ISSN: 2414-1895 DOI: 10.6919/ICJE.202209_8(9).0011

Research and Design on Distributed Independent Photovoltaic Power Generation System

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Abstract

With the rapid development of economic, progress of science andtechnology, more and more traditional energy will be on demand , which brings us a series of problems such as energy crisis and environment pollution. As a clear energy, solar energy has been paid attention to and will be a potential one new energy. This paper mainly introduces the independent solar photovoltaic control system, and expounds the charging and discharging control system of the battery and the inverter system. In the controller design part, the PWM inverter control mode is designed by analyzing the characteristics of the solar cell and the battery to charge the battery. The main circuit uses the BUCK circuit to realize the charging control design. In the inverter part, since the design is with DC load, the DC/DC conversion circuit is adopted, and the method of load maximum power tracking (MPPT) is adopted, which has the advantages of rapidity, stability and accuracy.

Keywords

Photovoltaic Charge and Discharge; Maximum Power Point Tracking; Buck Circuit; DC/DC Conversion.

1. Introduction

Since the French scientist E. Bequerel discovered the photovoltaic effect of liquid in 1839, solar cells have gone through more than 160 years of development history[1]. From the overall development point of view, basic research and technological progress have played an active role in promoting[2]. What played a decisive role in the practical application of solar cells was the successful development of monocrystalline silicon solar cells by Bell Labs in the United States, which played a milestone role[3]. So far, the basic structure and mechanism of solar cells have not changed. The subsequent development of solar cells is mainly the research and development of thin-film cells.

China began to develop solar cells in 1958, and the first solar cell with practical value was born in 1959. After more than 40 years of hard work, China's photovoltaic power generation technology has reached a certain level and foundation. By the end of 2004, more than 10 professional photovoltaic cell production plants have been built[4]. The annual production capacity of crystalline silicon photovoltaic cells is about 57MW, the annual production capacity of amorphous silicon modules is about 10MW, and the annual production capacity of photovoltaic cell modules is above 150MW. The global annual output of solar cells is growing rapidly. In 2007, the growth rate increased by 56% compared with 2006. The annual output of solar cells reached 3436MW. The market share of Chinese manufacturers increased from 20% in 2006 to 35%[5].

Since 2003, the whole world has entered a golden age of prosperity, energy prices have skyrocketed, European countries have implemented subsidy policies for solar power generation, and the solar photovoltaic industry has developed rapidly in recent years. With the continuous advancement of

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DOI: 10.6919/ICJE.202209_8(9).0011

photovoltaic power generation technology, the cost of solar modules has been continuously reduced. In the past 30 years, the cost of solar photovoltaic modules has been reduced by two orders of magnitude. In the field of solar power generation, Germany, Japan, and the United States maintain the world's leading positions. Germany's photovoltaic market share is the largest in the world, accounting for 51.0% in 2006 and 46.0% in 2007. 99%, according to the German Federal Association for Solar Energy Economics, the global installed capacity of solar power will increase from 1,210MW in 2005 to 3,000MW in 2010, with an annual growth rate of 22%. A quarter of the world's solar cells are produced in Germany, and Germany's global market share has remained at 10% in the past five years[6].

2. Overview of Solar Photovoltaic Systems

2.1 Solar Photovoltaic Array

A solar panel is generally defined as more than one cell packaged and connected together. Solar panels come in different voltage and current ranges, but generally have a power generation capacity of 50W to 300W. Solar cells and panels have many of the same parameters, such as , P and I-V curves, Figure 1 is the I-V characteristic curve of solar cells.

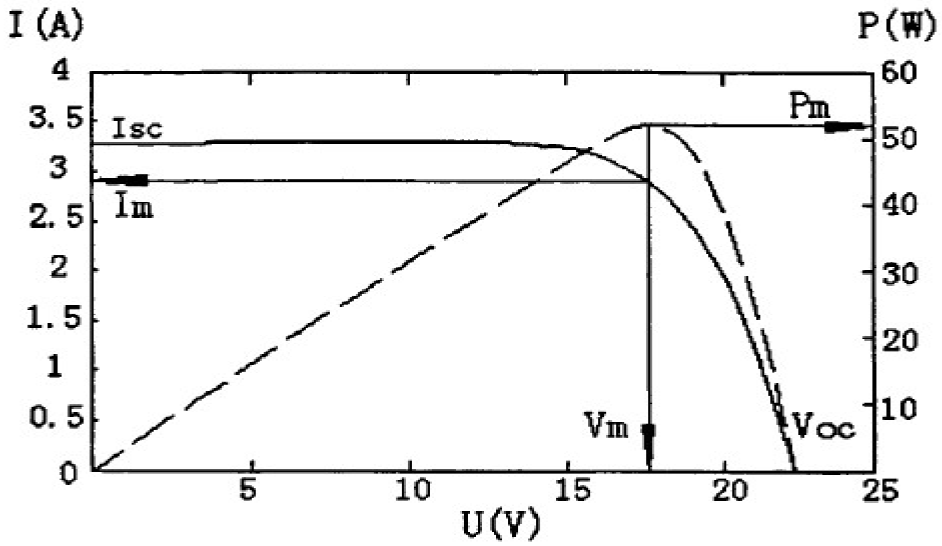

Figure 1. The I-V characteristic curve of solar cells

2.2 Research on Battery Performance

The battery is a device for storing electrical energy. The commonly used battery is a chemical battery, which mainly converts electrical energy into chemical energy through the redox reaction of chemical substances and stores it. When working, the chemical energy is converted into DC electrical energy through its reverse reaction.

In a solar independent photovoltaic power generation system, the charging control method used for the battery directly affects the performance of the system. The quality of the charging control method affects the amount of charge of the battery, and also affects the service life of the battery. The amount of charge determines the ability of the solar independent photovoltaic power generation system to supply power to the load, and the service life of the battery is related to the cost, cost and service life of the system. Therefore, choosing a reasonable charging control method is to improve the performance of the solar independent photovoltaic power generation system. effective means. At present, the commonly used charging controls for batteries include constant current charging, constant voltage charging, two-stage and three-stage charging methods.

This paper adopts the three-stage charging method as shown in the figure 2 below: Each stage is charged with constant current or constant voltage, depending on the set values of current and voltage

Eb 1, Ib 1, Eb2 , Ib2. The first stage is charged with a constant current of Ib 1, and when the voltage reaches Ebl, the second stage is transferred. The second stage is charged with constant voltage. As the battery terminal voltage increases, the current will gradually decrease. When the charging current reaches Ib2, it will turn to the third stage. The third stage is charged with constant current. At this time, the battery voltage is further increased. When the voltage reaches Eb2, it is charged with Eb2 constant voltage. At this time, the charging current is further reduced. When the specified number of ampere hours is reached, the charging is stopped.

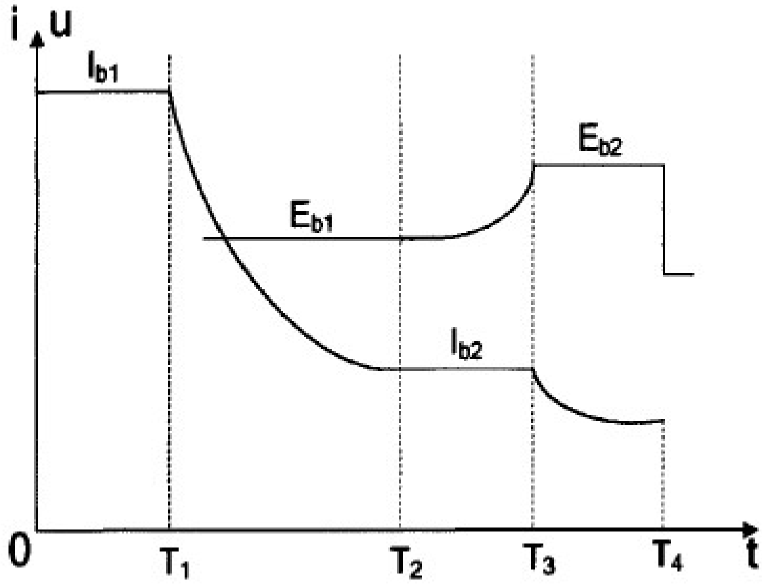

Figure 2. Three-stage charging process curve of battery

3. Solar Charge Control System

3.1 Maximum Power Point Tracking Principle

It can be seen from the above that the output characteristics of solar cells are affected by factors such as battery temperature and light intensity. Even when the external environment is stable, the output power of photovoltaic cells will change with the external load. Only when the external load changes The photovoltaic device will only output the maximum power when the impedance matching with the photovoltaic device is achieved. At this time, the photovoltaic device is said to work at the maximum power point (Maximum Power Point, MPPT for short). The photovoltaic cell is neither a constant current source nor a constant voltage source. It is a non-linear DC power supply. By continuously adjusting the operating point of the photovoltaic device, the photovoltaic cell always works in the process of outputting the maximum power, which is the maximum power point tracking of the photovoltaic cell (MPPT). It can be seen from the characteristic curve of the photovoltaic cell that when the output voltage of the battery is less than the maximum power point voltage, its output power increases with the rise of the voltage V; when the battery output voltage is greater than the maximum power point, its output power decreases with the rise of the voltage V. Therefore, the implementation of MPPT is essentially a process of dynamic self-optimization. By detecting the current output voltage and current of the array, the current output power of the array is obtained, and then compared with the stored power at the previous moment, the smaller one is selected. , and then detect and compare, and so on, so that the solar cell array always outputs the maximum power. At present, the DC/DC conversion circuit is generally used to achieve the maximum power output, and the transformation ratio is adjusted by adjusting the duty cycle of the switch tube of the converter, thereby realizing the maximum power point tracking of the solar cell array.

3.2 Several Algorithms of MPPT

3.2.1 Constant Voltage Control Method

The output power of the photovoltaic array is mainly affected by the temperature of the battery and the intensity of the illumination, but compared with the influence of the temperature change of the solar panel on the output power, the change of the illumination intensity has a greater impact on the output power of the photovoltaic array. The output voltage V corresponding to the maximum power point does not change much under different irradiation intensities. A large number of experiments show that the ratio of V to open circuit voltage under the same irradiance is only related to the parameters of the photovoltaic module, and is not sensitive to changes in ambient temperature. , which can be approximated as a constant. Therefore, the maximum power tracking algorithm designed based on the above characteristics is called the constant voltage control method.

3.2.2 Perturbation Observation Method

The perturbation observation method is one of the most commonly used methods to realize MPPT control. Its control principle is through. Apply disturbance to the circuit, change the working state of the solar cell array, observe and calculate the output power of the solar cell in real time, compare the calculation result with the previous time point, and use this as a basis to control the next disturbance of the solar output power point direction, so that the output of the solar photovoltaic cell is always stable in the vicinity of the maximum power point. The disturbance variables of the disturbance observation method can be input voltage, output voltage, duty cycle of the output circuit and so on according to the actual situation and conditions. Among them, the MPPT algorithm with the output voltage as the disturbance variable mainly controls the power. The turn-on and turn-off of the rate switch tube changes the output voltage of the solar photovoltaic cell.

3.2.3 Conductivity Incremental Method

The incremental conductance method is also a commonly used control algorithm for MPPT control. In order to improve the power loss problem caused by the disturbance observation method, K.H.Hussein proposed the incremental conductance method in 1995. It is collected by collecting the voltage at the end of the photovoltaic cell (electrical current), and complete the maximum power point tracking according to the relationship between the rate of change of its power to voltage and the output voltage and current purpose of tracking. From the P-V curve of the photovoltaic cell array, it can be known that the slope at the maximum power point P is zero, so at the maximum power point there are:

$$=V*I \tag{1}$$

$$dP/dV=I+dl/dV=0 \tag{2}$$

$$dI/dV=\text{one } I/V \text{ or } VdI=\text{one } IdV \tag{3}$$

①When $dP/dV=0$, the photovoltaic cell works at the maximum power point;

②When $dP/dV<0$, the photovoltaic cell works on the right side of the maximum power point;

③When $dP/dV>0$, the photovoltaic cell works on the left side of the maximum power point.

3.3 Design of DC/DC Converter

The maximum power point tracking is realized by a DC/DC converter. The DC/DC converter includes a boost (BOOST) type, a step-down (BUCK) type, and a buck-boost (BUCK.BOOST or CUCK) type. Determined according to solar module voltage, battery voltage and load operating voltage. The DC/DC converters used for charging and discharging small and medium-power batteries in solar energy systems generally use BUCK-type or BOOST-type circuits with relatively simple structures,

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DOI: 10.6919/ICJE.202209_8(9).0011

which have higher conversion efficiency. In this paper, the buck-type structure is selected for its convenience and low cost. Its structure figure 3 is as follows:

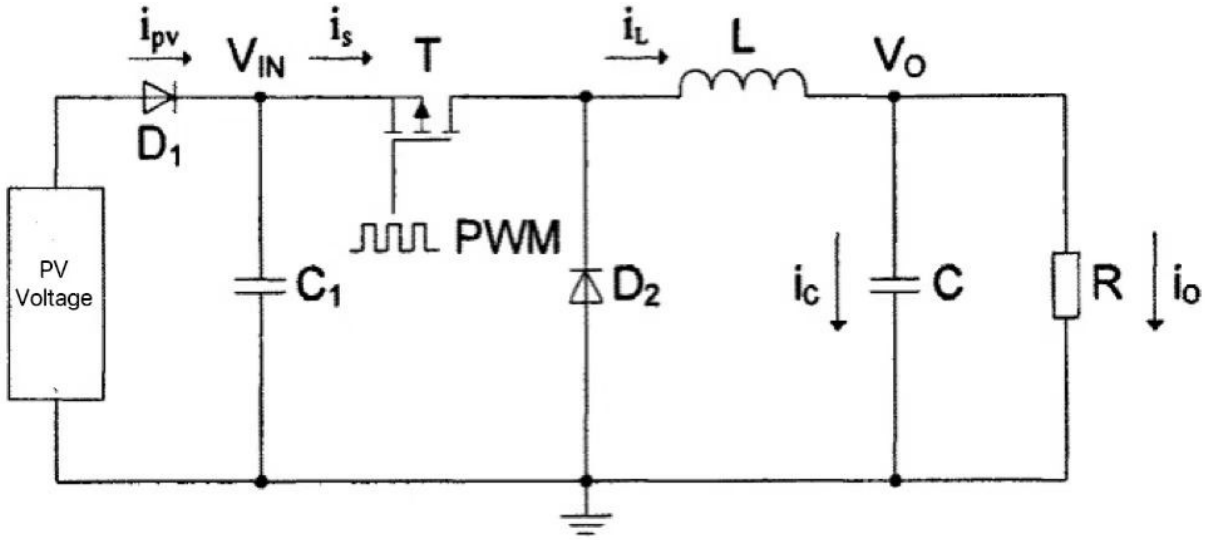

Figure 3. BUCK converter structure diagram

4. Control System Hardware Design

4.1 Overall Block Diagram of the Control System

The block diagram of the control system based on the PIC16F877 microcontroller chip is shown in Figure 4. The control system includes: power supply auxiliary circuit part, protection circuit, bus interface part, drive circuit, signal detection part, and PIC16F877 microcontroller.

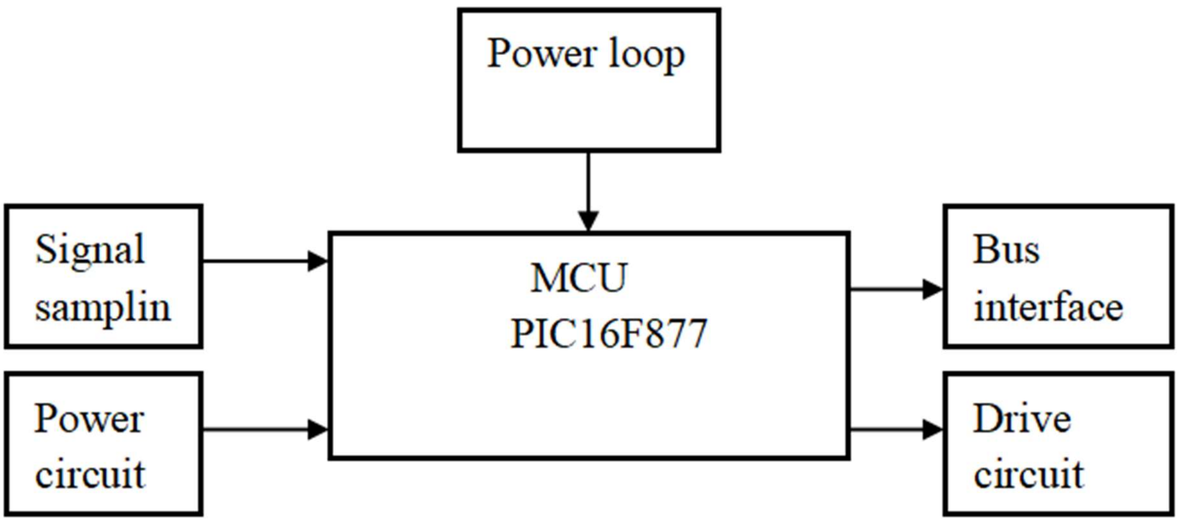

Figure 4. Control system structure block diagram

The voltage and current of the solar cell array and the terminal voltage and current of the battery are sampled by the Hall sensor and sent to the PIC16F877 chip. The schematic figure 5 of the control system is as follows:

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DOI: 10.6919/ICJE.202209_8(9).0011

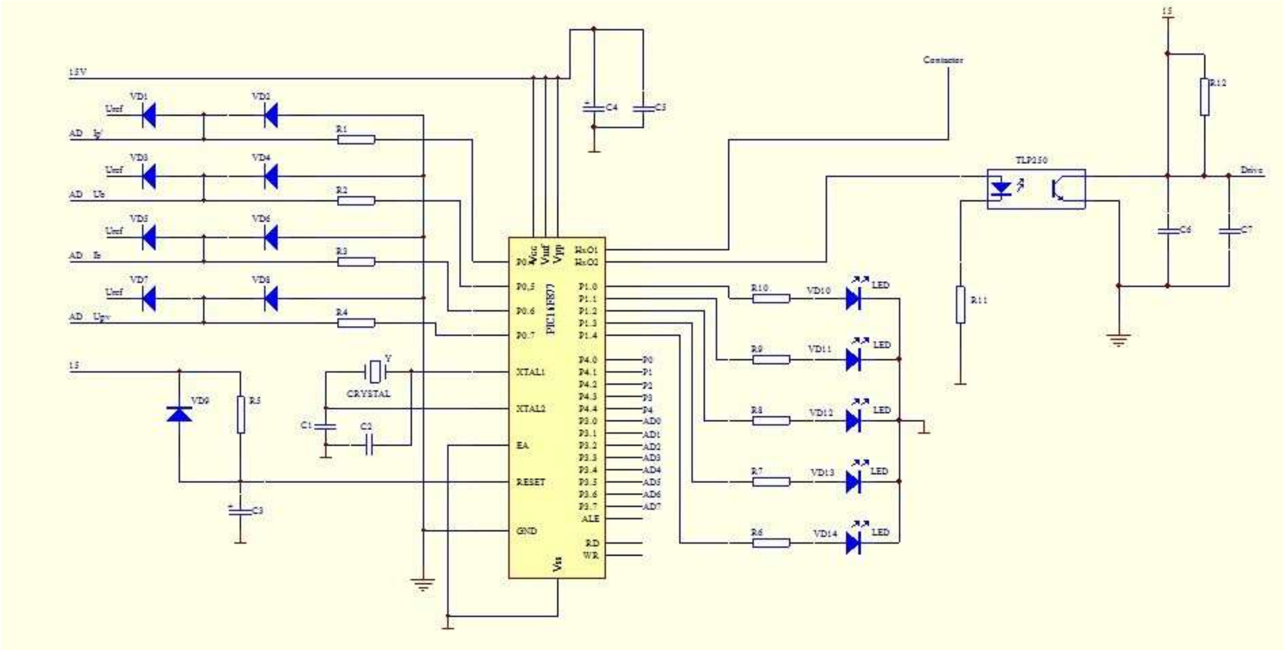

Figure 5. Control System Schematic

4.2 MOSFET Drive Circuit Design

Power MOSFETs have the advantages of low on-resistance and large load current, so they are very suitable as rectifier components for switching power supplies. Its requirements for the gate drive circuit mainly include:

(1) The trigger pulse must have fast enough rise and fall speeds, and the front and rear edges of the pulse must be steep;

(2) When turned on, the gate capacitance is charged with low resistance, and when turned off, a low resistance discharge loop is provided for the gate charge to improve the switching speed of the MOSFET;

(3) In order to turn on reliably, the gate drive voltage should be higher than the turn-on voltage of the device;

(4) The driving current required for MOSFET switching is the charging and discharging current of the gate capacitor. In order to make the switching wave have sufficient rising and falling steepness, the driving current should be large enough. According to the parameter characteristics of MOSFET TL494, the designed driving circuit is shown in Figure 4-2. The purpose of the drive circuit is to isolate and amplify the PWM signal generated by the MCU, and make this control signal enough to drive the MOSFET reliably on and off. This PWM modulator is implemented by TL494, and the peak value of its internal triangular wave oscillation is Upp=3V. The internal resistance-capacitor oscillation frequency can be expressed as:

$$f_{OSC} \approx \frac{1.1}{R_T C_T} = F_{SW} = 20kHz \tag{4}$$

Since the optocoupler does not directly couple the electrical signals on the input side and the output side, but indirectly couples with the optocoupler, it has high electrical isolation and anti-interference ability. The optical coupling drive circuit diagram is shown in Figure 6 above [7].

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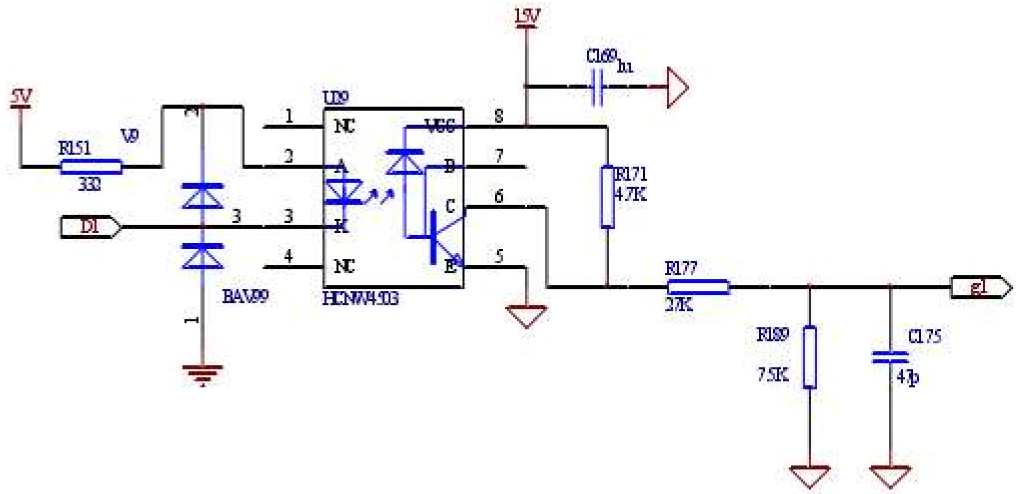

Figure 6. Optical coupling driver circuit

4.3 Software Design

4.3.1 Overview of the Basic Functions of the Software

Whether the solar power generation system can work normally is not only related to the rationality of the hardware circuit design, but also to the perfection of the software design. Based on the overall function of the solar power supply system and the MPPT algorithm, the software can be divided into six modules:

Main program module, interrupt subroutine module, A/D sampling program, MPPT operation program and communication program. The structure and function of each part are outlined below:

(1) Main program module: initialization of the control system, setting of MCU-related registers, and checking of system-related parameters to complete the startup of the system.

(2) Interrupt terminal subroutine module: including timer interrupt, key interrupt, external interrupt and other interrupt subroutines. Complete the response and processing of the system interrupt.

(3) A/D sampling procedure: regularly sample the parameters of solar cells, storage batteries, and each module of the system. Complete the corresponding processing from analog to digital. And in the sampling program, the sampling value is de-jittered to improve the sampling accuracy.

(4) MPPT operation program: This program module can quickly calculate the output duty cycle of the maximum power of the solar cell through the MPPT algorithm, and give the corresponding control waveform.

(5) Communication program: It mainly completes the initial debugging of the system, the establishment of the network system in the later stage and the remote monitoring of the working status of the system.

4.3.2 Main Program Design

The solar array, battery and load work in two modes that can be automatically switched: charging mode and discharge working mode.

(1) Charging working mode: Two tasks are performed in charging mode. ①The power of the solar cell is greater than the power of the load to supply power to the load, and the excess power to charge the battery, and adjust it to work in the MPPT state; ②The load is disconnected, and the solar cell array only charges the battery.

(2) Discharge working mode: In the discharge working mode, the system also performs two tasks: ① The power of the solar cell is less than the load power, and the excess power is supplemented by the battery. At this time, the MPPT algorithm is used to realize the maximum power point tracking of the solar cell, so that the battery discharge current Minimum; ②The solar cell array has no output

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power, and only the battery supplies power to the load at this time. Figure 7 is the flow chart of the main program of the control system.

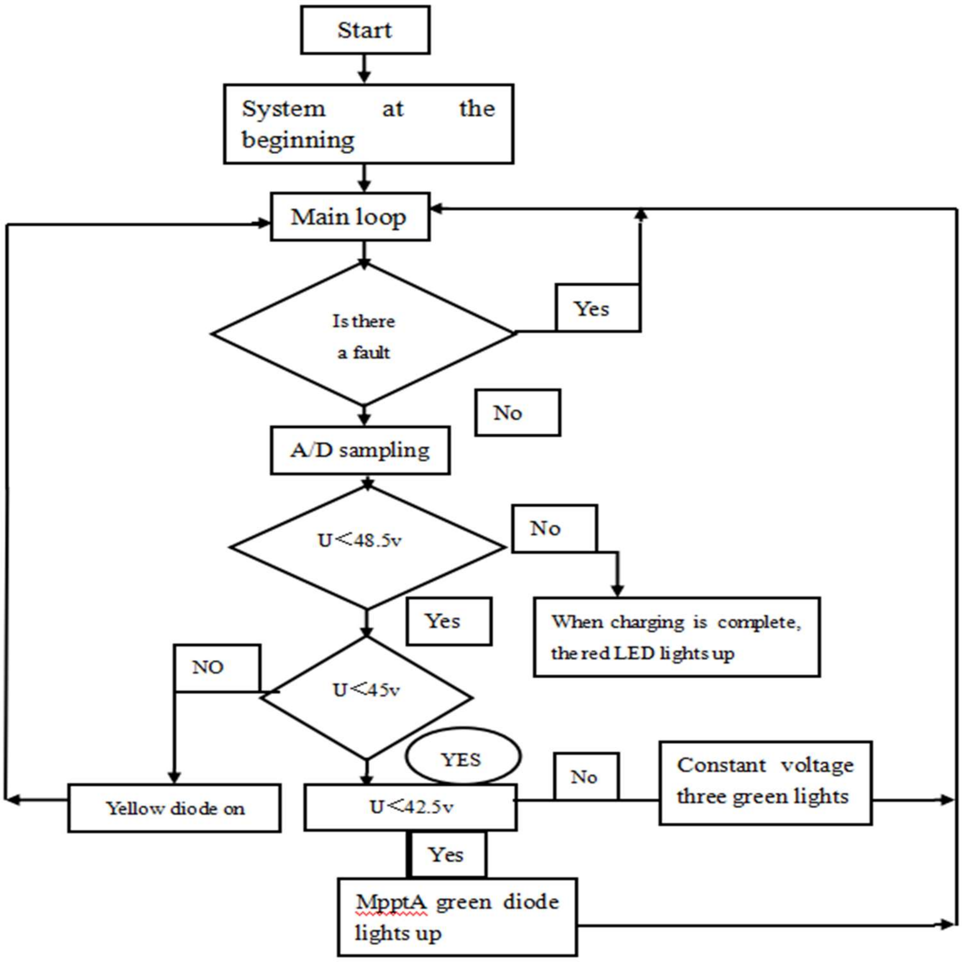

Figure 7. Control system main program flow chart

5. Conclusions and Recommendations

The process of completing the subject is a process of continuous learning and innovation, and it is also a process of continuous improvement and improvement of the subject. After a long period of research on this topic, a lot of exploration and experimental work have been carried out, and the following work has been mainly completed:

(1) On the basis of analyzing the power generation principle and output characteristics of solar cells, the basic principle of the maximum power point of solar cells is described in detail; the necessity of maximum power tracking of solar cells is emphasized, and several commonly used maximum power tracking methods are analyzed and compared. Control algorithm, and finally use the adaptive disturbance observation algorithm to track the maximum power point.

(2) The PIC16F877 chip is used to build the hardware platform of the solar photovoltaic independent power generation control system, and the BUCK control circuit is used as the main circuit topology of the power generation system. The driving circuit, sampling circuit, protection circuit, auxiliary power supply circuit, human interaction circuit and other parts are designed to form a complete control system.

(3) The lead-acid battery is used as the energy storage device of the independent power supply system, and the electrochemical reaction mechanism during the charging and discharging process of the lead-acid battery is briefly expounded; the battery charging circuit that meets the system requirements is

designed; the circuit effectively controls the charging and discharging of the battery, to avoid overcharging and overdischarging of the battery in the application. Thereby, the battery can be better protected, the service life of the battery can be prolonged, and the electric energy generated by the solar cell can be utilized to the maximum extent.

(4) For the network construction and subsequent grid connection construction of the photovoltaic independent power generation system, the hardware circuit has designed rich interface circuits, which has laid a technical foundation for the photovoltaic power generation system networking control; it also provides long-distance working status monitoring for the independent power generation system a good solution.

(5) The self-adaptive disturbance observation algorithm program is realized by using C language; the mixed programming technology of C language and assembly language is used to complete the driver program of TMS320F2812 and the overall software design of the system.

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