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Model of Grid Connected PV Power Generation Inverter Control System

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Abstract—*A study on PWM control strategy is done based on the power output side of photovoltaic grid connected generator system to find the effectiveness of each control method. The control methods being have studied are 1) voltage source inverter control method and 2) power type PWM inverter control method. Finally on the basis of experiment a single phase grid connected Improved PWM inverter control method is constructed. It uses MATLAB/SIMULINK software to simulate & analyze. The result of the simulation shows that the improved PWM inverter control system can effectively control the grid current sine waveform using the less computationally demanding harmonic suppression technique Meanwhile it can achieve the maximum power point tracking. The proposed system is designed to be integrated in a dynamic simulation program. It is able to put the arbitrary power out to the load or to the grid to maintain the stability and reliability of the power system.*

Index Terms*: PV Power generation, PWM Inverter, PV Array, photovoltaic cells.*

1. INTRODUCTION

Due to the increasingly urgent energy issues, the world attaches great importance to begin the development of new energy and related technology. At present, large-scale photovoltaic power generation and scale of renewable energy has become important parts of development strategy, meanwhile it is the way to guide the development of photovoltaic industry [1],[2]. However, because of its different characteristics from conventional power generation, grid-connected PV power station and its security, stability and reliable operation became new challenges which power grid and PV power plant need to face.

The paper describes two inverter control methods including the voltage source inverter control method and the power type PWM inverter control method and improved PWM inverter control method [3]. Voltage source inverter control method regulates phase angle of the grid mainly through receiving voltage signals from DC side of inverter which is called the outer loop to control the grid voltage, while it regulates the voltage reference from the AC side load voltage to control the inverter output current which is called the inner loop [4]. However, the process of the inner loop will not affect the results of the outer loop. Power-type PWM inverter bridge circuit formed by the two groups, which uses two reverse diodes synchronized transformation. Required power can be obtained by changing the modulation rate of PWM inverter. Therefore, whether the grid-connected PV generation inverter control system is able to achieve the maximum power point tracking (MPPT) and to ensure high power quality of the photovoltaic cells or not are the key issues in electric power system [5]. In this paper our work is mainly based on following two techniques. First is Grid connected PV generation system, secondly Inverter control technique.

Grid-connected PV Generation System

Grid connected PV Generation System

Grid-connected PV generation system is mainly composed of the PV array, the inverter device with the function of maximum power tracking and the control system. The inverter device with the function of maximum power point tracking can inverse the electric power into sinusoidal current, and connect to the grid [6]. The control system mainly control the maximum power point tracking of photovoltaic, current waveform and power of the output of grid-connected inverter, which makes the output to the grid correspond with the export by PV array.

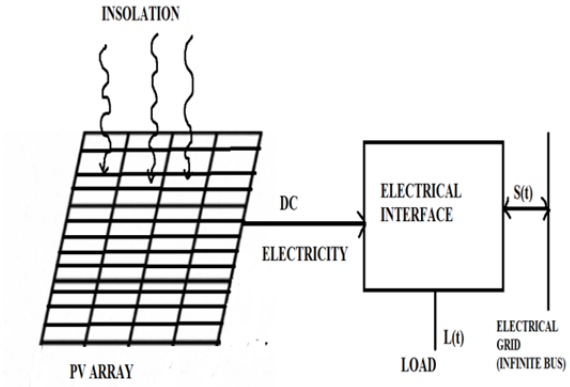

Fig. 1: Grid-connected PV power generation structure

B. Inverter Control Theory

Inverter can control the switch state of shut and conduct, thus the system may form two different working ways which are parallel operation and independent operation. When the system is working in a parallel operation way, the inverter belongs to the current mode.

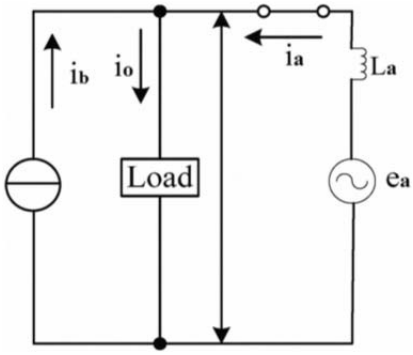

Fig. 2: Equivalent circuit of the inverter in parallel operating mode

Working of PV Cell

Working of PV cell is based on the basic principle of photoelectric effect. Photoelectric effect can be defined as a phenomenon in which an electron gets ejected from the conduction band as a consequence of absorption of the sunlight of certain wavelength by the matter. So, in a photovoltaic cell when sunlight strikes its surface, some portion of the solar energy is absorbed in the semiconductor material. If absorbed energy is greater than the band gap energy of the semiconductor, the electrons from the valence band jumps to the conduction band. By this, pair of hole electrons are created in the illuminated region of the semiconductor. The electrons thus created in the conduction band are now free to move. These free electrons are forced to move in a particular direction by the action of electric field present in the PV cell. These flowing electrons constitutes current and can be drawn for external use by connecting a metal plate on top and bottom of PV cell. This current and voltage created because of its built in electric fields produces required power.

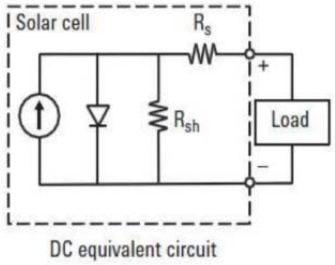

Fig. 3: D.C Equivalent Circuit.

The photovoltaic cell output voltage is basically functioning of the photocurrent which is mainly determined by load current depending on the solar irradiation level during the operation.

VC = (A*K*TC/e)ln[(Iph+I0-IC/I0)-RS*IC

The symbols used are

VC = cell output voltage

TC = reference cell operating temperature

RS = series resistance of cell

IPh = photocurrent, function of irradiation level and junction temperature

I0 = reverse saturation current of the diode

IC = cell output current

INTRODUCTION OF TWO TYPICAL INVERTER CONTROL METHODS

Voltage Source Inverter control method

The PV array's working voltage is set to the standard voltage should be matched with the working voltage when the PV array is in the maximum power output state. The standard current should be kept to sinusoidal while the power factor should be kept to one which can be realized by the voltage source inverter and its control method. The process of inverter control system is rather complex which uses the former class system voltage fluctuations and waveform distortion signal to control the next class system. To ensure power supply, the switch of inverter output will make frequency management control complex and difficult. It will increase the complexity of the control system of the main circuit if setting another AC switch, meanwhile the single phase system will have a big power fluctuation

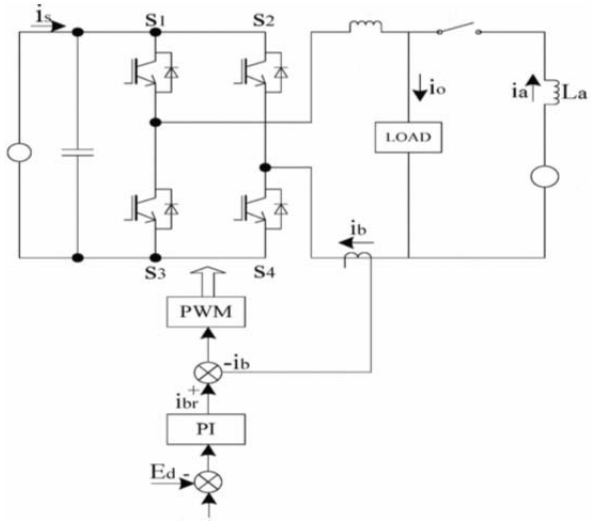

Fig. 4: Voltage source inverter and its control method

Power Type PWM Inverter Control Method

Power type PWM inverter is composed of two bridge circuits, which used two reverse diodes to carry out synchronous transformation. Meanwhile it applied discontinuous current

manipulating technique to increase or decrease output voltage of PV, getting needed power which will be controlled through changing modulation rate of PWM. Power type PWM inverter control system is shown in Fig. 5.

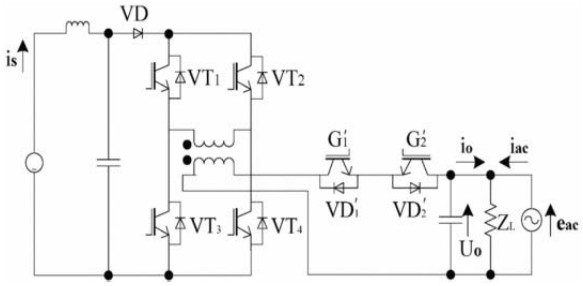

Fig. 5: Power type PWM inverter control system

IMPROVED PWM INVERTER CONTROL METHOD

The improved PWM inverter control system abolishes two reverse diodes in the power-type PWM that can save a lot in the control system. And the setting of the drive voltage phase of the inverter is based on the grid voltage phase which means the output power factor will be kept to a high value. The improved PWM inverter control system also uses the outer loop to control voltage and the inner loop to control current which is the same with the voltage source inverter control, and then it tracks the maximum power point after using the output current transforms to a fit type, which can ensure maximum power output of the battery [7]. In this way, the system inverter structure is simpler than the power-type PWM, and ensures the stability of the power output.

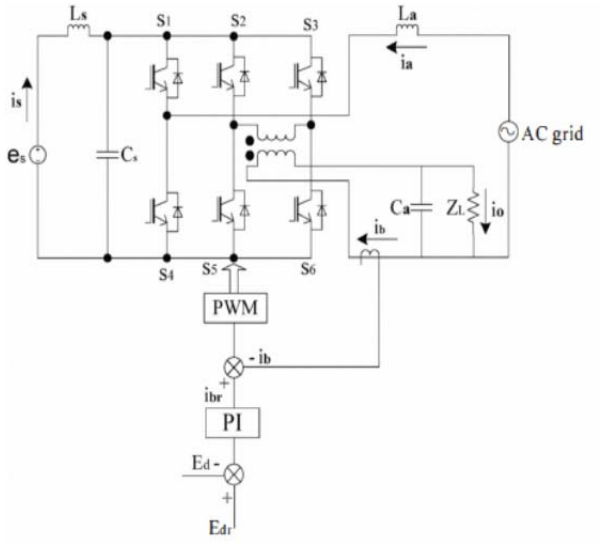

Fig. 6: Improved type PWM Inverter Control System.

SIMULATION

The simulation mainly use MATLAB/Simulink software to build a single-phase grid-connected PV generation system, which combines with the improved type PWM inverter control method, the structure is shown in Fig. 7. The system is mainly composed of PV array module, IGBT inverter module, LC filter module and PWM regulator module.

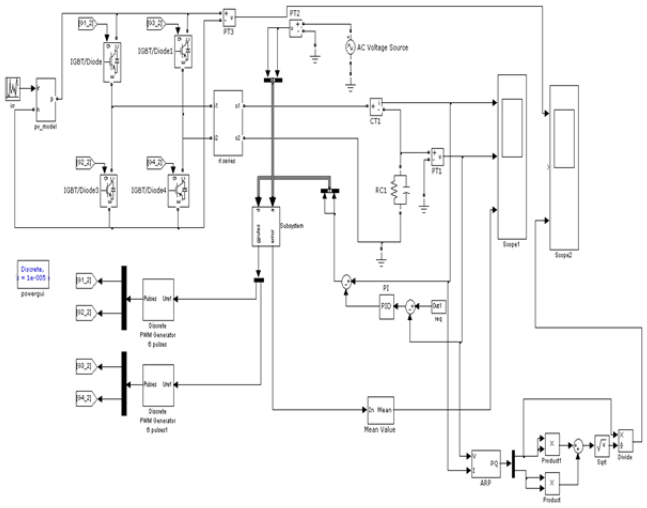

Fig. 7: Single-phase PV grid-connected generation system

In the example, the voltage of PV cell is set to 1000V, the load is in form of resistance and inductance whose resistance is set to 100 Ω, and the inductance is set to 50mH which is equivalent to 500W. PWM regulator controls the current of inverter through using the outer loop to control voltage and using the inner loop to control current, whose modulation index is 0.8. The load current and the output voltage of inverter can be got by calculation. The load current effective value is 37A, while the output voltage effective value of inverter is 800V. PV array output voltage curve, Grid-connected load voltage curve and Grid-connected load current curve, load P.F, load Error are shown in Fig. 10, Fig. 11, Fig.12 and Fig. 13 separately.

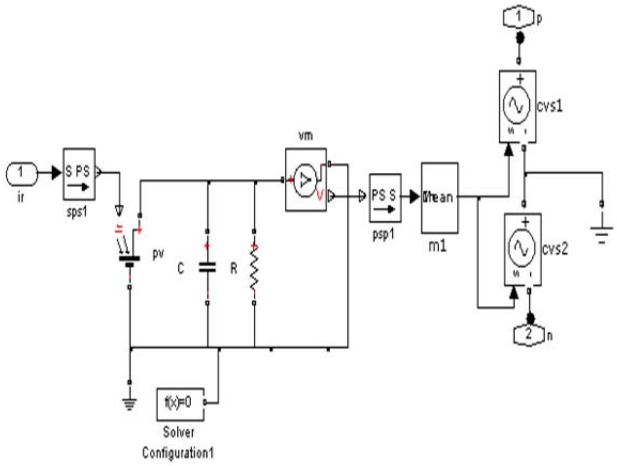

Fig. 8: PV Model

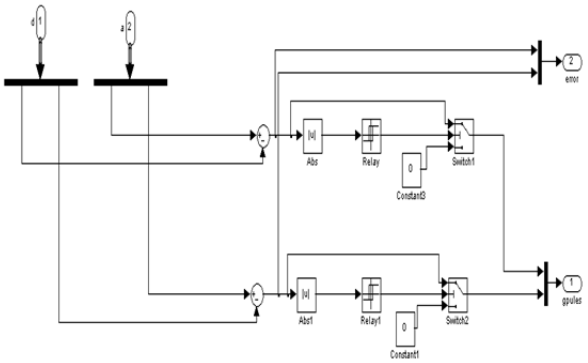

Fig. 9: Comparator

VII. SYSTEM OUTPUTS

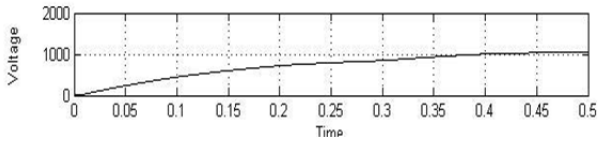

Fig. 10: Output voltage of PV Cell

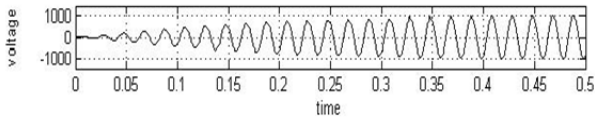

Fig. 11 Grid connected load voltage Curve

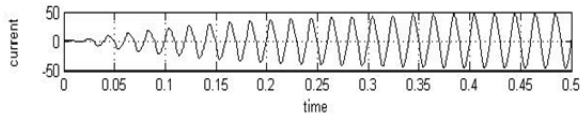

Fig. 12: Grid connected load current Curve

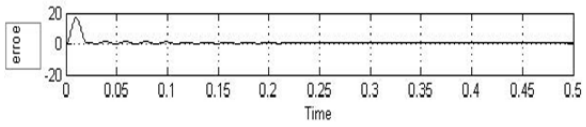

Fig. 13 Grid connected load Error Curve

Fig. 11 and Fig. 12 are the load voltage curve and load current curve separately. From the two curves, operating voltage and current are unstable up to 0.3 sec, and then return to near-sinusoidal waveforms quickly, which shows the improved PWM inverter control method can achieve a stable output power better and faster. The power is arbitrary sent to the grid through controlling the PWM regulator, after analyzing the spectral; the power factor will reach to 0.95, which is fully satisfied with the requirement of PV grid-connected generation.

VIII. CONCLUSION

Improved PWM inverter control system is based on the voltage type control method and the PWM power type control method. The result of simulation and conclusions shows that the improved PWM inverter control method can make the voltage and the current waveform of the grid tend to sine wave effectively and quickly, and the power factor will reach to one. The power can be sent to the grid or load arbitrary through controlling the PWM regulator, while the control system has a good stability. It also shows that as the increasing number of inductive load penetrate the grid, the load waveform distortion is produced, but it will not affect the reliability of power supply.

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