Research and Design of PV MPPT Based on STM32

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Abstract: Aiming at the problem of maximum power point tracking (MPPT) of PV power generation, combined with the purpose of temperature adjustment of rural PV heating system, the MPPT method based on the model of adjustable load resistance matching is proposed. The output characteristics of PV cells and the principle of load matching are analyzed, and the MPPT of PV generation is realized by perturbation and observation (P&O) method. Regarding the heating equipment as the resistive load, a group of resistors with a wide range and small step length which can be controlled by the relay are designed to test. Finally, taking STM32 as the core processor, adjusting the step size and tracking the change of PV output voltage, the controller can track the change of the external environment accurately, that is, it can track the maximum power point of a PV power system effectively.

Key Words: PV Power Generation, MPPT, STM32, Load Matching, P&O Method

1 INTRODUCTION

Nowadays, the traditional energy is faced with the exhaustion crisis and the environmental pollution is increasing. Rapid economic development requires the research, development and utilization of new and renewable energy. As a kind of new energy, solar energy has become the focus of research because of its inexhaustible, safe and clean. Photovoltaic power generation is widely concerned as one of the three main forms of solar energy utilization [1-2].

A lot of research work has been done on the maximum power point tracking (MPPT) problem of PV system at home and abroad, many MPPT algorithms have been put forward and many controllers have been made. In [3], a variable step PV MPPT controller based on neural network is designed, and the MPP is reached very rapidly especially in fast changing environment conditions. In [4], a MPPT controller for PV system under local shading is designed. In [5], a PV system MPPT controller supplied SRM using BAT search algorithm is designed. In [6], a fuzzy logic MPPT controller on a FPGA platform is designed. However, MPPT research is seldom carried out on the actual load.

With the temperature adjustment of rural PV heating system as background, the PV power generation system with adjustable resistive heating equipment is studied in this paper. Taking STM32 as the core controller, the MPPT controller of PV power station is designed from two aspects of hardware and software, and the maximum power output of a PV system is realized mainly by using the principle of maximum power transmission.

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2 THE PRINCIPLE AND STRUCTURE OF PV POWER GENERATION SYSTEM

The overall block diagram of PV power generation system as shown in Fig.1. The main energy conversion circuit consists of a single buck converter, the load is adjustable resistive load. Using STM32F103 microcontroller as the core of the system control, its core is arm company's CORTEX-M3, working frequency is 72MHz, Flash can reach 512kB, two 12-bit ADC, 5 Usart, 11 16-bit timer, fully meet the requirements of system resources.

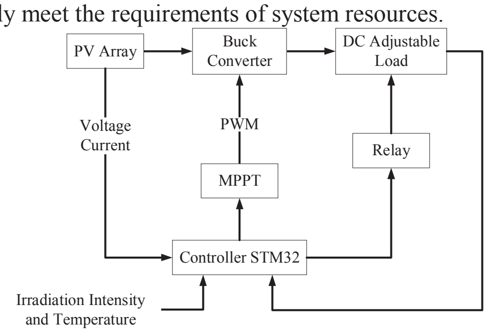

Fig.1 Overall Block Diagram of PV Power Generation System

According to the requirement of indoor temperature change, STM32 can control DC adjustable load by relay, and the output voltage of unstable DC energy of the PV array is decreased by PWM control DC/AC converter for achieving stable heating. Due to the voltage requirements of DC load is not high, the PV array can be directly connected to the DC adjustable load, then use the relay to achieve a simple size adjustment of load. The voltage and current of PV arrays are collected by voltage and current converters, and the irradiation intensity and temperature parameters are collected by photosensitive sensors and temperature sensors, and all the data are uploaded to the STM32 eventually.

3 PRINCIPLE AND REALIZATION OF MPPT

3.1. Output Characteristics of PV Cells

PV cells are a kind of non-linear DC power supply, Fig.2 shows the output characteristic curve of PV array under different irradiation intensity and different temperature. As shown in Fig.2a, at the same temperature, with the increase of irradiation intensity, the power-voltage characteristic curve is almost shifted upward wholly. With the increase of irradiation intensity, the maximum power point (MPP) increases obviously. But under the uniform irradiation intensity, the power-voltage characteristic curve only has one MPP. As shown in Fig.2b, with the increase of temperature, the characteristic curve moves approximately to the left with the increase of temperature, that is, the open circuit voltage is obviously reduced and the short-circuit current increases slightly. Based on the analysis of PV cell characteristics, it can be concluded that the output of the PV array depends on irradiation intensity and temperature, and only one MPP exists under the condition of uniform irradiation [7-8].

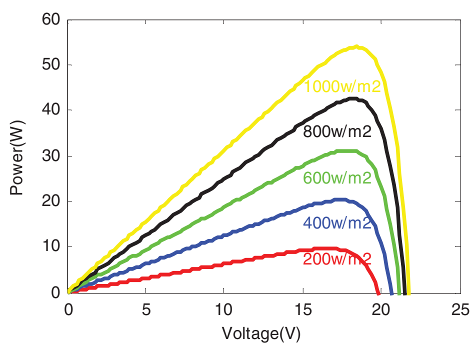

Fig.2a Output Characteristics of PV Arrays under Different Irradiation Intensities

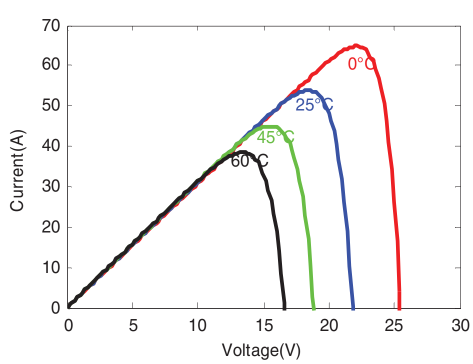

Fig.2b Output Characteristics of PV Arrays at Different Temperatures

3.2. Load Matching

The heating equipment in the rural photovoltaic heating system is simplified to a resistive load, which has the characteristics of linear adjustable. By analyzing the characteristics of PV cells, it is necessary to find out the MPP of PV array under the current environment in order to generate maximum power. Using load-matching ideas, as shown in Fig.3, any electric network can be divided into "source" and "load" two parts. According to the principle of the maximum power transfer theory, when the load resistance is equal to the power supply resistance, the power supply to load transmission maximum power, and this time called impedance matching.

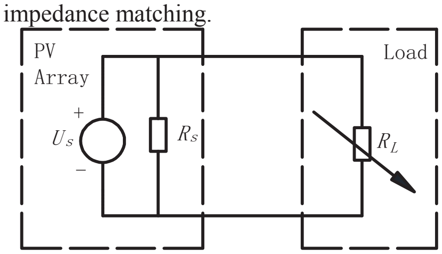

Fig.3 Maximum Power Transmission

3.3. Control Algorithm of MPPT

At present, the most commonly used algorithms of MPPT include constant voltage method, perturbation observation method [9], conductance increment method, Fuzzy logic control [10], Artificial neural network [11] and so on. The constant voltage method assumes that the open circuit voltage does not change much, according to the voltage of MPP is proportional to the open circuit voltage $U_m = kU_{oc}$ .This method is only applied to the independent PV system with smaller power and stable external environment. The incremental conductivity method is based on the conductance of MPP is zero.

$$\frac{dP}{dU} = I + U\frac{dI}{dU} = G + dG = 0 \tag{1}$$

Determine the current PV system working point by judging the positive and negative conductivity. The method has the advantages of good control effect, good stability and fast tracking, but it also requires higher hardware. Fuzzy control blurs the information, does not depend on the precise mathematical model, and is suitable for fast tracking of the sharp changes of sunshine, but it is uncertain.

At present, the most commonly used and reliable method is the perturbation and observation method, also known as interference method or mountain climbing method. That is, to increase or decrease the voltage at intervals, observe the direction of the power change and then change the PV voltage size. The perturbation and observation method has the advantages of simple principle, fewer parameters to measure and easy to implement. However, it is not suitable for the sudden change of sunshine quantity, which may be misjudged and oscillate around MPP.

4 DESIGN OF SYSTEM

4.1. Design of Hardware

As shown in Fig.4, the test platform for the system experiment. The System control unit adopts the STM32F103ZET6 processor as the core controller. Relay uses DC 5V power supply, with optocoupler isolation, low level effective 8-way relay module. The current sensor adopts ACS712ELC-20A module based on Hall principle, the module measurement range of current is -20A~20A, the corresponding analog output is 100mv/a. The voltage sensor is designed according to the principle of resistance partial pressure, the resolution is 0.00489V.

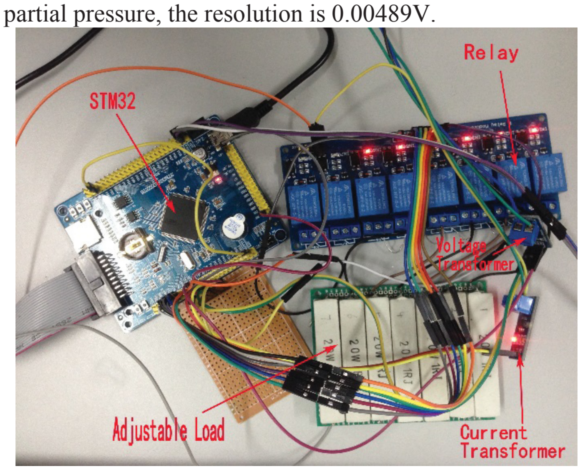

Fig.4 Test Platform of Hardware

The adjustable load is composed of 19 cement resistors of 1~22Ω, the specific design of resistance is shown in table 1. When the total resistance needs to have a large change, putting or cutting the unit resistance of 20 or 10Ω for coarse adjustment. When the total resistance value needs a small change, putting or cutting the unit resistance of 1ω resistance for fine adjustment. Using this design, the resistance value can be adjusted in the 1~150Ω ranges with a few relays, with the 1Ω step. Buck Circuit is designed with LM2596 chip, as shown in Fig.5, can achieve 12V input and 5V step-down output.

Tab.1 Resistance of Resistor Module

resistance number	resistance	resistance number	resistance
1	10.3	10	1.3
2	10.2	11	1.1
3	10.2	12	1.1
4	10.1	13	1.1
5	10.1	14	1.3
6	21.8	15	1.1
7	21.6	16	1.1
8	21.6	17	1.3
9	22.0	18	1.1
		19	1.0

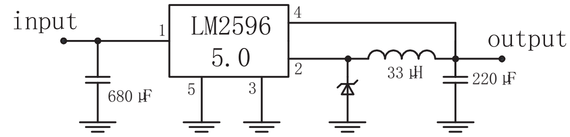

Fig.5 Buck Circuit Based on LM2596

4.2. Method of Algorithm Control

The core processor collects the output voltage and current value of the PV module through voltage converter and current converter. Then the direction of voltage and power is compared by P&O to judge the working state of the PV power system. As shown in Fig.6, changing the current voltage value, whether it is increasing or decreasing, and then observe the power change. If the direction of the voltage change is the same as the direction of power change, the current voltage value is increased. If the direction of the voltage change is opposite to the direction of power change, the current voltage value is reduced. The judgment will continue to be repeated during the whole system running. However, in order to prevent the system in the MPP of constant oscillation, usually set a constant ε, when the absolute value of power change is less than the constant, it is considered that the power is basically unchanged and do not perform any operation, continue to judge until power changes.

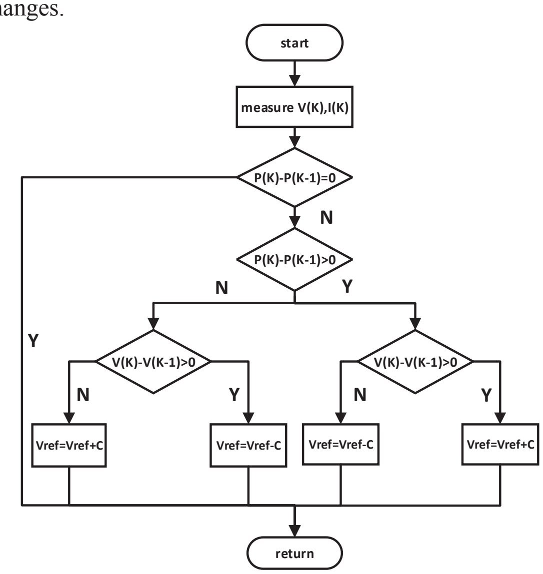

Fig.6 Perturbation and Observation Method

The change of voltage values is mainly realized by using PWM to control the duty ratio of the DC/AC converter by STM32 processor. According to the output characteristics of the photovoltaic cell, the duty ratio should be raised for the buck circuit when the irradiation intensity is enhanced, whereas the duty ratio should be reduced when the irradiation intensity is weakened.

5 EXPERIMENTAL TEST

Assuming the photovoltaic system is in a stable environment, the controller tracks the MPP of the PV system. As shown in Fig.7, by adjusting the step size constantly, it is found that the tracking process is slow but the fluctuation is not small when the step is 0.1v. This is caused by the system's own error rather than the setting of step. When the step is 0.2v, the time required for the tracking process is significantly shorter than the step is 0.1v, and the fluctuation is almost unchanged. In the case of the step is 0.3v, the fluctuation is much higher and the tracking time is shortened slightly. As a result, the length of the stride causes the fluctuation to increase and the small step size will make the tracking time too long. Through the above analysis, that setting step as 0.2v is more appropriate, step should not be too large or too small.

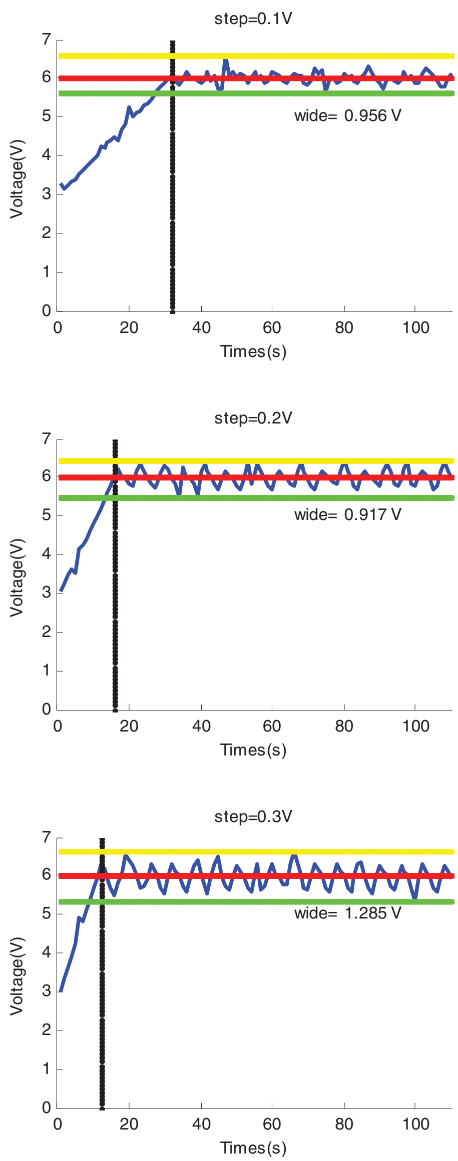

Fig.7 Tracking Process of MPPT

6 DISCUSSION

With the temperature adjustment of rural PV heating system as background, aiming at the characteristic of linear adjustable resistive load, design a set of resistors that can be easily linearly tuned to provide a basis for load matching. Through the test, it is found that too large and too small step size is unfavorable to the realization of MPPT. The final appropriate step is determined to be 0.2V by the test, and it is concluded that the better tracking effect of MPP is achieved. Although the error of the system itself and the shortcomings of the algorithm, the process of MPPT is still fluctuating. For practical applications, good dynamic and steady-state performance makes the control have good practical value.

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