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Design the control for a photo-voltaic system with sinusoidal output voltage

Quynh Nga Duong, Thi Hai Yen Tran, Quynh Nhat Duong

Abstract— **The research of Photo-voltaic system is very important in order to completely exploit the unlimited natural resource while traditional resources are gradually decreasing. The Photo-voltaic system connected to the electrical grid is a flexible and economical solution at the moment. However, it is not easy to control the grid-connected Photo-voltaic system. To connect the Photo-voltaic system to the national electricity network, the output voltage of the photo-voltaic system must be synchronous with the voltage current of the electrical grid. So it is essential to make the Photo-voltaic system have sinusoidal output voltage with the frequency of 50Hz. This is the very first step to design a control for the grid-connected Photo-voltaic system.**
The paper gives a solution for controlling the Photo-voltaic system with sinusoidal output voltage.

Index Terms — **The Photo-Voltaic system, solar power, The grid-connected Photo-Voltaic system**

I. INTRODUCTION

Solar energy is one of the most valuable renewable energy sources. At the same time, it is also the origin of other renewable energy sources such as wind energy, biomass energy, energy of rivers. Solar energy is unlimited. However, the exploitation and use of this energy source are a matter of concern for domestic and foreign researchers.

Vietnam is a developing country, so energy demand is increasing. At present, Vietnam's national policy on energy needs is based on the establishment of hydropower, steam and wind turbines, etc. However, to ensure sustainable development and balance the nation's energy in the future, Vietnam has been focusing on researching and developing new energy resources including solar energy. Recent changes show that solar energy application and exploitation have made new strides.

To exploit and use solar energy effectively, it is necessary to have an intelligent grid system. After sunlight creates direct current (DC), it is converted into alternating current (AC) by the inverter. The control has the function of transmitting this energy to the load. This paper gives a solution for controlling the Photo-voltaic system with standard sinusoidal output voltage.

Quynh Nga Duong, Department of Electrical Engineering, Thai Nguyen University of Technology, Thai Nguyen, Vietnam, +84977866253.

Thi Hai Yen Tran, Department of Electrical Engineering, Thai Nguyen University of Technology, Thai Nguyen, Vietnam, +84978610626.

Quynh Nhat Duong, Department of Electronic Engineering, Thai Nguyen University of Technology, Thai Nguyen, Vietnam, +84868040287.

II. OVERVIEW OF PHOTO-VOLTAIC SYSTEM

An independent photo-voltaic system is a source which is not connected to the national or local electricity network. This system is applied in areas without electrical grid. In addition to the solar battery panels, a photo-voltaic system also consists of other components shown in figure 1.

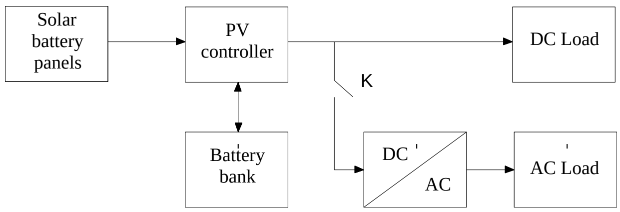

Fig. 1: General block diagram of a photo-voltaic system

Solar battery panels consists of one or more panel modules put together. Solar batteries are assembled from many photovoltaic cells. Photovoltaic cells are semiconductor devices containing a large number of P-N diodes. In the sunlight, photovoltaic cells can generate electricity or in other words they can convert solar energy into electricity. This conversion is called the photoelectric effect. Multiple solar panels can be assembled into a photovoltaic system. Solar batteries have a single crystal or polycrystalline form. Depending on the type, panels can be efficient from 15% to 18%, power from 25Wp to 200Wp and have an average life expectancy of about 25-30 years. Depending on power, voltage and current requirements, solar panel modules can be connected in series, parallel or mixed. The output power of the solar battery panels is directly proportional to the intensity of the solar radiation.

The battery set may also comprise one or several batteries connected in series, parallel or mixed. Its role is to store power to supply power consumption devices which are often refered as loads. The capacity of the battery set (measured in Ah or Wh) must be calculated in accordance with the capacity of the solar battery panels.

The controller is an electronic device that automatically regulates the processes of the solar battery panels that charge the battery set to power the loads. Specifically, when the battery is full, the capacity reaches 100%, the control automatically stops or reduces the charging current from the PMT panels to prevent the battery from overheating and demaging. Then when the battery capacity has decreased to some preset bad value, the control automatically closes the circuit to recharge the battery. Otherwise, for some reasons such as bad weather, little or no sunshine, the battery can be exhausted, leading to battery damage. So when the battery capacity decreases to below "danger limit" (usually when the battery capacity is only 30-40%), the control automatically disconnects the load circuit, preventing the loads from continuing to use electricity. When the battery capacity has reached above the danger limit , the control will automatically close the load circuit. Thus, the control automatically prevent the battery from being overloaded or underloaded.

DC loads are DC devices. They are connected directly after the control. Obviously, the capacity and voltage of the control must be compatible with the capacity and voltage of DC loads.

AC loads are devices that use alternating current (for example, the current of 220V, 50Hz).

The DC/AC converter is a DC converter that converts DC current from the solar battery panels or the battery set into AC current to supply AC loads.

In reality, we have encountered many independent solar power sources. This type of source technology is often applied in areas without industrial electricity network or for special consumption with small capacity loads. The disadvantage of independent source technology is that the battery must be used, which is both expensive, must be maintained regularly, and pollutes the environment. On the other hand, the battery can only store a limited amount of power. And, for the solar battery panels of tens or hundreds of kW, using the battery is a big problem, even impossible.

For large scale applications, grid-connected photovoltaic system is used. In some remote areas or islands, the electrical grid has not reached yet, so the photovoltaic system used to provide electricity for on-site loads prevails.

III. SOLUTION FOR CONTROLLING THE PHOTO-VOLTAIC SYSTEM WITH SINUSOIDAL OUTPUT VOLTAGE

This paper proposes a solution for controlling the photovoltaic system with sinusoidal output voltage. The control algorithm for each part and the whole system is simulated on Matlab Simulink.

3.1 Solar battery panels

Choose solar battery panels:

- Module type: SunPower SPR – 305 – WHT
- Quantity: 330 modules
- The solar battery panels consist of 66 rows of battery panels placed in parallel with one another. Each battery row consists of 5 modules in series. Battery capacity is: 66.5.305,2 = 100,7 kW.

Battery panel specification:

- Open circuit voltage: U_{oc}=64,2 V;
- Short-circuit current : I_{sc}=5,96 A
- Current and voltage at the maximum capacity point: U_{mp} = 54,7 V; I_{mp} = 5,58 A.

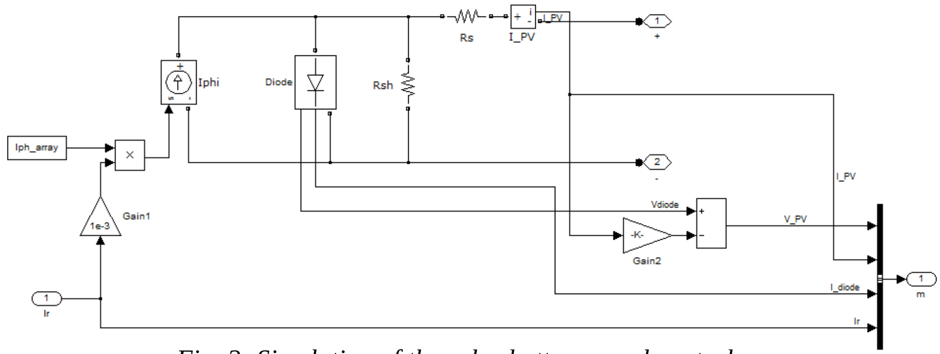

Fig. 2: Simulation of the solar battery panel control

3.2 Control circuit for Boost Converter

The control for the boost converter takes the input signal from the voltage of the solar battery panels U_{PV}, releases output U_{DC} to transmit to DC/AC inverter.

The Boost converter has a duty of converting DC voltage from 273,5V to 500V. During the voltage conversion process, there is an intervention of the control taking the MPPT maximum power point of the solar battery panels.

Conduct simulation for Boost converter on Matlab Simulink software with parameters: C_3 = 100 µF, C_1 = C_2 = 12000 µF, L_1 = 5 mH, R_1 = 0,005 Ω will have results shown in figure 3.

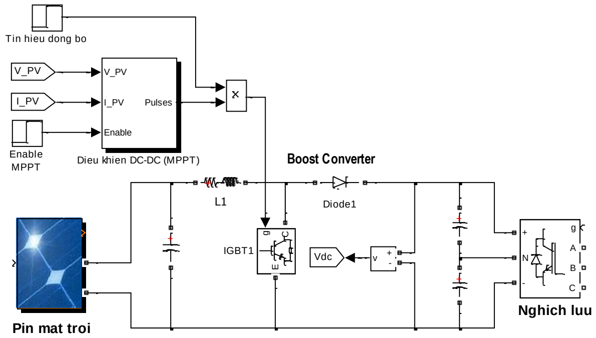

Fig. 3: Simulation of Boost Converter

3.3. Control circuit for three-phase DC/AC inverter (Voltage Source Inverter - VSI)

To control DC/AC inverter, there are two main ways: current control and voltage control. But the current control method is more common to grid connection. The current control has the advantage of being less sensitive to phase shift voltage and grid voltage distortion so that the harmonic wave is reduced to a minimum. On the contrary, the voltage control is the result of an excessive increase in the inverter voltage and a large harmonic wave can occur if the grid voltage is distorted. If the photovoltaic system works independently from the grid, the control voltage can be selected naturally. But when the system works in grid mode, the current control is the dominant control method. Therefore, in this paper, the author chose the current control method to control the inverter.

The inverter control circuit will generate a signal to control the operation of IGBT, the inverter control signal is designed in the mode of pulse width modulation (PWM). However, in order to reduce harmonics, improve the quality

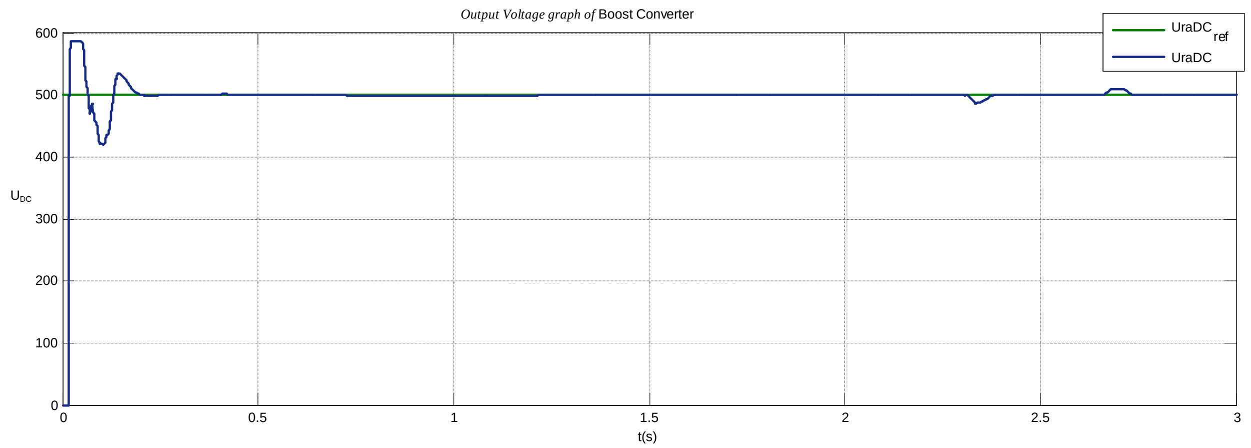

Fig. 4: Output Voltage graph of DC-DC converter

of the output voltage, spatial vector modulation (SVM) is used.

The inverter control system uses two control loops. The first one is the external control loop used to stabilize the DC link voltage at 250V. The second one is the internal control loop to control the feedback current from the grid I_d and I_q.

I_{dref} current is the output of the external DC voltage control. To maintain the system power factor, choose $I_{qref} = 0$.

The voltages U_d and U_q are obtained at the output end of the current control. These two voltages are calculated to give a reasonable U_{ref_abc} voltage signal to the control pulse generator using the SVM modulation method in the DC/AC inverter.

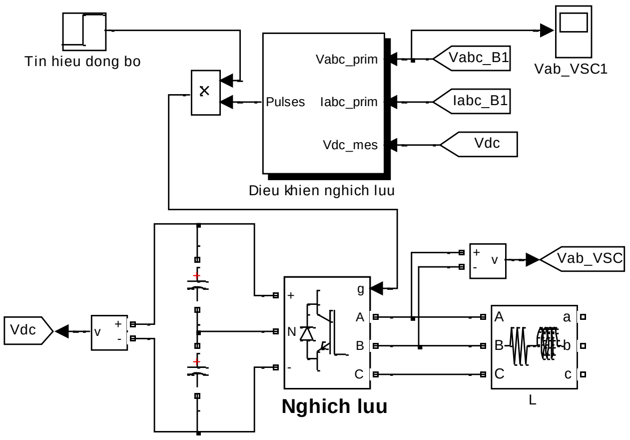

Fig. 5: Control simulation of DC/AC inverter

3.4. Phase-locked- loop (PLL)

Phase-locked-loop (PLL) is a feedback system that consists of a Phase detector, a Low-pass filter (LPF), an amplifier and a Voltage-controlled oscillator (VCO). In some PLL circuits, the VCO can be replaced by a Current-controlled oscillator (CCO).

In fact, PLL operates on the principle of a control loop whose input and output parameters are frequencies and they are compared with each other in phase. The phase control loop is responsible for detecting and correcting errors in the input and output frequencies, In other words, PLL gives the output frequency f_O of the output signal compared to the input frequency f_i of the input signal.

When there is not input signal V_i, the output voltage amplified $V_{out} = 0$, the oscillator (VCO) operates at the natural frequency f_N (set by external resistors and capacitors).

Detect the numerical phase with EXOR port.

The use of EXOR port to compare phases has two advantages: high resolution gain compared to other ports and the output pulse of double the frequency regardless of the input frequency. The control circuit of the whole system shown in figure 7.

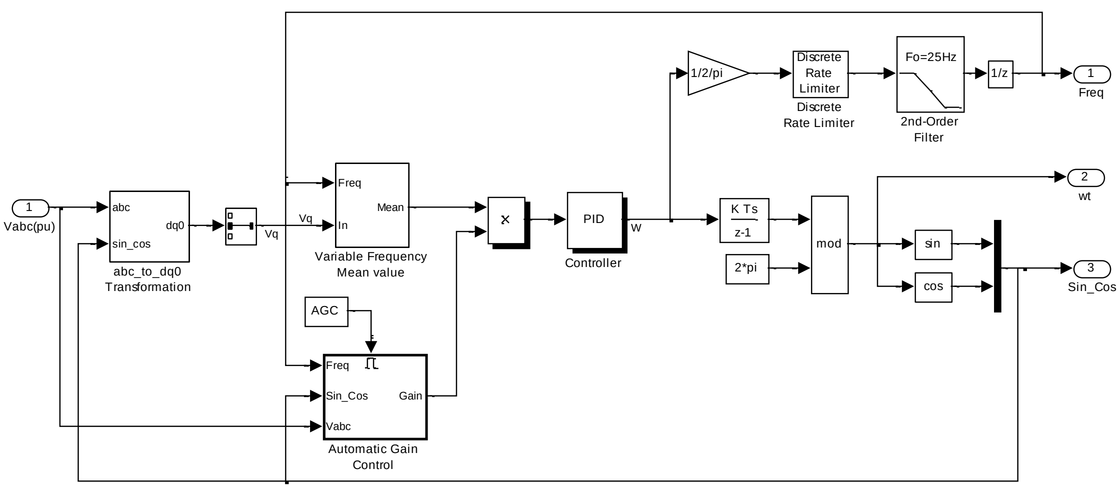

Fig. 6: Phase-locked-loop (PLL)

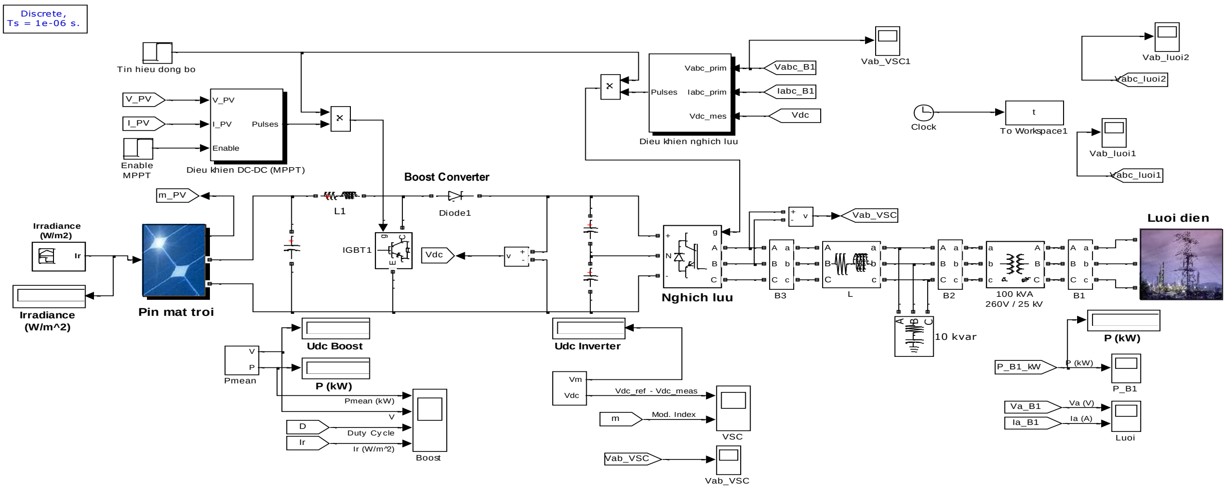

Fig. 7: The control circuit of the whole system

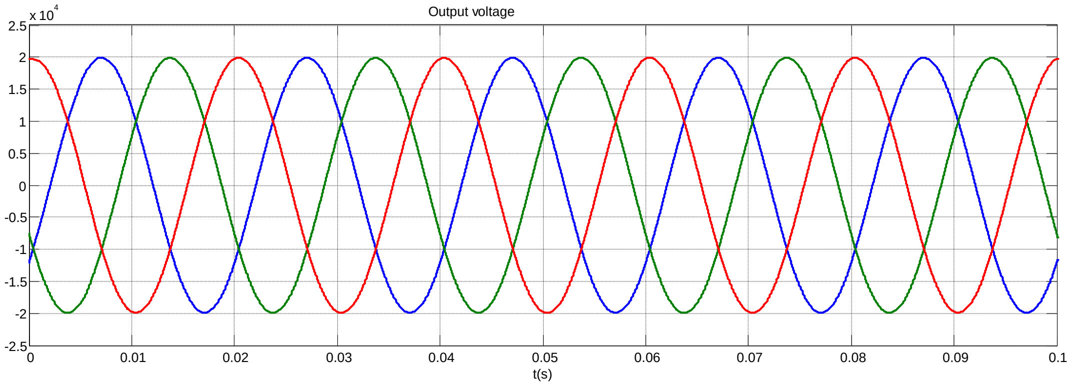

Figure 8: The Output voltage of the system

IV. Conclusion

This paper has presented some overview of solar energy. This paper has also proposed a solution for controlling the photovoltaic system; Conducted simulation on Matlab-Simulink and given the simulation results. The simulation results are honest, confirming the correctness of building control algorithms. The paper has initially controlled the photovoltaic system with standard sinusoidal output voltage.

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References

[1]. **Dương Quỳnh Nga** *"Thiết kế điều khiển hệ thống điện sử dụng năng lượng mặt trời hòa lưới điện quốc gia"*, Luận văn cao học, Trường đại học Kỹ thuật công nghiệp, 2013.

[2]. **Nguyễn Doãn Phước** "*Lý thuyết điều khiển tuyến tính*", Nhà xuất bản Khoa học và Kỹ thuật, 2002.

[3]. **Nguyễn Phùng Quang** (1998) *Điều khiển tự động truyền động điện xoay chiều ba pha (tái bản lần thứ 1)*. Nhà xuất bản giáo dục.

[4]. **Nguyễn Phùng Quang** (2004) *MATLAB & SIMULINK dành cho kỹ sư điều khiển tự động*. Nhà xuất bản Khoa học và Kỹ thuật

[5]. **Nguyễn Phùng Quang, Andreas Dittrich** (2002) *Truyền động điện thông minh*. Nhà xuất bản Khoa học và Kỹ thuật

[6]. **C. Cho; J. Jeon; J. Kim; S. Kwon; K. Park.; S. Kim,** "*Active Synchronizing Control of a Microgrid*" IEEE Transactions on Power Electronics, issue 99, pp., 2011

[7]. **Trần Bách**, "*Lưới điện và Hệ thống điện*", Nhà xuất bản Khoa học và Kỹ thuật, Hà Nội, 2000

[8]. **Lã Văn Út**, "*Phân tích và điều khiển ổn định hệ thống điện*", Nxb Nhà xuất bản Khoa học và Kỹ thuật, Hà Nội, 2001

[9]. **Nguyễn Hồng Anh, Nguyễn Minh trí**, "*Ứng dụng hệ mờ điều khiển SVC trên lưới điện*" Tạp chí khoa học số 15 + 16 Đại học Đà Nẵng

[10]. **Phạm Thị Hồng Anh**, "*Xây dựng bộ điều khiển nối lưới nguồn năng lượng mặt trời*," Luận văn thạc sỹ kỹ thuật, chuyên ngành tự động hóa; 2012

MSc Quynh Nga Duong is master in Electrical engineering at Thai Nguyen University of Technology, Viet Nam. She is working at Faculty of Electrical Engineering, Thai Nguyen University of Technology, Thai Nguyen City, Vietnam. Research interests: Electrical Engineering, Automation, Solar energy.

MSc Thi Hai Yen Tran is master in Electrical engineering at Thai Nguyen University of Technology, Viet Nam. She is working at Faculty of Electrical Engineering, Thai Nguyen University of Technology, Thai Nguyen City, Vietnam. Research interests: Electrical Engineering, Automation, Control.

MSc Quynh Nhat Duong is master in Electrical engineering at Thai Nguyen University of Technology, Viet Nam. She is working at Faculty of Measurement Control, Thai Nguyen University of Technology, Thai Nguyen City, Vietnam. Research interests: Electrical Engineering, Automation, Control, Identification.