voltage AC to supply the user load.

In China, the standard distribution system is single phase 220V/50Hz. The rectifier converts the low voltage AC to 48V DC, and then through the charger to convert the 48V DC to the required high voltage DC power, it is AC Fang Bo about 380V~410V. A stable high voltage DC power is obtained after the full bridge rectifier and the voltage regulator. Then through the full bridge inverter circuit and output filter circuit, we use the unipolar SPWM modulation method to control the inverter switch tube, and generate 220V/50Hz AC.

III. RESEARCH ON CONTROL STRATEGY

A. the Simulation of PID Control of Wind Power System

The voltage PID control system is shown in Figure 1: the reference input value U_{ref} is compared with the measured value U_o. The error signal is processed by the PID controller to generate the SPWM control signal and control the power switch of the inverter.

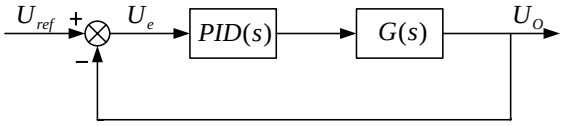

Fig 1. Voltage PID control system chart

where $PID(s)$ represents the PID controller and $G(s)$ represents the mathematical model of the inverter.

$$PID(s) = K_P + \frac{K_i}{s} + K_d s$$

$$G(s) = \frac{1}{LCs^2 + r_L Cs + 1}$$

where K_P, K_i and K_d are proportional, integral and differential coefficient. Filter inductance L=10mH, filter capacitor C=100uF, load resistance R= ∞ .

In this paper, trial-and-error method is used to obtain the ideal control parameters of the PID controller. On the basis of the establishment of the simulation model of PID controller, the most ideal parameters are obtained, they are as follows: $K_P = 47.5$, $K_i = 24.5$, $K_d = 2$

In order to verify the control effect of PID in the wind power system control, the MATLAB is applied to establish the simulation model with voltage PID control, and during the procession we add the sudden disturbance. The parameters of the system are as follows: DC bus voltage $E = 400\ V$, DC bus voltage interference signal is the AC voltage of 20V/60HZ, switching frequency f_s =1250Hz, filter capacitor C =100uF, filter inductance L =l0mH, inductance equivalent series resistance r_L =0.1 Ω , load resistance R=10 Ω , the reference voltage is 220V/50HZ AC.

After the establishment of the simulation model, during 0.07s - 0.125s we add sudden resistance of the load $R_{load} = 50\ \Omega$ to simulate the sudden increase and decrease of user load in power generation system, and observe the output waveform of oscilloscope in Figure 2.

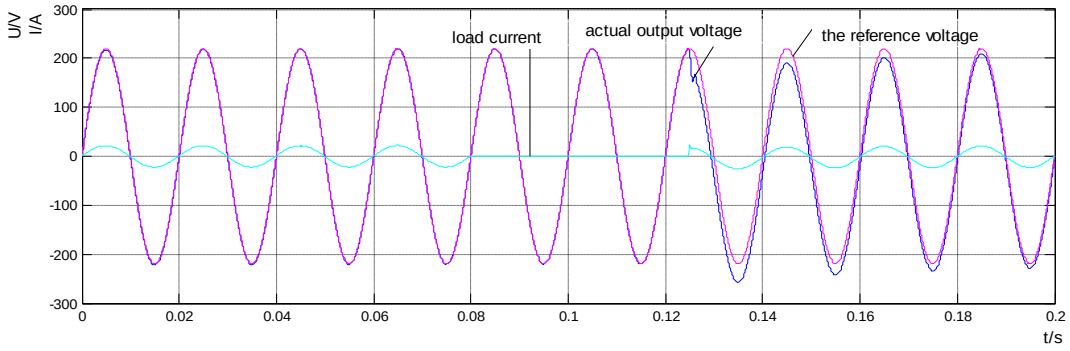

Fig 2. The output waveform of PID control with sudden disturbance

It can be seen from the figure, in a stable state, the output voltage has significant deviation with the reference voltage, especially in peak and trough. When suddenly add the load at 0.07s, the voltage fluctuation at the trough is more obvious. And when suddenly remove the disturbance at 0.125s, the voltage is fluctuated, and the fluctuation is large, and the time required to adjust to the steady state is longer.

B. the Simulation of Double Closed-Loop Control of Wind Power System

The double closed-loop control system of voltage outer-loop current inner-loop includes two types, one is voltage outer-loop inductance current inner-loop and the other is voltage outer-loop capacitor current inner-loop. We can know the detail principle of double closed-loop in [6]. The study uses the first control system. Compared with the traditional PID control, the double closed-loop control system is complex and requires two controllers, but it is characterized by high accuracy, good stability, fast dynamic response, and can improve the static and dynamic characteristics of inverter output voltage.

Voltage error signal U_e is obtained by comparing the output voltage U_o with the reference input voltage U_{ref}, after the voltage outer-loop controller $PID1(s)$, the inductor current reference signal i_{ref} is obtained, and the current error signal is processed by comparing with actual inductor current, and then through current inner-loop controller $PID\ 2(s)$ and generate SPWM modulation signal to drive the circuit to control the power switch tube to open and shut off. The control system block diagram is shown in Figure 3.

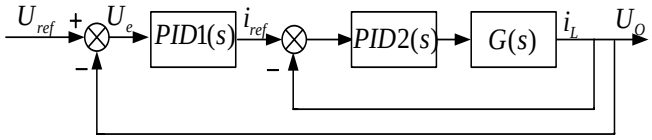

Fig 3. Double closed-loop control system chart

A simulation model is established and the order of parameters tuning is the outer loop after inner loop, and get a set of the most ideal parameters, outer loop parameters are $K_P = 30$, $K_i = 2$, $K_d = 0.1$ and inner loop parameters are $K_P = 40$, $K_i = 3$, $K_d = 0$.

In order to verify the control effect of the double closed-loop control of the wind power system, the simulation model of the double closed loop control with sudden disturbance is established by using MATLAB. Related parameters are as follows: DC bus voltage $E = 400\ V$, DC bus voltage interference signal is the AC voltage of 20V/60HZ, switching frequency f_s =1250Hz, filter capacitor C =100uF, filter inductance L =l0mH, inductance equivalent series resistance r_L =0.1 Ω, load resistance R=10 Ω, the reference voltage is 220V/50HZ AC.

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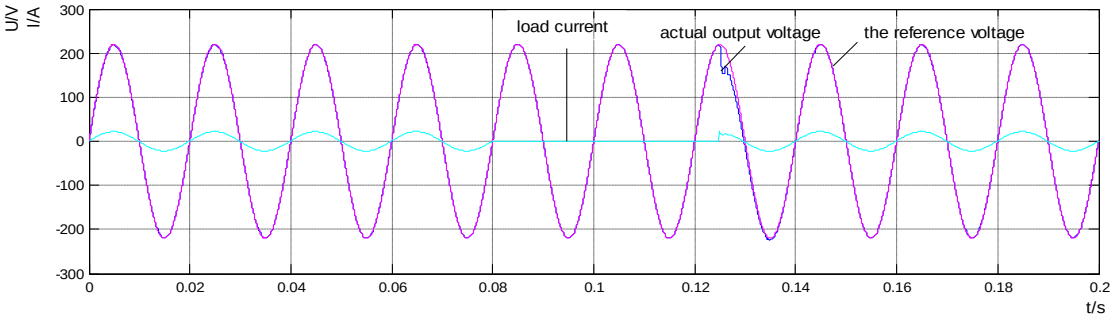

Fig 4. The output waveform of double closed-loop control with sudden disturbance

Compare figure 4 with figure 2, at the steady state, the deviation of the output voltage and the reference voltage is not obvious and control deviation is smaller than PID control. Also it has the better output voltage tracking reference voltage and the better control results. Especially at the time of adding sudden resistance, the output voltage almost has no deviation, tracking effect is very good. And when suddenly remove the disturbance

at 0.125s, the actual output voltage has littler fluctuation, but compare with PID control, it is almost perfect. Further more, the time of fluctuations is also very short, and then adjust to the steady state quickly.

IV. CONCLUSIONS

In this paper, the control strategy of the typical off grid wind power generation system is deeply studied, and the theoretical analysis and simulation experiments are carried out on the PID control and double closed-loop control strategy. It is concluded that the anti-interference ability and the steady state accuracy of the double closed loop control are better than the PID control, and also it has the better control effect. At the end of this paper, we use MATLAB to test the double closed-loop control system for many times, and finally obtain a set of ideal parameters. Using these parameters we achieve the ideal control effect, and the result shows that the system has good steady performance and strong robustness of load disturbance.

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