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Research on the application of solar photovoltaic power control model for eco-agriculture

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ABSTRACT— To further realize the deep coupling of agricultural equipment and facilities with solar photovoltaic power generation technology, we have conducted a study on the application of solar photovoltaic power generation control model for ecological agriculture concept, taking green intelligent irrigation as an example. Based on a deep understanding of the components and power generation mechanism of the current mature solar photovoltaic system, we combined the energy flow characteristics and load structure of the solar modules to build a power generation control model suitable for agricultural irrigation equipment and made a reasonable selection of system hardware and precise design of software control to form a complete solar photovoltaic power generation system. The test results show that the error between the theoretically calculated power generation and the applied power generation is within 5 %, which is in line with the actual farming operation and the test results are good. It can promote the application of photovoltaic power generation technology in agricultural equipment and facilities, and provide a certain research direction for the upgrading of ecological agriculture in China.

KEYWORDS: Photovoltaic power generation technology; Eco-agriculture; New energy technology.

1. INTRODUCTION

In recent years, as China's agricultural management continues to develop in an ecological and environmentally friendly direction, solar energy is being promoted as a non-polluting and environmentally friendly factor. A review of the literature shows that scholars at home and abroad are working on how to integrate solar photovoltaic energy technology into agroecological management models more efficiently, including the use of fruit and vegetable greenhouses to design solar photovoltaic power generation systems, the establishment of distributed power plants that complement fishery and light energy, and new agricultural equipment supplemented with solar photovoltaic power generation devices [1]. Eco-agriculture, as a new era concept, promotes an agricultural production method that utilizes layers and turns waste into treasure and covers a multi-factor ecological management model and comprehensive use of resources at all levels, thus forming a new pollution-free and green agricultural system. To improve the intelligent management of agriculture and the efficient use of energy and materials, we intend to combine the two to conduct applied research on the control of power generation in specific farming facilities and equipment [2].

2. Overview of Eco-Agriculture and Photovoltaic Power Generation

The production and management based on ecological agriculture is a multi-technology system with the characteristics of rational use of resource diversity, including inter-crop mix, scientific use of food chain constraints, etc. The energy supply is essential in this process. The traditional power generation system has disadvantages such as waste of resources and low operational efficiency, etc. Solar photovoltaic power generation technology can collect and convert solar radiation energy into usable electricity for agricultural equipment and facilities [3]. The reasonable degree of its structure is the key factor to determine the efficiency of photovoltaic power generation.

The main components of a complete solar PV system include PV panels, DC conversion circuits, filtering circuits, and inverter circuits. Under a certain operation mechanism and orderly coordination, voltage and current data are generated and transmitted through the MPPT algorithm, SPWM algorithm, voltage boost, and rectification. The architecture of the solar photovoltaic power generation system for ecological agriculture is shown in Fig.1. The core of the smart PV system is a parameter control device for farm monitoring, which processes the energy with high efficiency by the voltage and current sampling circuit and sends it to the end-load (large area sprinkler irrigation facility) for power utilization through the control conversion and inverter drive circuit [4].

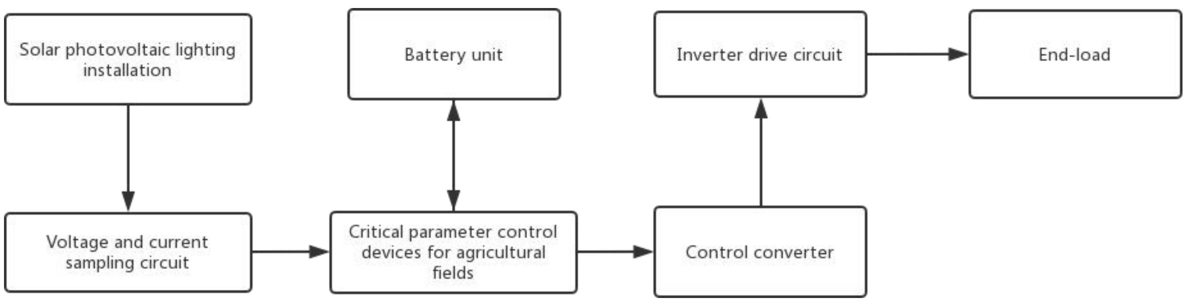

Fig.1 Sketch of solar PV system architecture for eco-agriculture

3. Agricultural photovoltaic power generation system design

3.1 Photovoltaic power generation control modeling

The design of a solar photovoltaic power generation system for agriculture is carried out, and the sprinkler unit for large-area sprinkler irrigation is selected as the object of study, which consists of the mainframe, walking drive, and operation device. The solar photovoltaic power generation system converts light energy into mechanical energy by effectively collecting light energy to complete the walking and spraying action smoothly. The load structure model is

$$\begin{cases} C_{pi} = \dfrac{P_{fi} - P_{\infty}}{0.5\rho v_0} \\ u_{si}(Z) = \dfrac{\sum_{i=1}^{n} C_{pi} A_i}{A_i(Z)} \end{cases}$$

C_{pi} -load pressure of PV power system structure;

P_{fi} -static pressure on the surface of the PV power system structure;

P_{∞} - reference point hydrostatic pressure of PV power system;

ρ -Ambient air density in the operating field;

v_0 - the incoming wind speed in the field;

$u_{si}(Z)$ - load structure coefficient of the surface of PV power system i;

A_i - surface area of the measurement point of the hydrostatic pressure coefficient on the surface of the PV power system structure;

$A_i(Z)$ - surface area of the surface of PV power system i.

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The mechanism of controlling the flow of received energy by using the power generation of solar photovoltaic panels The theory can be obtained:

$$\begin{cases} k = 1.5(u_0 I_u)^2 \\ \varepsilon = \dfrac{C_u^{0.75} k^{1.5}}{l} \end{cases}$$

Where k - turbulent energy for solar PV system;

u_0 - the average wind speed of the solar photovoltaic system during operation;

I_u - turbulence intensity at the operating surface of the solar PV system;

ε - turbulence dissipation rate for solar PV system;

l - turbulence integration scale at the operating surface of the solar PV system;

C_u - Calculation coefficient of the solar PV system flow.

Further combined with the control power model of this agricultural PV power generation system model, we can obtain:

$$P = I_P(U_B + U_d)$$

Where P -system photovoltaic power generation battery pack power;

I_P -system photovoltaic power generation battery pack output current;

U_B -system battery pack float voltage sub;

U_d -system line loss pressure drop.

Based on the control mechanism of the system, parameters are set for the solar PV system components (Table 1), crystalline silicon with high comprehensive utilization efficiency is selected as the main light- harvesting material, 10 battery banks are set, and certain relay protection thresholds such as under-voltage are given to design the core model of solar PV power generation system based on ecological agriculture management (Fig.2), after a series of component configuration, parameter setting and The model's operational stability is achieved through a series of component configuration, parameter setting, and accuracy of circuit transceiver data execution [5].

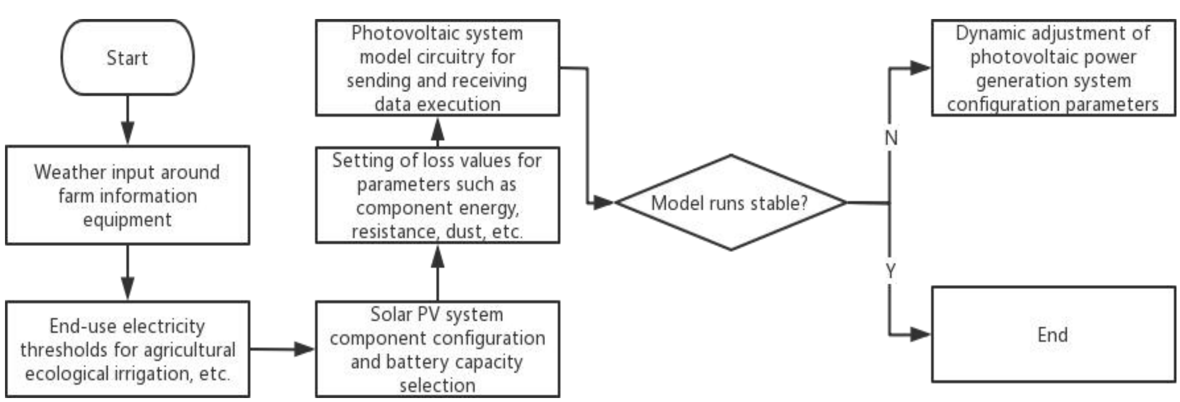

Fig. 2 Model design of solar photovoltaic power generation system based on ecological agriculture

Table 1 Core parameter settings of solar PV system components based on eco-agriculture

Serial number	Component name	Component core parameters	Unit	Parameter value
1	Photovoltaic Power Generation Modules	Power	W	287
		Voltage	V	49.95
		Current	A	5.75
2	Battery Pack	Rated voltage	V	12(10)
		Rated capacitance	Ah	200
3	Photovoltaic power generation Control devices	MPPT Threshold	V	48~165
		Under (over) voltage protection	V	40.7(58.5)

3.2 Photovoltaic power generation system hardware configuration

The hardware configuration for the photovoltaic power generation system, after comparing the performance parameters, the TMS320 series measurement and control chip with high processing accuracy and speed are selected, the humanized control module of watchdog and dynamic lock is set, and the bus structure of multiple PWM pulse control and HFA is used to realize the efficiency of the inverter circuit of the photovoltaic system [6].

To realize the reasonable conversion between analog and digital signals of the angle obtained from solar PV panels, 8 channels of analog input with 16-bit precision conversion are set. The core parameters of the system hardware data acquisition module are set as shown in Table 2. In the execution link of the power supply module of the photovoltaic power generation system (Fig. 3), segmented utilization is adopted to realize intelligent charging and discharging control of the solar photovoltaic power generation system by separating the voltage and power after the bidirectional channel conversion circuit to save energy effectively.

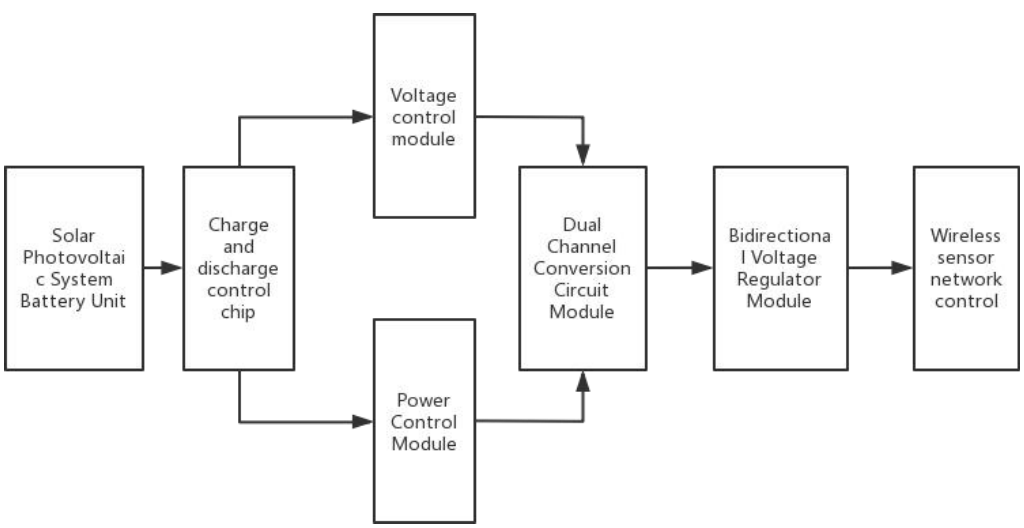

Fig. 3 Hardware implementation sketch of solar PV system power supply module based on eco-agriculture

Table 2 Parameter design of the hardware data acquisition module of the solar photovoltaic power generation system

Serial number	Parameter name	Corresponding parameter value
1	AI Input	0－10V /0 ～ 20mA
2	MAX Input	DC±18V /0 ～ 40mA
3	DO Output	0 ～ 16383
4	PID Output	0 ～ K4095
5	EX Speed	1.5ms/channel
6	AU	DC24V±10% /150mA

3.3 Photovoltaic power generation system software design

Depending on the amount of power provided by the motor drive of the irrigation equipment, the software control module of the solar photovoltaic system (Table 3) is set up according to the number of automatic programs, interfaces and processing points required for the internal system to ensure good insulation of the system and precise closed-loop control in the execution of the pulse and response codes [7].

Table 3 Software control module parameter settings for solar PV power system

Serial number	Parameter name	Corresponding parameter value
1	System program capacity	512kB
2	Control communication interface	RS485 /X－NET
3	Number of data storage points	1024 ～ 25000
4	Data processing points	40 ～ 8000
5	Number of internal coil points	1280 ～ 75000
6	Processing speed	0. 05μs
7	Insulation voltage	＞DC500V 2MΩ

According to the control node execution process (Fig.4), after the system's operation command is issued, the network channel seeking under the network protocol is carried out, and it is added to the network control according to certain rules so that the data of the sensor module is judged and transmitted to the farmland electricity terminal (i.e., intelligent irrigator terminal) to realize the real-time collection and transmission of operation data information [8].

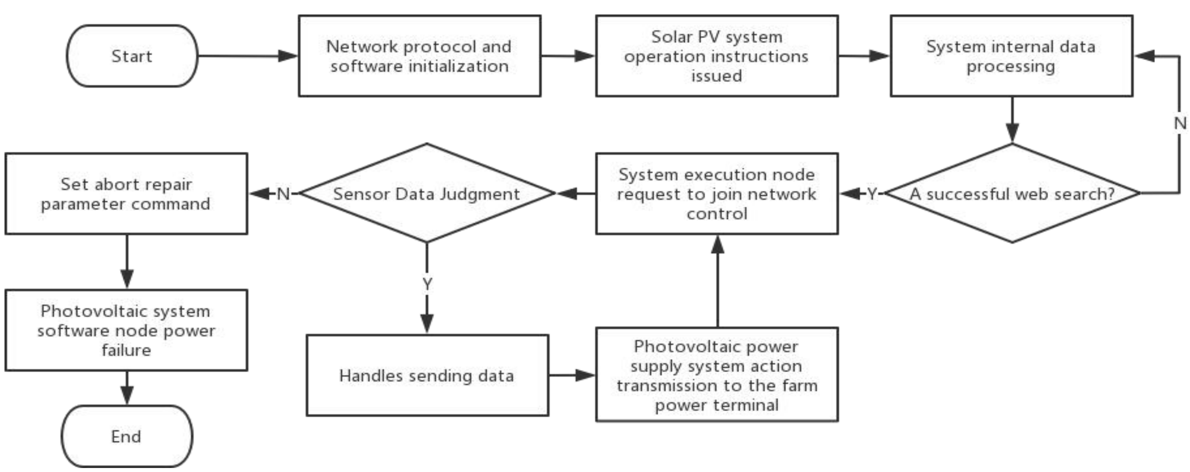

Fig. 4 Sketch of solar PV system software control node execution flow

To further ensure the accuracy of the input and output quantities within the system, a control algorithm based on the fuzzy control concept was incorporated internally, as shown in Fig.5 for the specific implementation

[9]. At the same time, the core algorithm control structure is established and a fuzzy subset affiliation function is constructed to weigh the factors under the correct fuzzy control decision to reduce the error of the power generation control model acting on the irrigation machine [10].

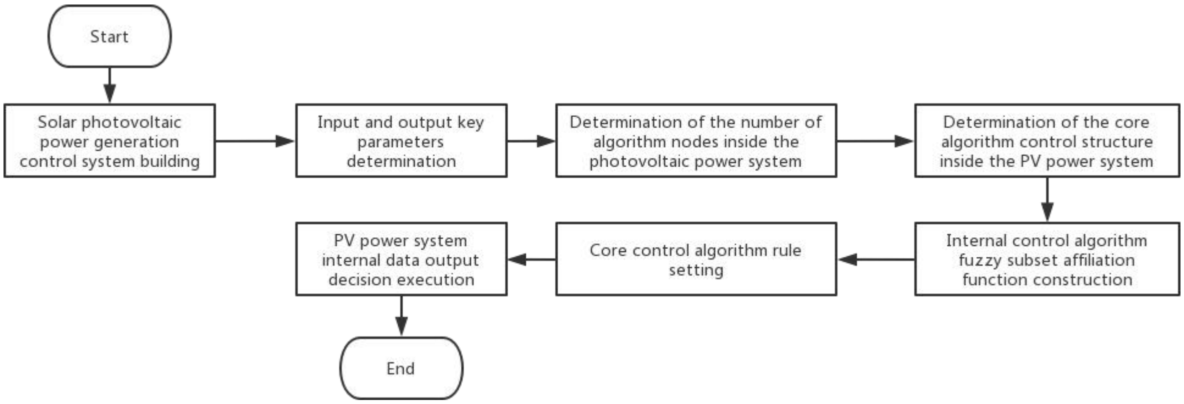

Fig. 5 Sketch of the internal core algorithm control of the solar PV system

4. Application testing of agricultural photovoltaic power generation systems

4.1 Condition Setting

The test of solar photovoltaic power generation system application under the concept of ecological agriculture was conducted. According to the design steps of the PV power generation system application test shown in Fig. 6, the power matching of the PV power generation system is carried out after the start-up of the electric facilities in the farmland, and the demand determination of the navigation and positioning control device of the whole machine is made; after the compliance, the system hardware and software instructions are executed and the feedback power supply parameters are corrected simultaneously [11].

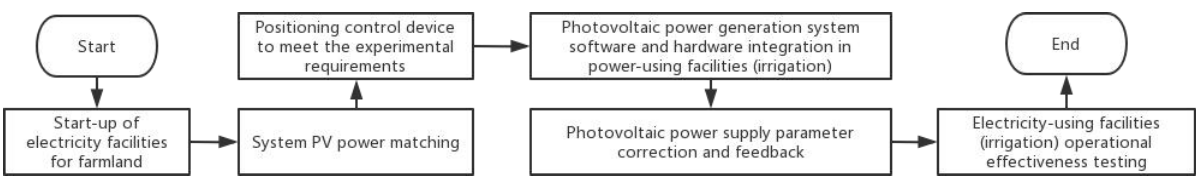

Fig. 6 Test design steps for the application of PV power generation system based on ecological agriculture

The prerequisites for setting are:

1) The environmental conditions of the field operation of the test device of the electricity-using facility remain consistent;

2) The operation of the data transmission equipment of the PV power generation system is coordinated with the electricity-using facilities;

3) PV power generation system component parameters (peak power, voltage, current, etc.) are within the threshold range.

4.2 Test Analysis

The power generation was recorded at different operating speeds of 0.5, 0.8, and 1.2 m/min. Two sets of data were recorded at the same operating speed and analyzed to obtain comparative data of the tested parameters, as shown in Table 4. [12]. It can be seen that the power generation of the irrigation unit with the solar photovoltaic control system is 106.90W and 108.46W at 0.5m/min, and the power generation calculated by the control model is 104.06W, with a relative error of 2.73% and 4.23%; the power generation at 0.8m/min is 176.88W and 184.85W, and the power generation calculated by the control model is 180.00W. The relative errors are 2.04% and 2.37%; the power generation at the operating speed of 1.2m/min is 251.12 and 245.97W, and the power generation calculated by the control model is 241.18W, with relative errors of 4.12% and 1.99%. The application error of the photovoltaic system is within 5% accuracy, and the overall operational efficiency of the irrigation unit can be kept above 85% on average [13].

Table 4 Application test statistics of solar PV power control system for ecological agriculture

Serial number	Test speed/m·min^{-1}	Test power generation Power /W	Calculated power generation Power/W	Error /%
1	0.5	108.46	104.06	4.23
2	0.5	106.90		2.73
3	0.8	184.85	180.57	2.37
4	0.8	176.88		2.04
5	1.2	251.12	241.18	4.12
6	1.2	245.97		1.99

5. Conclusion

1) Led by the concept of ecological agriculture, the solar photovoltaic power generation technology is combined with agricultural equipment and facilities to build a solar photovoltaic control model based on ecological agriculture and to design its power generation system.

2) The PV power generation control model is based on the fuzzy control theory algorithm as the core, and it is installed in the power supply module of the intelligent power supply facilities (irrigation units), through the hardware architecture and circuit configuration and software internal control execution function design, forming an energy-efficient solar PV power generation control system, and conducting power generation application tests.

3) The test results show that the actual power generation of the irrigation unit with the solar photovoltaic power generation control system is within 5% of the theoretical power generation error at different operating speeds, and the system is stable and accurate to meet the operational requirements.

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