Synchronisation In Grid-connected PV Generation Inverter Control System

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Abstract – In this paper explain the operational principal and structure of the grid-connected photovoltaic system and reducing cost of project without using battery with the use of inverter control method and describe the control strategy based on a maximum power point tracking (MPPT) control using P & O method on the basis of inverter control method, we will present an improved PWM inverter control system that can be applied in grid-connected PV generation and uses MATLAB/SIMULINK software to simulate and analyze. the result of simulation shoes that the improved inverter control system can effectively control the grid current waveform which tends to sine wave, means while it can achieve the maximum power point tracking, besides it is able to put the arbitrary power out to the load or to the grid , while the control system has a good stability.

Index Terms – Grid connected PV system; MPPT; Inverter control system; PWM Inverter.

1. INTRODUCTION

Distributed generation for renewable energy sources is penetrating the electric power system due to the rising cost of traditional energy sources and the environmentally friendly features of renewable energy. Over 60 countries around the world have set targets for renewable energy supply. The types of renewable energy include solar, wind, hydrogen, biomass, geothermal, hydropower, and biodiesel. Many of these renewable energy sources are designed to supply energy into the electric power system. Photovoltaic allow the consumers to generate electricity in a clean, reliable and quiet manner. Photovoltaic are often abbreviated as PV. Photovoltaic cells combine to form photovoltaic systems. Photovoltaic cells are devices that convert light energy or solar energy into electricity. As the source of light is usually the sun, they are often referred to as solar cells. The word photovoltaic is derived from photo meaning light, and voltaic, which refers to production of electricity. Hence photovoltaic means production of electricity directly. The paper describes inverter control

Methods the power type PWM inverter control methods which are common used at present. 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. 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 got 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.

2. 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. Photovoltaic system use solar panels to convert sunlight into electricity. A system is made up of one or more solar PV panels, an AC or DC power converter that holds the solar panels, and the interconnections and mounting for the other components.

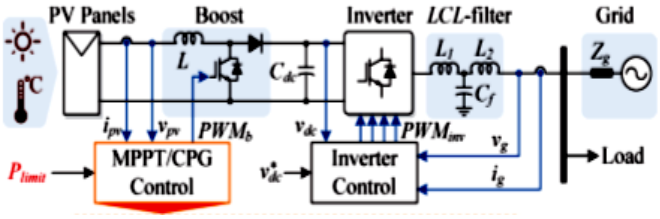


Fig.2: Grid-connected PV Power generation structure.

Photovoltaic modules or solar panels:- A photovoltaic array is a linked assembly of PV modules. Most PV array use an inverter to convert the dc power produced by the modules into alternating current. The modules in a PV array are connected in series to obtain the desired the voltage, the individual string

are then connected in parallel to allow the system to produce more current.

2.1 Maximum Power Point Tracking (MPPT):-

Solar inverters use maximum power point tracking to get the maximum possible power from PV array. Solar cells have a complex relationship between solar irradiation, temperature and total resistance that produces a non-linear output efficiency known as the I-V curve. It is the purpose of a MPPT system to sample the output of the cells and determine a resistance to obtain maximum power for any given environmental conditions.

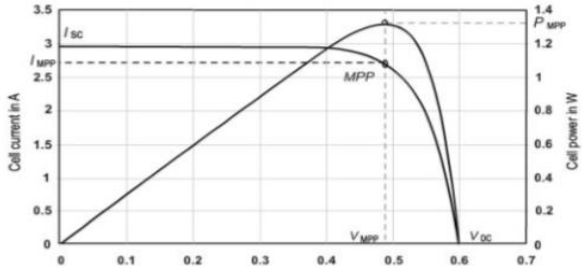


Fig2.1:P-V &I-V curve of a solar cell at given temp & solar irradiation.

The I-V & P-V curve for a solar cell are given in fig. it can be seen that the cell operates as a constant current source at low value of operating voltage source at low value of operating current.

MPPT is not a mechanical tracking system that "physically moves" the modules to make them point more directly at the sun. MPPT is a fully electronic system that varies the electrical operating point of the modules so that the modules are able to deliver maximum available power. Moving towards general discussion of various MPPT method, we come across two method.

a) Perturb & Observe

b) Incremental conductance

a. Perturb & Observe:-

The Proposed method solves the problem caused in hill climbing process from those caused by irradiance changing by decoupling the PV power fluctuation. This method adds an irradiance changing estimate process in every perturb process to measure the amount of power change caused by the change of atmospheric condition and thus compensates it in the perturb process.

2.2 Boost converter:-

Boost converter steps up the input voltage magnitude to a required output voltage magnitude without the use of a transformer. the main component of a boost converter are an inductor, a diode & a high frequency switch. These are co-ordinated manner supply power to the load at a voltage greater than the input magnitude the control strategy lies in manipulation of the duty cycle of the switch caused the voltage change. There are two mode of operation of a boost converter those are based on the closing and opening of the switch. The first mode is when the switch is closed; this is known as charging mode of operation. The second mode is when the switch is open, this is known as the discharging mode of operation

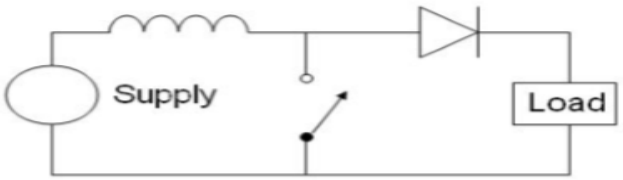


Fig2.2 .Boost converter

2.3 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 independently operation. When the system is working in parallel operation way, the inverter belongs to the current mode. Equivalent circuit of the inverter in parallel operating mode is shown in figure below .

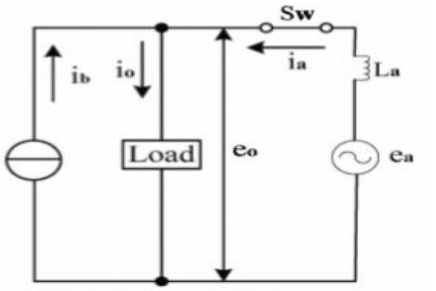


Fig.2.3.1: Equivalent circuit of the inverter in parallel operating mode

$$eb = e_a - La(dia/dt) \quad (1)$$

$$ia = i0 - ib \quad (2)$$

where, e_a is the source voltage, e0 is the AC voltage of the load, ia is the contact current, i0 is the load current, ib is the output current of the inverter. According to above equations, the relation equation of fundamental component of voltage and current is easily got, as in equation (3).

$$e01 = ea1 - La[d(i01-ib1)/dt] \quad (3)$$

The voltage fundamental Ea1 seen as the base line vector, thus the fundamental value E01 by the output of inverter and its phase is δ. Based on factor starting above, the vector figure in

parallel mode can be drawn as shown below. From fig (3), the relation equation of the active component Ia1p and reactive component Ia1q of contact current Ia1 can be reach as in (4),(5).

$$Ia1p = -(E01\sin\delta)/xa \quad (4)$$

$$Ia1q = (E01\cos\delta - Ea1)/xa \quad (5)$$

where, xa =ωLa the equation of active power Pa and reactive power Qa in parallel mode are shown in (6), (7)

$$Pa = Ea1Ia1p = -(Ea1E01\sin\delta)/xa \quad (6)$$

$$Qa = Ea1Ia1q = Ea1(E01\cos\delta - Ea1)/xa \quad (7)$$

where, Ia1p is the substraction of active component which stand for the load current and the inverter current. Thus the value of the active component received by the ac grid will be controlled by the phase between the output voltage of the inverter and the source voltage. Additionally, the load voltage can be written as

$$E01 = (Ea1 + I01q\ xa - Ib1qxa)/\cos\delta \quad (8)$$

The reactive component Ib1q is produced by inverter, which can be compensated through controlling Ea1 and I01.

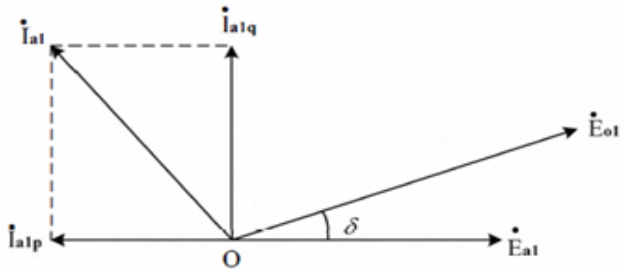


Fig.2.3.2: The vector figure in parallel mode

2.4: Improved PWM inverter control method:-

In improved PWM inverter control method the two reverse diodes used in power type PWM is removed. 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 use 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. In this way, the system inverter structure is simpler than the power-type PWM, and ensures the stability of the power output. The improved PWM inverter circuit can realize the following mode. For one thing, work as AC switch. Using the switch S1 and S4 of the three-phase inverter module, it can separate the system from grid when power off, instead of the AC switch SW. For another, work as inverter. Single-phase PWM inverter is composed of switch S2. S3. S5. S6. When it is in parallel operation mode, S1 = S2, S4 = S5, so the output port P1 and P2 are connected. However, when the system is in independent mode, the port S1 and S4 are not conducted, the inverter related to the load will be cut off from grid. The requirement for the system is the inverter output power shouldn't be delivered from DC side to the AC grid in any circumstance. This improved type PWM inverter control method adopted the isolated transformer to allow the load to achieve the required voltage, which plays an important role of separating AC system from DC system. The control system is composed of three parts which are AC voltage control, DC voltage control and phase angle control. As to the AC voltage control part, let's set the AC output voltage to Eo, and its standard voltage is Eor , this signal reflect the phase of source voltage, directly impact power transmission between AC grid and DC system. Additionally, it should add a control signal which maintains a certain DC voltage. Based on the two signals, sine function generator produces the AC control standard voltage. Inside of the voltage control loop contains current control loop which it is not directly impact the result of voltage control. In actually fact, the PV output current is not the same with DC source. Because this current contains the high frequency component including output of active filters, time constant of current regulator should not choose too large. As to the DC voltage control part, the AC output power of inverter is set to Pb which corresponds with the power Pd of the DC side. Pa is the power received from grid.

$$Pa = Po - Pb = Po - Pd$$

According to the power symbol, the direction of power can be determined. As to the phase angle control part, the DC voltage Ed will change once unbalance between the output power Ps of PV cell and output power Pd which produce $\Delta P = Ps - Pd$. Through using DCfeedback method, Edr and standard value are the same, and then the phase θ which is related with the operating angular frequency will be determine

$$\theta = \int$$

The relationship among operating angular frequency ω, standard frequency ωo and slip angular frequency Δω is shown here

$$\omega = \omega o + \Delta\omega$$

Δω can also be calculated through determining power deviation, the equation is shown.

$$\Delta\omega = Kp(Edr - Ed)$$

If Δω is too large, the control system may be unstable, so saturation circuit should be set to restrict Δω to change too large.

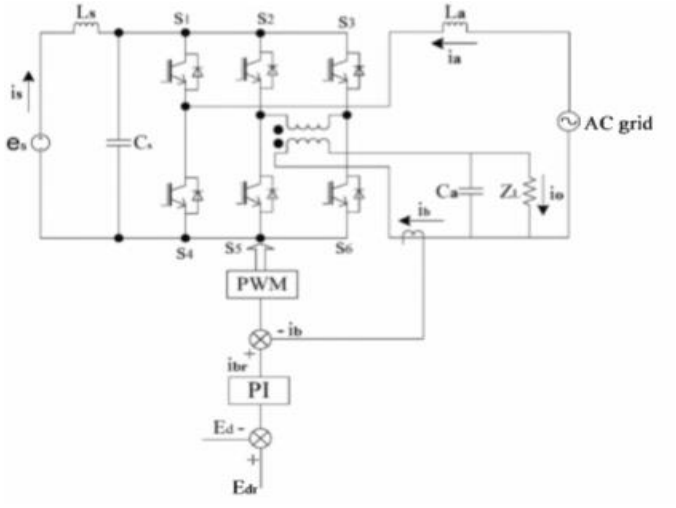


Fig.2.4: Improved PWM inverter control

3. SIMULATION AND EXPERIMENTAL RESULTS

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.

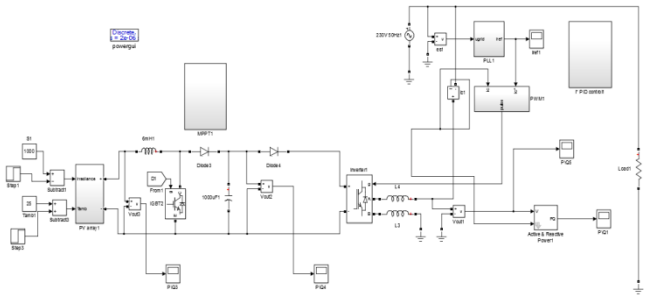
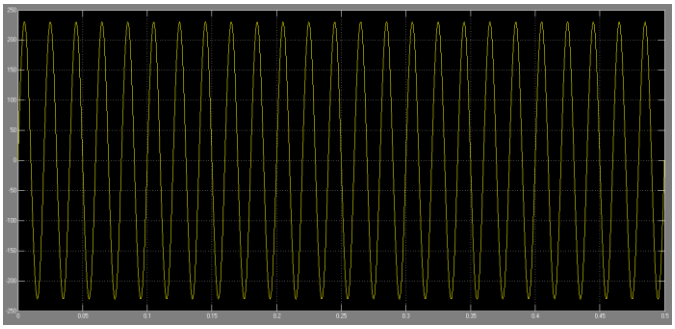


Fig3. Single-phase PV grid-connected generation system

Result of simulation:-

The result of synchronisation output of inverter with the grid supply is given bellow



4. CONCLUSION

The structure of improved PWM inverter control system is very simple which is based on the voltage type control method and the PWM power type control method. From the result of simulation, conclusions are come to as follows. First, 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. Second, the power can be sent to the grid or load arbitrary through controlling the PWM regulator, while the control system has a good stability. Third, as the increasing number of inductive load penetrate to the grid, the load waveform distortion is produced, but it will not affect the reliability of power supply. Finally, many inverter control systems are used in grid-connected at present, but there are several problems which need be to solved about how to keep a good stability of the power system when the grid changes from island to grid-connected. Today, research of a large number of grid-connected PV generation inverter control system is still very important for everyone.

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