International Journal of Latest Research in Science and Technology ISSN (Online):2278-5299
Volume 5, Issue 1: Page No24-28, January-February 2016
https://www.mnkpublication.com/journal/ijlrst/index.php

DESIGN AND IMPLEMENTATION OF SMALL EXPERIMENTAL PLATFORM FOR PHOTOVOLTAIC POWER GENERATION

[1]Wu Yanqun,[2]Zhang Haining,[1,a]LiuWeiliang,[1,b]Liu Changliang
[1]Department of Automation, North China Electric Power University, Baoding, Hebei,China
[2]Key Laboratory of Grid-Connected Photovoltaic Technology, Electric Power Research Institute of Qinghai Power Grid Corporation, Xining, Qinghai, 810008 China
[a]Email:lwlfengzhiying@163.com

Abstract- ***For the purposes of research and teaching work on photovoltaic power generation technology, a small experimental platform is designed and implemented this paper. Principle of photovoltaic power generation technology is briefly introduced, hardware part and software part of the experimental platform is designed, and the platform is implemented based on embedded technology and C# development environment. Application results show that the experimental platform could carry out the volt-ampere characteristics, MPPT control, inverter control and other experiments of photovoltaic cells with the characteristics of concise intuitive, friendly human-computer interaction and good extensibility.***

***Keywords* –:** Photovoltaic Power Generation; Experimental Platform; MPPT; Inverter

I. INTRODUCTION

In recent years, the traditional energy sources become increasingly tense like coal, oil, natural gas and etc., so developing and utilizing new energy sources have received more and more attention. As one of the main forms of new energy utilization, solar photovoltaic power generation has the characteristics of no pollution, flexible operation, simple maintenance, etc., and it has great significance for the remote areas that the large power grids cannot cover or special occasions with large power network coverage [1-3]. With the acceleration of the implementation of the National green energy strategy, the research of photovoltaic technology and personnel training are particularly urgent. PV experimental platform is the carrier to carry out research and teaching work of photovoltaic technology. Only a few domestic institutions build the platform due to limited funding and space constraints[4-8].This paper designed and implemented a set of small photovoltaic power generation experiment platform, including hardware devices and software components. Firstly, this paper introduces the principle of photovoltaic technology, and then discusses part of hardware devices and the design and implementation of software components. Finally, this paper tests the functional of platform by application examples.

II. PRINCIPLE OF PHOTOVOLTAIC POWER GENERATION

The Principle of photovoltaic power generation is the Photovoltaic effect. When light shines on the battery plate, its PN junction will generate electromotive force. Equivalent Circuit of Photovoltaic Batteryis shown in Fig.1.

In this figure, I_{LG} is the Current source of Photovoltaic Battery, I is the Output Current of Solar battery, and I_d is the Diode operating current, I_{sh} is Leakage Current, R_s is Equivalent series resistance of the photovoltaic battery, R_{sh} is Equivalent parallel impedance of photovoltaic battery.Form Fig.1,we can obtain the U-I characteristics of photovoltaic battery.

$$I = I_{ph} - I_d[e^{\frac{q(U+IR_s)}{AKT}} - 1] - \frac{U+IR_s}{R_{sh}} \quad (1)$$

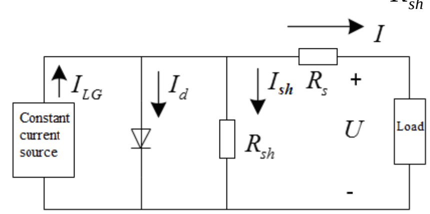

Fig.1 Equivalent Circuit of Photovoltaic Battery

In the formula,U is the output voltage of photovoltaic battery, T is the temperature of the battery, q is the electron charge, A is ideal factor,K is the Boltzmann constant. When Load changes from zero to infinity, we obtain the I-U and P-U characteristic curve of photovoltaic battery, such as Fig.2. We found some of the results. Output current and output voltage of photovoltaic battery exhibits inverse relationship, and when weadjusted load toR_m, we obtain a point M on the curve, where the product of voltage and current is maximum, $P_m=U_m \times I_m$, and this point M is the maximum output power point (MPP).

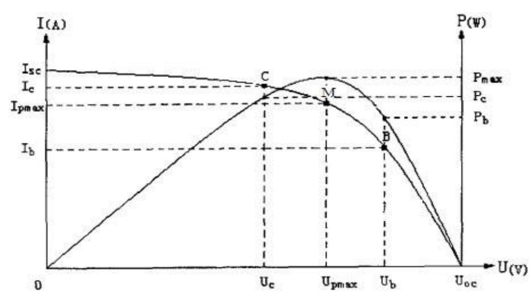

Fig.2 Characteristic curve of photovoltaic battery

Publication History
Manuscript Received : 28 January 2016
Manuscript Accepted : 8 February 2016
Revision Received : 24 February 2016
Manuscript Published : 29 February 2016

III. HARDWARE DEVICE OF THE PLATFORM

Photovoltaic power generation can be divided into independent generation system and grid connected power generation system according to the system output whether joins grid or not. Its block diagram of hardware devices is shown in Fig.3 and the main parameters of the inverter are shown in TABLEI. The hardware device is consists of seven parts that include Microcontrollers, DC / DC Converter, Inverter bridge,Filter,Load,Control loop,Human-computer interaction and Monitor display section. Human-computer interaction includes Keyboard, LED lights,Buzzer,Voice broadcast system,LCD Monitor and RS232 communication interface.

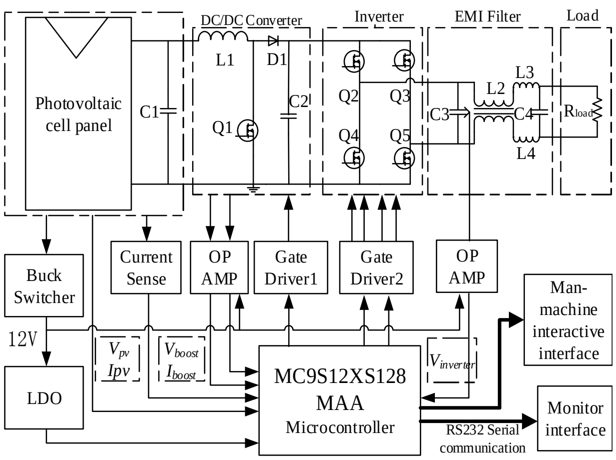

Fig.3The overall block diagram of the hardware device

TABLE II MAIN REQUIRED PARAMETERS OF INVERTER

Parameters	Minimum	Maximum	Target value
DC input voltage	15（V）	25（V）	20（V）
DC/DC voltage	30（V）	50（V）	40（V）
Inverter output voltage	——	50（V）	22（V）
Inverter output current	——	2(A)	——
Output voltage frequency	——	——	50（Hz）

Microcontroller Selection

Because MPPT process and inverter process need the high-real-time requirements for the control chip, this paper uses Freescale HCS12X Series microcontroller 16bit control chip MC9S12XS128MAA.Its main characteristic is that the bus frequency is as high as 40MHz, the operation speed is fast, the memory of the chip is large, and the peripheral is rich. In the inverter operation process, Voltage and current analogare sanded into MC9S12XS128MAA microcontroller AD portafter they are sampled by Voltage and current sensor. MCU controls PWM port and generates PWM wave according to the software program.Drive circuit drives BOOST circuit and Switch of inverter circuit, thereby controls the inverter operation.

Circuitdesign of DC / DC converter circuit

DC / DC convert choses BOOST circuit in the switching power supply. The main work is to choose the power tube Q1 and output energy storage inductor L1 in circuit design. This paper selects MOSFET as the power switch for BOOST circuit. Under the premise of leave some margin, this paper selects specific models reference device voltage and current rating to ensure device safety and reliability. For this device, it is directly connected with photovoltaic panels. Its input voltage range is 15-30V that is three times the voltage margin. It’s MOSFET rated voltage should be above 90V, so MOSFET can use IRFS4321 and its rated voltage is 150V and its current is up to 83A and its resistance is 15 mΩ. Considering the ripple, the switching frequency of the output current, ultimately we select the inductor L1 to 330uH. Because of the limited of the capacity of the microcontroller pulse width modulation module driver, This article does not guarantee power switch reliable trigger, so this paper used MICROCHIP company's MCP14E14 as MOSFET driver chip. The chip is a dual-speed power MOSFET driver IC, the peak output currents up to 4A, and it has a wide voltage range, driving ability, speed, etc. Fig.4 is a drive circuit diagram.

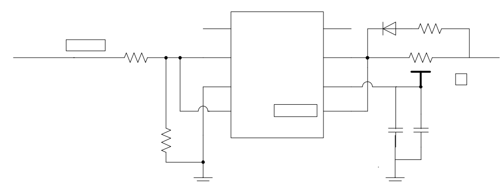

Fig.4 Switch driver circuit diagram

Inverter bridge circuit design

Four N-channels MOSFET constitute Inverter Bridge andits model is the IRF540N, drain-source breakdown voltage is 100V, maximum drain current is 33A, the on-resistance is 44 mΩ. Inverter bridge MOSFET driver circuit uses 74HC00 binding IR2104 driver chip, as shown in Fig.5.

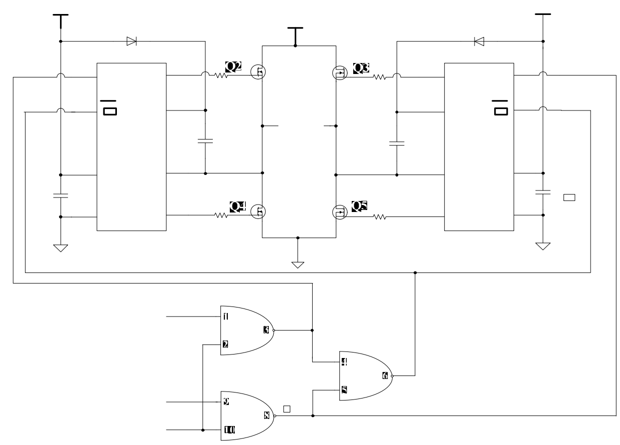

Fig.5 Drive circuit of inverter bridge inverter switch

74HC00 chip contains four sets of two-input NAND gate circuit. DIR1 and DIR2 signals are high signal and low signal of the microcontroller IO port output. PWM signal is the sinusoidal PWM modulation signal of the microcontroller pulse width modulation port output. The logic table of MOSFET drive signal is shown in TABLEIIIIV.

Detection circuit design

There are 6 analog signals in hardware devices. Respectively, the photovoltaic cell junction temperature is *T*, the PV cell output voltage is V_{pv}, and output current is I_{pv}, BOOST circuit output voltage isV_{boost}, output current isI_{boost} and inverter output voltage is V_{grid}. V_{grid} is AC voltage, and the other five are DC signal. Current sensor model is ACS712ELCTR-05B-T Hall linear current sensor, which is shown in Fig.6,the output sensitivity is 185mV / A, and the measurable current rangesis -5 ~ +5A.

TABLEVI MOSFET DRIVE SIGNAL LOGIC TABLE

DI R1	DI R2	SP WM	A	C	B	Switching patterns	Voltage polarity
L	H	L	H	H	L	Q2、Q3 break-over Q4、Q5 cut-off	—
		H	H	L	H	Q2、Q5 break-over Q3、Q4 cut-off	positive half wave
H	L	L	H	H	L	Q2、Q3 break-over Q4、Q5 cut-off	—
		H	L	H	H	Q3、Q4 break-over Q2、Q5 cut-off	negative half wave

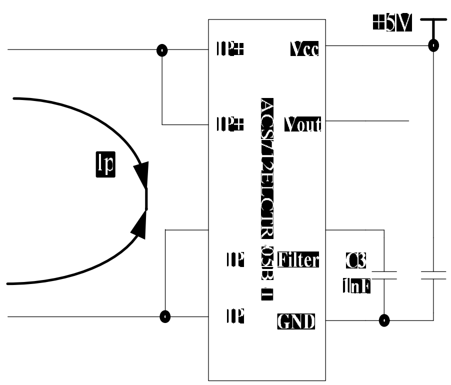

Fig.6 Schematic diagram of the current sensor

In Map, IP+ and IP- are current signal input terminal, V_{out} is to measure current output signal, and the relation between output voltage and measured current is

V_{out}=2.5V+ΔI*0.185V (ΔI is current to be measured). In order to improve the sensitivity of the current sensor and reduce the relative error, the signal conditioning circuit is designed, which is shown in Fig.7. The sensitivity of the current measurement circuit is 925mV/A. The amplifier is MCP6022 chip for system.

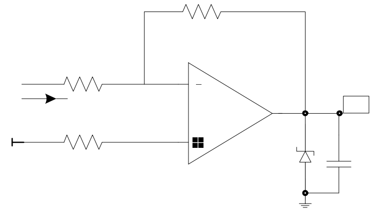

Fig.7Measure circuit of PV output current signal

According to the "virtual short" and "virtual circuit", we get *Ipv*: voltage signal of output current of photovoltaic cell.

$$I_{pv} = 2.5 \pm V_{out} \times 0.925 \quad (2)$$

At present, AC voltage sensor is mostly in large scale and high cost. The system has a low output current. In order to improve the measurement accuracy, reduce the relative error and reduce the cost, this system used operational amplifier circuit measure Inverter output AC voltage，as shown in Fig.8.

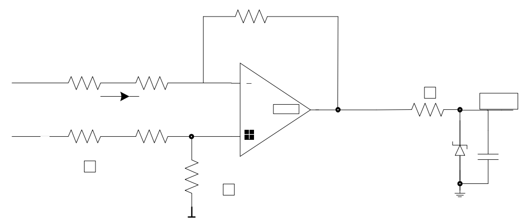

Fig.8 Measured circuit diagram

According to the "virtual short" and "virtual circuit" available:

$$V_{grid} = V_{ref} + \frac{R10}{R1+R2}(V_{ac\_L} - V_{ac\_N}) \quad (3)$$

By the numerical:

$$V_{grid} = [2.5 + \frac{1}{20}(V_{ac\_L} - V_{ac\_N})] \quad (4)$$

Therefore, the output voltage of the inverter bridge is -40~40V, and the range of V_{grid} is 0.5~4.5V.

IV.SOFTWARE DESIGN

The operating mode of the hardware device can be divided into three types, which are the starting mode, the operating mode and the failure mode.

When the system initialization is complete, the hardware device is detected, and if the initial state parameters of the PV cell voltage and the system are in line with the starting conditions, the hardware device communicates with the host computer, after normal communication, the hardware device is controlled by the monitoring software to enter the operation mode.Operation mode: the hardware device completes the corresponding data acquisition and arithmetic operations according to the instruction of the monitoring software, and sends the collected data to the host computer. The failure mode is mainly used to guarantee the system to work in the normal state, such as photovoltaic battery under voltage, DC boost chopper circuit output voltage, the current output of the inverter is too large and so on any case, the system enters the failure mode.Software design is mainly divided into two parts, one is the design of the MPPT control, the inverter control, and the other part is the design of the upper computer monitoring software.

The algorithm design of photovoltaic power experiment

The system uses Freescale MC9S12XS128MAA chip as the main controller, CodeWarrior software programming and debugging.

Power characteristic experimental program design

The purpose of the power experiment is to obtain the P-U curves and U-I curve in different light intensity and the temperature of the battery plate. Design idea is this: in [0,1] range, constantly disturbing DC / DC converter power tube Q1 PWM , equivalent to gradually change the photovoltaic panels of equivalent load, thus affecting the output voltage and output power, records corresponding P-U and U-I number and plots the characteristic curve.

Maximum power tracking control program design

Three MPPT control algorithms are designed in this experiment platform, which are voltage control method, perturbation method and conductance increment method. Monitoring software send different instructions to hardware device to choose a different MPPT control algorithm for MPPT control experiments, and set the parameters of the algorithm such as constant voltage, perturbation step, etc.

Inverter control program design

Inverter system includes two parts of the pre-stage BOOST control and the back-level inverter control, as shown in Fig.9. The purpose of the BOOST step up control is to achieve the stability of the former level voltage. The purpose of the back stage inverter control is to make the output voltage of the power frequency sine wave, and the two level controls is the PI control algorithm.

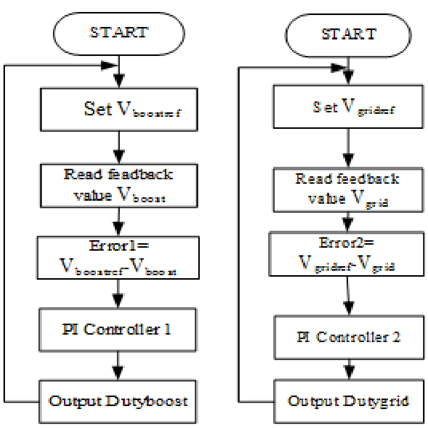

Fig.9 BOOST control and inverter control flow chart

The peak value of output voltage of inverter is 50V.The frequency is 50Hz.To carry out the experiment, the actual inverter peak output voltage is 48.6V,the frequency is 50.04Hz, peak voltage error is -0.4V and the frequency error is 0.04Hz.They are within acceptable limits.According to the inverse data obtained from the hardware device, the inverse curve is shown in Fig.10.

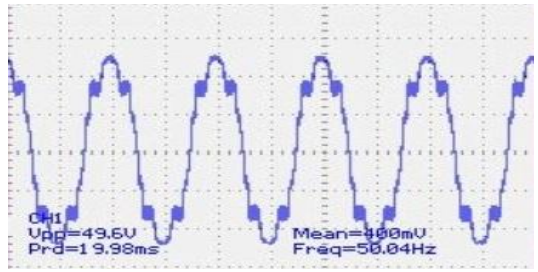

Fig.10 The result of the experiment

Expand experiment

Battery charge and discharge control experiment

Battery pack is the main energy storage device of photovoltaic cells, at the sunshine good weather to store excess energy and at night or rainy weather time to load power supply. Excessive charge or excessive discharge of the battery can cause adverse effects on the performance of the battery, so it is necessary to carry out reasonable control. On the basis of the hardware device, this paper makes a little changein the battery packto support the battery charge and discharge test.

MPPT and inverter control based on Neural Network

Neural network as the mainstream of intelligent control method has been widely used in the photovoltaic maximum power tracking control and inverter control. The operation of conventional microprocessors is limited, so it is difficult to meet the needs of the neural network model. Therefore, FPGA can be used as a special purpose of neural network connected with the hardware device to complete the MPPT control based on neural network and the inverter control experiment.

Monitoring software design

Based on the design of the hardware structure and the experimental method, monitoring software of the upper computer of the smallphotovoltaic power generation experimental platform is developed. Monitoring software bases on Visual Studio Microsoft 2010 platform C# programming language, and usesWinform. The main function is to receive the real-time data of each measurement, control node of the small experimental platform, carry out data analysis and curve display and send the control instruction.

The PC monitoring software has the characteristics of simple, intuitive and friendly man-machine interaction. Cooperatingwith the hardware device, it can flexibly control the experimental process, and intuitively display of the experimental results, as shown in Fig.11and Fig.12.

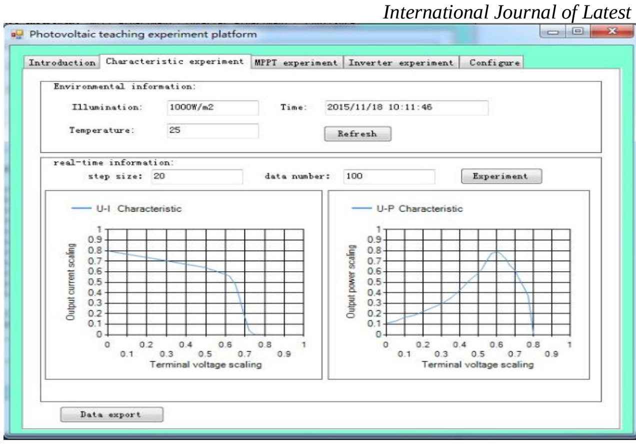

Fig. 11 Experimental process curve of U-I characteristics

V. CONCLUSIONS

In this paper, a small photovoltaic power generation experimental platform in low voltage is designed. This paper briefly introduces the principle of photovoltaic power generation, and then presents the experimental platform in detail from the hardware part and the software part. The hardware device is described in the aspects of the selection of the microprocessor, the design of the sampling circuit, and the construction of the bridge. The software part mainly recommends the design of the maximum power tracking and the inverter program,and the design of the software monitoring interface. At the same time, itsuggests that the experiment the experimental device may be carried out. The practical application shows that this experimental platform can complete many experiments such as the characteristics of solar cell, the maximum power tracking experiment and the experiment of the inverter, and has good expansibility. It has important significance for the research and teaching of photovoltaic power generation technology.

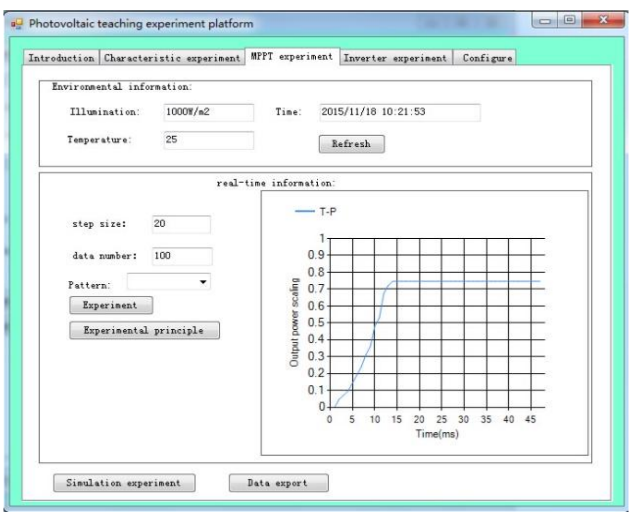

Fig.12 MPPT experimental process

ACKNOWLEDGMENT

The work of this paper is supported by "the Fundamental Research Funds for the Central Universities" of North China Electric Power University (2015ZD17) and Science and Technology Project of State Grid Corporation of China (2014-Z-Y34A).

REFERENCES

[1] Ding Ming, Wang Weisheng, Wang Xiuli, Song Yunting, Chen Dezhi, SunMing.A Review on the Effect of Large-scale PV Generation on Power Systems [J]. Proceedings of the CSEE, 2014, 01:1-14.

[2] Chen Quan, Li Lingdong, Wang Qunjing,Duan Xiaobo, Ye Jingen, Zeng Ye.Simulation Model of Photovoltaic Generation Grid-Connected System and Its Impacts on Voltage Stability in Distribution Grid [J]. Transactions of China Electrotechnical Society, 2013,03: 241-247.

[3] Hill C A, Such M C, Chen D M, et al. Battery Energy Storage for Enabling Integration of Distributed Solar Power Generation [J]. Smart Grid, 2012, 3(2): 850-857.

[4] CaiYongsheng, Wang Deyan.SolarPower Generation Experiment Platform Based on Photovoltaic System [J]. Experimental Technology and Management, 2011,02:66-67+71.

[5] Zhou Jingsen, Chen Hougui. Design of the Experimental Facilities for Exploring New Energy and Generating Photovoltaic Power [J]. Telecom Power Technology, 2011,05:53-54+56.

[6] GuoRui,LiuLiying,WangShuaijie,GaoWei.Design of Photovoltaic Power Generation Experimental System [J].Journal of Shenyang Institute of Engineering(Natural Science), 2013,03:198-200.

[7] GaoHuiping , TianJianjun , ZhangZhenlong , Mao Yanli.Teaching Exploration of Comprehensive Design Experiments Based on Solar Photovoltaic System [J]. Experiment Science and Technology, 2015,01:100-102+169.

[8] Yan Na. Design and Construction of bench about Photovoltaic Power Generation System [J]. Experimental Technology and Management, 2012,12:71-74.