

Design of Grid-Connected Photovoltaic Micro-Inverter

Based on DSC

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Abstract: This paper designs a grid-connected photovoltaic micro-inverter based on double DSC control strategy. According to the characteristics of double DSC control strategy, we make appropriate innovation and improvements on circuit topology. In the part of DC/DC module isolation transformer is used. The two DSC chips respectively control the circuits before inverting and after, which realizes completely isolated. Detailed analysis the working principle and control strategy of each module and make the corresponding hardware circuit which was tested. The experiment achieved the desired results, verified the feasibility of the scheme.

Introduction

As the environment degradation, the depletion of energy and the development and utilization of solar energy have drawn more and more attention. Photovoltaic inverter technology as a key technology in the development and utilization of solar energy has important research significance. At present, most of the research in the control of photovoltaic inverter rely on a chip to achieve, this not only makes the control program large and complex, more importantly, Complete electrical isolation of the circuit before and after inverter can not be achieved. In this paper, we designed a micro-grid inverter based on double DSC chip. The design uses DC / DC-DC / AC circuit topology, Which DC / DC module using a transformer to achieve electrical isolation, DSC chip 1 controls the DC / DC module, mainly to achieve the maximum power point tracking technology, DSC chip 2 controls the DC / AC module, mainly to realize rid technology and islanding detection technology. The division of labor between the two DSC chips, completely isolated, making the entire system control accuracy and stability have been enhanced^[1,2].

System Overall Design

The overall system structure is shown in Figure.1. The DC power generated by the photovoltaic array is changed into a DC half wave after the boost of the DC/DC module, the frequency is two times the frequency of power grid. The DC half wave is processing into a power frequency AC through the DC / AC module ,the alternating current is filtered and incorporated into the power grid.

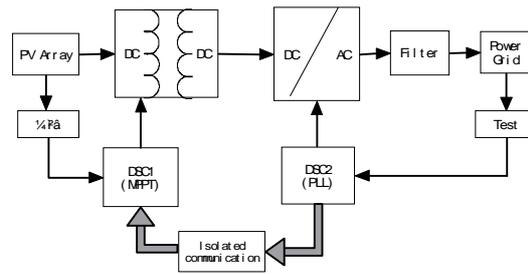


Fig. 1 Miniature grid-connected photovoltaic inverter system structure

Two control chips use freescale's DSC series chips. The chip that controls the DC/DC module chooses MC56F8245, We call it DSC1 and use it as the master controller chip. The chip that controls the DC/AC module chooses MC56F8006, We call it DSC2 and use it as a secondary control chip. DSC1 mainly to achieve the following four functions: the monitoring and protection circuit control state of the PV array and DC/DC module; drive control of DC/DC module; realization of MPPT technology. DSC2 mainly to achieve the following three functions: Condition monitoring and circuit protection control for power grid and DC/AC module; drive control of DC/AC module; PLL and the realization of the function of the grid; Islanding detection and control.

Circuit Topology

DC/DC module. The function of the DC / DC module is mainly to convert the DC voltage output by the PV array into a DC half-wave sine. The structure diagram shown in Figure 2:

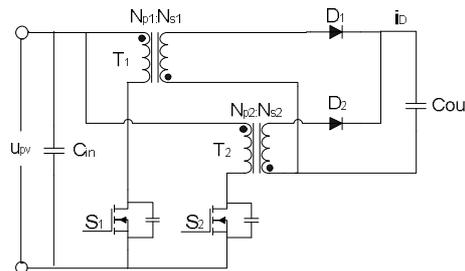


Fig. 2 Schematic diagram of DC/DC module

The structure of the circuit is interleaved flyback converter. Among them, S_1 and S_2 are the main power switching tubes of two interleaved flyback converters. T_1 , T_2 are two flyback transformers. N_{P1} , N_{S2} and N_{P2} , N_{S2} , are respectively the primary turns and secondary turns of T_1 and T_2 . D_1 and D_2 are two side rectifier diodes for two way converters.

The main power switch S_1 and S_2 are alternately turned on, take S_1 as an example to illustrate the working principle. When S_1 turns on, D_1 turns off and energy is stored in the T_1 inductor. When S_1 is off, D_1 turns on, energy is released via D_1 , and charges C_{out} . The longer the S_1 on time is, the more energy is stored in T_1 and the greater the peak current of S_1 flowing through D_1 and vice versa. Therefore, by controlling the on-off time of S_1 , the current profile of the current flowing through D_1 exhibits a variation of a sine half-wave, and the half-wave current i_D of the sine wave can be obtained after being filtered by the C_{out} capacitor.

The specific control methods of S_1 and S_2 are various, in this design, a soft switching control strategy using leakage inductance resonance is adopted, this can achieve zero voltage turn-on and zero voltage shutdown of S_1 and S_2 , reduce switching losses of S_1 , S_2 and improve inverter efficiency.

DC/AC module. The main function of the DC/AC module is to invert the sine half-wave output from the DC/DC module into a complete sine wave. The structure diagram shown in Fig.3:

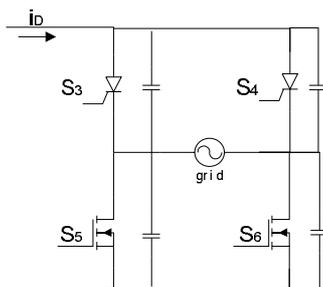


Fig.3 Schematic diagram of DC/AC module

Circuit structure uses H bridge inverter circuit. Among them, S_3 and S_4 are SCR, S_5 and S_6 are power tubes. The control strategy is as follows: When the grid voltage is in the positive half cycle, S_3 , S_6 controlled to turn down and S_4 , S_5 turn off. When the grid voltage is in the negative half cycle, S_4 , S_5 controlled to turn down and S_3 , S_6 turn off, so the sine half wave can be converted into a complete sine wave and incorporated into the power grid. Because the switching and closing of all switches are at the time of phase transition of the grid voltage, the voltage and current of the switch are almost zero when the switch is on and off, and the loss of the switch tube is reduced to the minimum.

The main working waveform involved in the entire inverter process is shown in Figure. 4:

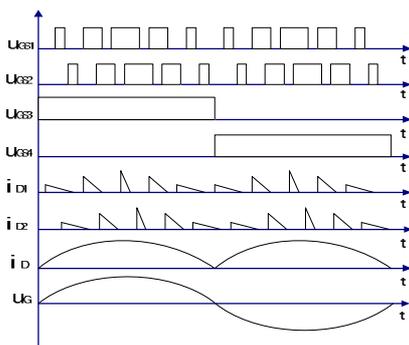


Fig. 4 Correlation waveforms of inversion process

Leakage inductance energy feedback circuit. Due to the existence of the transformer leakage inductance, a certain amount of energy must inevitably be lost in the form of leakage inductance energy during the inverter process, this will reduce the inverter's efficiency. At the same time, turn off the main switch at the moment, the oscillation caused by the leakage inductance and the parasitic capacitance of the main switching transistor forms an instantaneous high voltage between the drain and the source of the main switching transistor, this will make the main switch tube will lead to serious breakdown. Therefore, the necessary voltage clamping measures must be taken to ensure that the voltage between the main drain tubes of the main switch is in the safe range. The design of the leakage inductance energy absorption feedback circuit can successfully solve these two problems. The circuit diagram shown in Figure. 5:

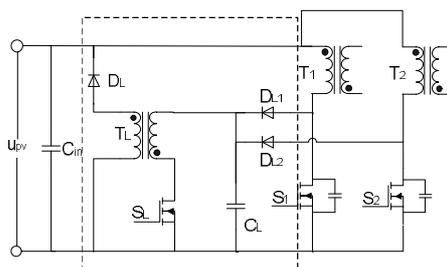


Fig. 5 Leakage inductance energy feedback circuit

The dotted line in Fig. 5 shows a leakage inductance energy absorption feedback circuit. The flyback converter is also used in the circuit, among them, D_{L1} , D_{L2} and C_L make up leakage inductance energy absorption circuit, D_{L1} and D_{L2} are leakage inductance energy absorption diodes, C_L is the clamp capacitor. D_L , T_L and S_L constitute leakage inductance energy feedback circuit. D_L is the leakage inductance energy feedback diode, T_L is a high-frequency transformer, S_L is the power switch tube.

The leakage inductance energy absorption circuit works as follows: when the main power switch S_1 and S_2 are turned on, diode D_{L1} and D_{L2} are cut off due to reverse bias, the leakage inductance energy absorption circuit does not work. when the main power switch S_1 and S_2 are turned off, diode D_{L1} and D_{L2} are turned on, the leakage inductance energy is absorbed and stored by capacitance C_L .

The working process of leakage inductance energy feedback circuit is independent of the working process of the main circuit, and has no influence on each other. The working process is as follows: when the power switch S_L is turned on, the rectifier diode D_L is cut off, the leakage inductance energy is stored in the inductance of the high frequency transformer T_L . when the power switch S_L is turned off, the rectifier diode D_L is switched off, the leakage inductance energy stored in the high frequency transformer inductance is fed back to the input via D_L .

The suppression of speak voltage can be controlled by PI regulation, through the PI regulation loop, the C_L voltage of the clamping capacitor is equal to the sum of the PV array input voltage and the grid voltage reflection voltage. This can not only ensure the leakage voltage of the main power switch tube in the safe voltage range, but also ensure that the main inductance energy of the inverter is not absorbed. The specific control strategy is as follows:

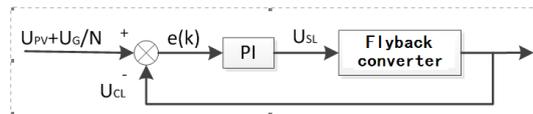


Fig. 6 PI control strategy

U_{PV} is the input voltage of photovoltaic array, U_G is the grid voltage, N is the main transformer primary side turns ratio, U_{CL} is the clamp capacitor voltage. U_{SL} is the leakage inductance energy feedback circuit and the gate voltage of the power switch tube, the waveform is a fixed frequency, PWM is duty cycle adjustable. The sum of the reflected voltage of PV array input voltage and grid voltage $U_{PV}+U_G/N$ is used as the setting value, the clamping capacitor voltage is the measured value. The difference $e(k)$ between the setting value and the measured value is used as the input parameter of the PI regulator, the output parameter of the PI regulator is the duty cycle of the PWM wave. The clamp capacitor voltage can be changed by using PWM wave to control the flyback converter of the leakage inductance energy feedback circuit.

Dual DSC Control Strategy

The control chip used in this design is the DSC chip of Freescale company, which are MC56F8245 and MC56F8006 respectively. The DSC chip is characterized by the combination of processing capabilities of digital signal processor (DSP) and microcontroller (MCU) functions on a single chip with a flexible set of peripheral devices. Among them, MC56F8245 has six eFlexPWM modules using NanoEdge layout technology, it can meet all kinds of harsh requirements of PWM wave in DC/DC process. There are two very high speed analog-to-digital converters. It can meet the real-time measurement of key parameters. MC56F8006's PWM function is not as powerful as MC56F8245, but its PWM module has programmable fault detection function to meet the requirements of DC/AC module. The two chips have the advantages of low cost, flexible

configuration and streamlined program code, and they are especially suitable for solar inverters.

The development environment for software writing is Codewarrior Ide 8.3 of the Freescale company. In this development environment, there is a ProcessorExpert function, which can greatly simplify the development process. Users only need to call the relevant functional modules and configure the relevant parameters, you can automatically generate code. Figure 7 shows the configuration interface for the PWM module of MC56F8245.

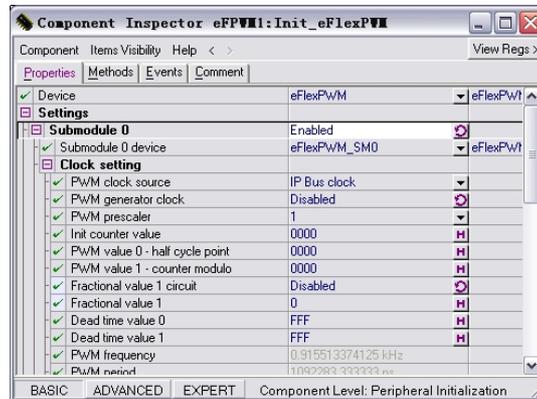


Figure 7 PWM module configuration interface

Soft switching control strategy^[3] can be used in inverter technology, Phase locked technology can be based on coordinate system transformation of digital phase-locked loop^[4]. There are two kinds of islanding detection methods, passive and active^[5]. Maximum power point tracking can use a tracking method without current detection^[6]. These can be achieved on the above DSC chip.

Conclusion

According to the scenario described in this paper, finally, the circuit board is produced, and the relevant code is written and tested. The experimental results have achieved the desired results, and the feasibility of the scheme is proved.

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