

# Research on Intelligent Regulation System of Solar Panels Driven By Low-Voltage Electric Energy

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**Abstract.** This paper proposes a design method for tracking solar panel light tracking control system based on microcontroller. The main structure of the system includes light intensity detection module, automatic control module, intelligent information processing module, human-computer interaction module, computer control module and interface circuit module. In this paper, the photoelectric method is used to track the position of the sun, the control process is modeled and simulated in the system. The system is optimally controlled by adding a Kalman filter to the output of the classic PID control. Actual tests show that the input voltage of the circuit is 1.2~5.5V, the maximum charging current is 1.2A, the minimum conversion efficiency of the circuit is not less than 72%, and the maximum conversion efficiency is more than 92%, and the power energy output of the solar panel can be collected and charged even under very weak lighting conditions. Solar energy utilization rate is high.

**Keywords:** low voltage electric energy drive; Solar panels; Intelligent adjustment; Solar cells; Electrical energy collection.

## 1. Introduction

With the continuous advancement of green energy construction, as well as the intensification of global energy shortage and environmental pollution and other issues, the urgent demand for solar photovoltaic power generation has been put forward, in the application design of solar photovoltaic power generation devices, the light chasing control design of solar photovoltaic power generation as an important application direction has received great attention from people, the construction of tracking solar photovoltaic panel light tracking control system, combined with the solar photovoltaic circuit lamp light chasing control design, improve the utilization rate of solar energy [1]. Through the design of solar panel automatic light tracking system, the establishment of light tracking control adaptive information acquisition model, through the automatic detection and perception of light intensity, mechanical devices and motor devices timely adjustment, to achieve automatic light tracking control of solar energy, the use of a full range of rotation tracking methods, solar photovoltaic panel control, improve the photovoltaic control panel all-round tracking and adaptive control capabilities, related tracking solar light tracking control system design method research has attracted great attention from people. This paper proposes a design method for tracking solar panel light chasing control system based on a single microcomputer, and the main framework of the system includes light intensity detection module, automatic control module, intelligent

information processing module, human-computer interaction module, computer control module and interface circuit module, etc., first of all, the overall design analysis of the system, and then the hardware modular design of the tracking solar light tracking control system, and finally the simulation test analysis, to draw the effectiveness conclusion.

## 2. Principle and design

### 2.1 Scenario Overview

The solar panel charges the battery and supercapacitor after passing through the protection circuit and the charge management circuit. The output of the supercapacitor is connected to the input of the boost conversion circuit, and the output of the battery is connected to the input of the buck conversion circuit. At the same time, the supercapacitor output is connected to the voltage comparator circuit (the reference voltage is the discharge cutoff voltage set by the supercapacitor), and the output of the voltage comparator is directly connected to the enable end of the supercapacitor boost conversion circuit, and the second is connected to the enable end of the battery buck conversion circuit after passing through the inverter. The outputs of the battery buck conversion circuit and the supercapacitor boost conversion circuit are connected to the load. When the solar panel is working normally, the supercapacitor voltage is greater than the set

cutoff voltage, the boost conversion circuit enables the active terminal, and the load system is supplied by the supercapacitor; When the solar panel is not working for a short time, the super capacitor is used to discharge deeply, make full use of its energy storage, as long as the super capacitor voltage is greater than the set cutoff voltage, the load system can be guaranteed to work normally; When the solar panel is not working for a long time, the supercapacitor is deeply discharged, and its voltage is less than the set cutoff voltage, the battery buck conversion circuit enables the active end, and the power supply of the load system is provided by the battery [2]. The system operation is supported by supercapacitors, taking advantage of the long-life characteristics of supercapacitors. In a few long rainy days, the battery support system works, which not only makes full use of the characteristics of large battery capacity, but also extends the service life of the battery. According to the above design scheme, the block diagram is shown in Figure 1.

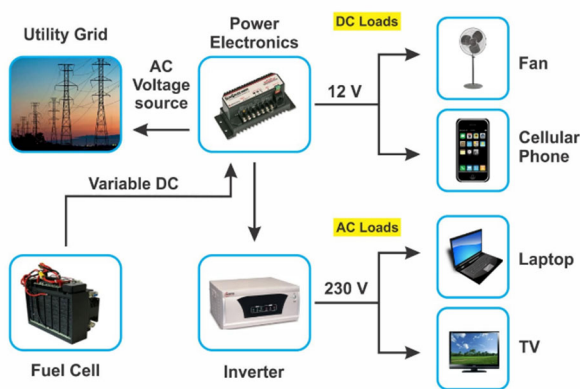


Fig. 1. Solar cell conditioning scheme

### 2.2 Solar charger

Solar panels are the most important products that convert light energy into electrical energy, and the biggest feature is that the output voltage and current change greatly with the change of light intensity. For example, a solar panel with a nominal 5V, 800mA output, in the case of direct sunlight, the output voltage can reach up to 6V, and in rainy weather, the outdoor test output voltage is only 2~3V. The ordinary lithium battery operates at 3.6V and the charging voltage is 4.2V. Therefore, in order to charge ordinary lithium batteries through solar panels, the simplest way is to choose a solar panel with high output voltage, and charge the lithium battery after stepping down to 4.2V, as shown in Figure 2.

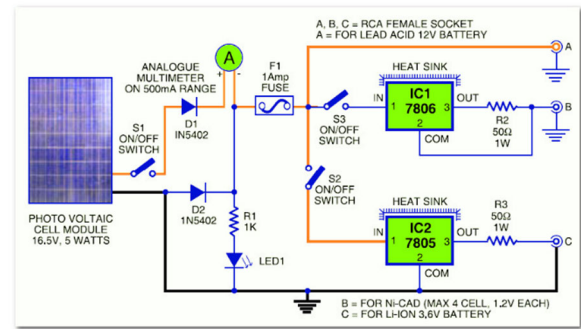


Fig. 2. Buck charging schematic

The circuit of this scheme is simple, but in actual use, when the light is less than a certain intensity, the output voltage of the solar panel is reduced, and the charger cannot be guaranteed to work properly. Therefore, the scheme has significant limitations [3]. To solve this problem, an improved approach is to first boost the output of the solar panel to stabilize to a fixed voltage, and then step down to 4.2V to charge the lithium battery as shown in Figure 3.

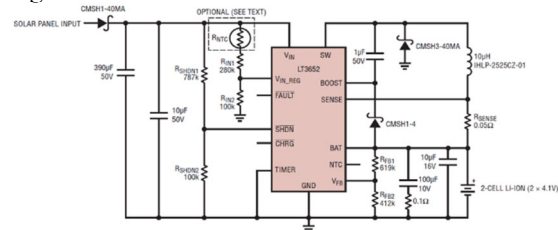


Fig. 3. Buck-buck charging schematic

Because the input voltage range of the boost circuit is generally relatively wide, it can be greatly guaranteed to charge the lithium battery in the case of a large range of light changes. The circuit structure of this scheme is complex, and the output of the solar panel is first boosted and then stepped, and the efficiency of the entire circuit is greatly reduced. At the same time, a serious problem with the scheme is that when the light is very strong, the output voltage of the solar panel may be higher than the maximum input voltage of the boost circuit [4]. If a solar panel with a lower output voltage is selected, when the light is weak, the output voltage of the solar panel will be less than the minimum input voltage of the boost circuit. The scheme uses a buck and boost automatic switching circuit, when the output voltage of the solar panel is higher than a certain value, the buck circuit is used to charge the lithium battery, and vice versa, the boost circuit is used to charge the lithium battery. Since only the first stage circuit is in operation at any one time, the efficiency of the entire circuit is very high. In order to achieve this function in this article, the core part of the circuit uses the TPS61200 intelligent power chip produced by TI. The chip has built-in boost and buck circuitry and can be automatically switched according to the relationship between input and output voltages. When the input voltage is lower than the output voltage, the chip operates in the boost mode; When the input voltage is higher than the output voltage, the chip automatically switches to the step-down mode. At the same time, the chip has a very low start-up voltage and operating voltage, and the circuit is still able to collect and

charge the lithium battery from the output of the solar panel under extremely weak light.

### 3. System hardware and software design

#### 3.1 Hardware design

The tracking system consists of a sensor, a controller, a driver, a stepper motor, a tracking mechanism, and a solar panel as shown in Figure 4.

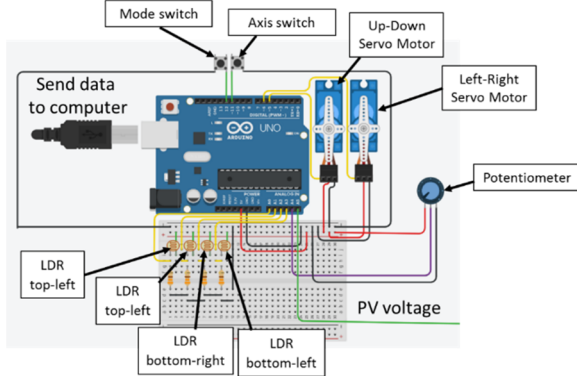


Fig. 4. The composition of the tracking system

##### 3.1.1 Controller

Q series PLC programmable controller is a medium and large PLC series products developed by Mitsubishi from the A series PLC basis. The basic components of Q series PLC include power modules, CPU modules, substrates, I/O modules, etc. The 00JCPU of the Mitsubishi Q Series PLC is an all-in-one system for the main substrate and expansion substrate that can control multiple input and output points, making it suitable for use in small devices [5]. This system uses QX40DC input module, QY41P transistor output module, Q64AD analog-to-digital conversion module. The QX40 is used as a switching input. The QY41P is a transistor-type module that can send high-speed pulses and can be used as the input pulse signal of stepper motors. Q64AD has four AD inputs, which are set to high resolution and acquire four sensor signals and environmental signals.

##### 3.1.2 Sensors

The light receiving component of the solar sensor is mainly composed of a four-quadrant photovoltaic detector. The four-quadrant detector is a photovoltaic detector device that arranges four photovoltaic panels with exactly the same performance according to the requirements of rectangular coordinates, and there is a "ten" shaped channel between them.

#### 3.2 Software algorithm design

The steering gear is mainly composed of a brushless DC motor and a position control circuit, which can usually accurately control the angle of its rotation through the D) signal, which is the core of controlling the attitude of the solar panel [6]. The steering gear in the design can be

wound from 0° to 180° in one plane. If you use ordinary motor modeling methods, the model will become cumbersome and difficult to analyze. Therefore, the impedance model is used in the application to model the motion process of the servo. Its motion is considered a damping motion as shown in Figure 5.

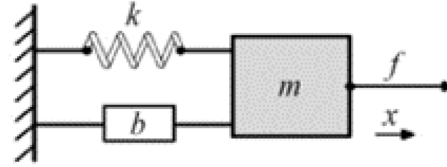


Fig. 5. Equivalent model of servo rotation

According to the impedance model, it can be obtained:

$$m\ddot{x} + b\dot{x} + kx = f \quad (1)$$

This is a typical second-order system whose transfer function can be described as:

$$G(s) = \frac{\omega_n^2}{s^2 + 2\varepsilon\omega_n s + \omega_n^2} \quad (2)$$

According to Equation 2), override the transfer function as

$$\frac{X(s)}{F(s)} = \frac{1}{M} \frac{1}{s^2 + \left(\frac{B}{M}\right)s + \left(\frac{k}{M}\right)} \quad (3)$$

$M$  is the inertial parameter and  $k$  is the stiffness parameter.  $M$  can be calculated according to the torque and rotation angle acceleration given in the servo parameter table.  $k$  The larger the stiffness, the greater the stiffness, and too small will cause a large tracking error, in order to simplify the model, and in the process of rotation, the deformation of the force arm is very small. We consider  $k = 0.1B$  to be the damping parameter. The value of  $E$  is obtained by adjusting  $\varepsilon$ . In this design, the weight of the solar panel is much smaller than the torque of the servo, so the value of  $\varepsilon$  is taken between. During the entire control process, the difference between the two photosensitive sensors is taken as the input, and the D signal of the control steering gear is used as the output of the controller. The system operates with measurement noise and observation noise. Therefore, a Kalman filter is added to the system output.

This is a typical second-order system. Introducing the transfer function of formula (C) into a state variable can write out its equation of state and output equations respectively:

$$\dot{x}(t) = Fx(t) + Hu(t) \quad (4)$$

$$y(t) = Lx(t) \quad (5)$$

Where  $u(t)$  is the output. Where the transfer function parameters are known, the value of the unknown coefficient matrix in the equation can be calculated directly by *MATLAB*. According to equations (5) and (7), and discretize them, write the equations of state and observation equations of the Kalman filter are:

$$x(k) = Fx(k-1) + H(u(k) + w(k)) \quad (6)$$

$$y_v(k) = Lx(k) + v(k) \quad (7)$$

Where  $w(k)$  is the process noise and  $v(k)$  is the measurement noise. They are all Gaussian white noise.

## 4. System detection

For ordinary voltage conversion circuits, one of the most important parameters is the conversion efficiency. For the energy collection circuit, in addition to efficiency, the main performance index is the lowest condition of the circuit start-up, that is, the lowest input voltage and current. Therefore, this article uses circuitry to test the input minimum voltage and current [7]. From the test results, it can be seen that when the input minimum voltage is 1.2V, in order to ensure normal charging, the input current is 44.2mA, that is, the output power of the solar panel is 55mW, which is very easy to achieve. As the input voltage increases, the current required gradually decreases, and the output power of the solar panel is reduced to 30mW. The test results are shown in Figure 6.

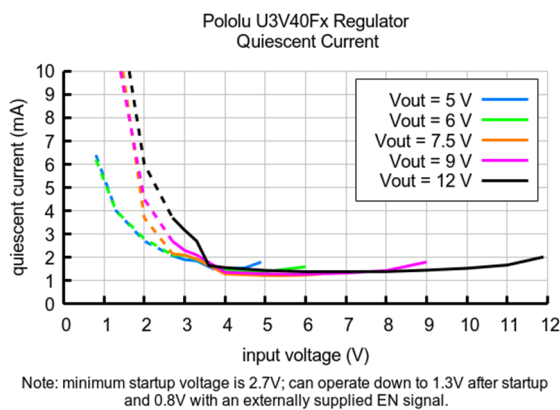


Fig. 6. The minimum start-up voltage is related to the input current, input power

## 5. Conclusion

By improving the original solar output characteristic measurement device, the angle between the light source and the solar panel can be adjusted, so that the influence of the light angle and the inclination angle of the solar panel on the output efficiency of the cell is studied, and the two-dimensional relationship curve of output efficiency with angle is obtained. Experiments have found that with the increase of lateral light inclination, the output power shows a tendency to increase first and then decrease. As the longitudinal inclination of the solar panel increases, the output power decreases. The improvement process of this experimental project helps to strengthen students' hands-on practical ability, and at the same time, it has a deep understanding of the rotation and rotation of the earth.

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