Design of Photovoltaic Power Generation System Based on Single Chip Microcomputer

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Abstract. This paper describes the design of photovoltaic power generation system based on SCM (single chip microcomputer). This system adopts the SCM with photoresistor sensor as the detective devices. By using the CSM with PID and the dual-axis servo, it can achieve the aim of automatic sun tracking, so that the solar panel will face sunlight at any time. Finally, the voltage data is shown to evaluate the proposed system by LabVIEW software, which ensured the measurement accuracy. What’s more, this system uses solar energy as the energy, which is economical and environment friendly. It accords with the human’s needs of environmental protection.

1. Introduction
To address the global concern on greenhouse gas emission and climate change, solar energy is supposed to be one of the optimal options. The technologies of solar energy rational utilization promise a promising prospect as the solar energy is a renewable and inexhaustible energy resource [1]. Most of the traditional photovoltaic modules are fixed installations [2-4], which greatly reduces the photoelectric conversion efficiency. Finally, people designed single-axis and dual-axis day-to-day systems based on single-chip and plc controllers [5]. The advantages of single-axis system are simple, low-cost, but low-efficiency. On the contrary, the dual-axis system has a high investment cost, but its control accuracy is high, which can make the system obtain a relatively high efficiency [6-8].

So, the system adopts MG995 dual-axis servo as the driving devices. By using the SCM with PID and the dual-axis servo, it can achieve the aim of automatic sun tracking.

2. System Overall Structure Design
The overall structure diagram of the photovoltaic power generation system is shown in figure 1. The system is mainly composed of main control module, power supply module, drive module, information acquisition and processing module, etc. Considering the actual application, the system has designed a working mode that automatically tracks sun, the SCM with photoresistor sensor detects the change of sunlight in the surrounding environment, and completes the task of controlling solar panel to track the sun by the MG995 dual-axis servo.

3. System Overall Structure Design
The whole system hardware composition is shown in figure 2, the system is composed of SCM, servo drive circuit interface, photoresistor sensor interface and solar battery, etc. The constructed model of photovoltaic daily power generation system is shown in figure 3.
3.1. SCM Minimum System
The system adopts STC15F2K60S2 microcontroller as the minimum system. It has many complete and powerful functions. It not only contains ultra-high-speed CPU core, large-capacity data memory, 16-bit reloadable timer/counter and other commonly used ports, but also includes SPI and IAP interface, high-speed AD conversion module, CCP/PWM/PCA and WDT circuit, etc. In addition, it also contains all the modules required for data acquisition and system control. In this system, the SCM with photoresistor sensor detects the change of sunlight in the surrounding environment and formulates a corresponding rotation strategy. Finally, it controls solar panel to complete the rotation of photovoltaic panel by the MG995 dual-axis servo. Then, computer will display the voltage value of solar panel by LabVIEW software.

The pin resources are shown in table 1. we select P4.1 and P4.2 ports as the PWM wave generation ports. the SCM inputs the generated PWM waves into the enable of the MG995 servo driver chip. The control circuit receives a control pulse of the signal source and drives the motor to rotate.

| MCU resources | Specific pins | Instructions for use     |
|----------------|---------------|--------------------------|
| I/O port       | ADC0~ADC3/P1.0~P1.3 | solar cell voltage collection |
|                 | ADC4~ADC7/ P1.4~P1.7 | environmental light intensity collection |
|                 | WR/P4.2, MISO_3/P4.1 | control the MG995 servo |
|                 | RXD/P3.0, TXD/P3.1 | serial communication |
| VCC, GND       | —, —          | 5V power supply, signal ground |

3.2. MG995 Servo Drive Circuit
The servo model is Tower Pro MG995 micro servo motor, which is a miniature servo control system. The schematic diagram of its control is shown in figure 4. It mainly consists of control circuit, motor, gear set, proportional potentiometer, and some peripheral circuits. The control circuit is a DC pulse
width modulation circuit, which is composed of a KC5188 chip and peripheral PNP transistors. The advantages of the KC5188 chip are small quiescent current, simple dead zone setting, superior power and temperature characteristics, it is convenient for grasping and using.

![Diagram](image_url)

**Figure 4.** MG995 servo control principle diagram.

The control circuit receives a control pulse of the signal source and drives motor to rotate. The gear set reduces the speed of motor by a large multiple, and amplifies the output torque of motor by the corresponding multiple. The potentiometer and the final stage of the gear set rotate together, and measure the rotation angle of the steering shaft. The circuit board detects rotation angle of the steering gear according to the potentiometer [9], and controls the steering gear to rotate to a target angle or maintains it at the target angle.

### 3.3. Light Intensity Detection Circuit

In order to “perceive” the changes of the surrounding sunlight, the system adopts a photoresistor sensor based on the principle of photoelectric effect. It is mainly composed of a photoresistor, LM393 comparator, potentiometer, and some surrounding circuits. The LM393 comparator is a wide voltage comparator [10]. It processes and outputs the feedback signal from the surrounding sunlight that the photoresistor “perceives”. The output signal is purer and more stable than the general comparator.

The principle of photoresistor sensor is to detect the change in the light intensity of the surrounding environment by the photoelectric effect principle of photoresistor, and adopt potentiometer to adjust the sensitivity of the photoresistor sensor [11], so as to judge the direction of sun. In this paper, the method of occlusion is adopted to determine the orientation of sun. Considering the accuracy of photovoltaic panel angle, four photoresist sensors are used to detect the light intensity. They are respectively installed in the four directions of east, west, north and south of photovoltaic panel.

### 3.4. Power Distribution

Because the system is static, there is no need for separate energy storage power supply. Therefore, the system selects the DC power supply with output voltage of 24 V, rated current of 1.5 A and rated power of 36 W.

The voltage conversion process: First, 24V DC power is reduced to 6.6V DC power by MP1584EN buck chip, which is supplied to MG995 servo and photoresistor sensor module. Second, 6.6V DC power is stabilized to 5V DC power by HT7350 voltage stabilizing chip, which is supplied to STC15 series microcontroller. The distribution of power supply as shown in figure 5.

![Diagram](image_url)

**Figure 5.** Power distribution.
4. System Software Design

4.1. Light Intensity Sampling Program
The light intensity acquisition adopts the AD module inside the SCM. Through the adc4 ~ adc7 channels of the AD module, it collects the surrounding sunlight and calculates the light intensity value. The system collects four light intensity values, once every 20ms, five times in total, totally 100ms. Through the average value data filtering processing, the light intensity value is finally obtained. The flow chart of light intensity sampling is shown in figure 6.

![Flow chart of light intensity sampling.](image)

4.2. PID Data Processing Program
The data obtained by the light intensity value sampling program, through the position PID data processing program output accurate PWM signal [12], and more stable and accurate control of the actuator movement. The position PID algorithm is based on a series of sampling points of light intensity values \( kT (k = 1, 2, 3\cdots) \) [13]. The infinite number of sampling points is approximately equal to time \( t \). Among them, the integral part adopts the matrix method for numerical integration, and the differential part is the backward difference of the first-order derivative, which can be described in the following equation \( (t \approx kT) \):

\[
\int_0^t e(t)dt \approx T \sum_{j=0}^k e(jT) \approx T \sum_{j=0}^k e(j)
\]

\[
\frac{de(t)}{dt} \approx \frac{e(kT) - e(k-1)T}{T} \approx \frac{e(k) - e(k-1)}{T}
\]

Get the discrete PID expression:

\[
u(k) = K_p e(k) + T_1 \sum_{j=0}^k e(j) + T_0 \sum_{j=0}^k (e(k) - e(k-1))
\]

\[= K_p e(k) + K \sum_{j=0}^k e(j)T + K_d \frac{e(k) - e(k-1)}{T}
\]

In the formula, \( K_i = \frac{K_p}{T_1}, \quad K_d = K_p T_0 \), \( T \) is the sampling period of the light intensity value, \( k (k = 1, 2, 3\cdots) \) is the sampling number of the light intensity value, \( e(k) \) and \( e(k-1) \) are the calculated deviation at time \( k \) and \( (k-1) \), \( u(k) \) is the signal output by PID, it directly controls the steering gear.
As shown in figure 7, the position PID data processing program adopts the interrupt system of the SCM, starts the timer, reads the light intensity value of the surrounding environment of the system obtained by the light intensity collection program, and calculates the steering angle of the steering gear. Then, the SCM begins sampling the steering gear. After that, the MCU starts to calculate the deviation between the set angle of the steering gear and the current angle as well as the change rate of the deviation, and calls the PID function to output the PWM signal [14], controls the steering gear to rotate. Finally, the MCU clears the mark, and interrupts the return.

![PID data processing flow chart.](image)

**Figure 7. PID data processing flow chart.**

4.3. *LabVIEW Display Interface Design*

The LabVIEW display interface is designed primarily to show the voltage value of solar panel. The SCM adopts Modbus protocol for serial communication [15], and its main communication process is relatively simple. First, the SCM will collect the voltage values of the four solar panels, and begin data processing. Second, the computer receives data by serial communication. Finally, the voltage data is shown by LabVIEW software [16]. So that users can intuitively see the energy conversion efficiency of the photovoltaic daily power generation system. The LabVIEW display interface is shown in figure 8, which mainly consists of four functions: namely serial port status, serial port information, data reading, and data display.

![LabVIEW UI.](image)

**Figure 8. LabVIEW UI.**

5. **Conclusions**

This system adopts the SCM with photoresistor sensor as the detective devices. By using the CSM with PID and the dual-axis servo, it can achieve the aim of automatic sun tracking, so that the solar panel faces the sunlight at any time. Finally, the microcontroller will adopt Modbus communication, and the voltage data will be shown to evaluate the proposed system by LabVIEW software, which ensured the
measurement accuracy. And, this system uses solar energy as the energy, which is economical and environment friendly. It accords with the human’s needs of environmental protection. The system debugging shows that the system performance is relatively stable, the data is time-effective, the control circuit is simple, and the cost is relatively low, which is conducive to market and use.

References

[1] Guan H, Zhang S, Cai X, Gao Q, Yu X, Zhou X, et al. 2019 CdS@Ni3S2 core-shell nanorod arrays on nickel foil: A multifunctional catalyst for efficient electrochemical catalytic, photoelectrochemical and photocatalytic H2 production reaction Mater. Chem. A 7 (2019) 2560-2574.

[2] Meksarik V, Masti S, Taib S, et al. 2003 Study the effective angle of photovoltaic modules in generating an optimum energy National Power an Energy Conference pp 312-316.

[3] Famoso F, Lanzafame R, Famoso F, et al. 2015 Performance comparison between low concentration photovoltaic and fixed angle PV systems Energy Procedia 81 516-525.

[4] Shi J and Liu J 2011 PV tracking sun controller based on MCU Water Resources and Power 29 (02) 144-145+186.

[5] Li M 2016 The Design of Energy-saving solar photovoltaic system Based on 51 single chip microcomputer Wireless Internet Technology 2016 (04) 69-70.

[6] Hou C L 2010 Study on the dual-mode control system of solar tracking device Renewable Energy Resources 28 (01) 89-92.

[7] Li P, Liao J C, Cai L L, et al. 2010 Study on motion control law of 2-axisSun tracking system Machinery 48 (6) 23-26.

[8] Wang S G, Gao W, Huang S H, et al. 2007 Research on the mixed Two-axes sun tracker Renewable Energy Resources 25 (6) 10-13.

[9] Meng Q H, Wang Z Q and Liu C M 2011 Realization of MG995 servo control system based on Panasonic FP0-PLC Science & Technology Information 2011 (14) 135-136.

[10] Li Z H 2008 Research on the Steering Gear Controller Based on ARM (Beijing University of Technology).

[11] Zhai Y J, Wu Z C and Shen C S 2011 Design of standardized module of sensor interface based on STM32 Electronic Technology 38 (08) 57-60.

[12] Zhu T Y 2016 Research on daily system of photovoltaic power generation based on CMAC and PID control Shandong Industrial Technology 2016 (07) 41.

[13] Yang L 2018 Design and MATLAB simulation of pressure control based on positional PID algorithm Electronic Technology & Software Engineering 2018 (24) 27.

[14] Hu X S and Ji P 2018 A study on optimization of photovoltaic power generation with Multi-way PID control Journal of Sutihua University 38 (08) 138-140.

[15] Ma Y L 2019 The realization of MODBUS communication protocol based on RS-485 on SCM Telecom Power Technology 36 (07) 60-62.

[16] Zhu J 2013 The Research of Sun Automatic Tracking Monitoring System Based on LabVIEW and MCU (Wuhan University of Technology).