

# Design of Power Inverter for Photovoltaic System

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**Abstract** – The need of the electricity is going to increase day to day with the development. The key challenge is to provide reliable and secure supply. But the country like mostly depends on the fossil fuel, which polluted the environment, which is another problem. So there must be the clean source of electricity such as Wind and solar. Solar is having the great potential in India. But the power developed by the solar is in the direct form and it is varying according to the environmental condition and time. The inverter is to use to convert the Dc power in to Ac in co-ordination with boost converter. P&O method is used for the maximum power point tracking from the Solar Array. In this paper proposed system is composed of the DC-DC boost converter and Seven-level inverter with the minimum number of switches. Only two capacitors are used to produce the seven level output waveform, simplifies the capacitor selection circuit. The six switch combination is used to convert the dc supply into ac out of which only one switch is operating at high frequency at any instant, reduces the switching power loss in the system and improves the overall efficiency of the system.

**Key Words:** Grid-connected, multilevel inverter, pulse-width modulated (PWM) inverter, Photovoltaic (PV) system, Maximum Power Point tracking (MPPT), Perturb and Observe (P&O) method.

## 1. INTRODUCTION

One of the major concerns in the power sector is increasing power demand day to day but the unavailability of resources to meet the power demand using the conventional energy sources. Demand has increased for renewable sources of energy to be utilized along with conventional systems to meet the energy demand. Renewable sources like wind energy and solar energy are the prime energy sources in country like India which are being utilized in this regard. The continuous use of fossil fuels has caused the fossil fuel deposit to be reduced and has drastically affected the environment depleting the biosphere and cumulatively adding to global warming.

In the recent year the development in the field of solar technologies result in the utilization the solar energy in domestic application. Due to increase in the demand of the solar product its production cost is decreasing from the decade. The grid connected roof top system becomes

famous in this era. Mostly poly-crystalline silicon wafer cell are used in the solar modules of domestic power plant. The power developed by the solar cell is depends on the atmospheric condition such as temperature and irradiation or sun intensity. To get the maximum output from the solar cell, all the irradiation fall on the cell must be converted in the electricity or maximum power must be get extracted from the cell. To extract the maximum power to kind of theory are presented i.e. mechanical tracking and electrical tracking. In the mechanical tracking physically the direction panel changes in the direction of the sun with the help of special kind of motor which consume power. In the electrical tracking system the power output of the system maintain at its peak by varying the voltage and current of the system. In this proposed system, electrical tracking is used.

The output of the system varies with changing condition of the atmosphere, but the power requirement remains same, so the inputs have to be boost. The DC-DC boost converter is used in the system. As the power developed by the solar is in the direct form, it can be used directly. It has to be converted in AC form with the help of the inverter. The various types of the topologies are presented about inverter. The most suitable type of inverter are cascaded multi-level inverter, with pure sinusoidal output wave forms with minimum distortion.

The proposed system is composed of the solar PV array, DC-DC converter and new seven-level inverter. The solar cell used in the system is electrical specification as 0.42V and 5 A current at standard test conditions. The output voltage of the solar PV array is about 70V, so the 70/0.42 number of cell are connected in series. This 70 V is feed to the booster to boost voltage level up to 210V. This 210V is feed to capacitor C2 and C1 which are connected in parallel with the help of transformer of the 2:1. This kind of arrangement makes the control circuit easy. This two capacitors are used to converter this generate the 3 level dc which is again converted into 7 level ac with the help of inverter. In this arrangement as the number of power electronics switches are less and only one switch is operating at high frequency at any instant, so the switching and conduction loss of the system reduces result in the overall improvement of the system efficiency of the system.

## 2. SOLAR PV MODEL

The solar PV cell is neither a current source nor voltage source, but it can be work as current generators with dependent voltage sources. PV arrays are built up with series or/and parallel combinations of PV solar cells, which are usually represented by a simplified equivalent circuit model such as the one given in Fig. 1

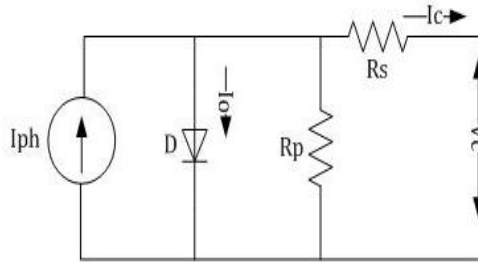


Fig-1: Equivalent circuit of photovoltaic cell.

The model consists of a current source ( $I_{ph}$ ), a diode (D), a series resistance ( $R_s$ ) and parallel resistance ( $R_p$ ). The basic equation from the theory of semiconductors that mathematically describes the I-V characteristic of the ideal PV cell is.

$$I_c = I_{ph} - I_0 \left[ \exp\left(\frac{qV}{AKT}\right) - 1 \right] \quad (1)$$

The basic (1) of the elementary PV cell does not represent the I-V characteristic of a practical PV array. Cells connected in parallel increase the current and cells connected in series provide greater output voltages. Practical arrays are composed of several connected PV cells. The PV array requires the inclusion of additional parameters to the basic equation

$$I_c = I_{ph} - I_0 \left[ \exp\left(\frac{q(V-IR_s)}{AKT}\right) - 1 \right] - \frac{V+IR_s}{R_{sh}} \quad (2)$$

Where the symbols are defined as follows:

e: electron charge ( $1.602 \times 10^{-19}$  C).

k: Boltzmann constant ( $1.38 \times 10^{-23}$  J/K).

$I_c$ : cell output current, A.

$I_{ph}$ : photocurrent, function of irradiation level and junction temperature (5 A).

$I_0$ : reverse saturation current of diode (0.0002 A).

$R_s$ : series resistance of cell (0.001  $\Omega$ ).

T: reference cell operating temperature (25  $^{\circ}$ C).

V: cell output voltage.

$K_v$ : the open-circuit voltage/temperature coefficient.

$K_i$ : the short circuit current/temperature coefficient.

The assumption  $I_{sc} \approx I_{pv}$  is generally used while the modeling of PV devices because in practical devices the series resistance is low and the parallel resistance is high.

The saturation current of diode is given by

$$I_0 = \frac{I_{sc} + K_i \Delta T}{\exp\left(\frac{V_{oc} + K_v \Delta T}{AV}\right) - 1} \quad (3)$$

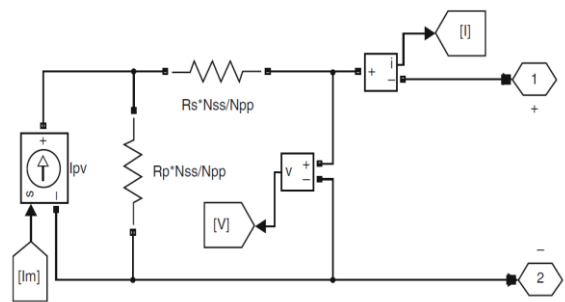
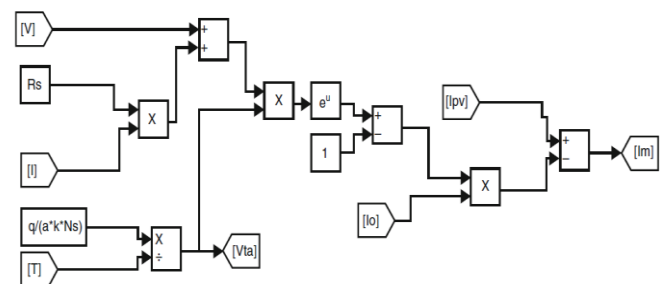
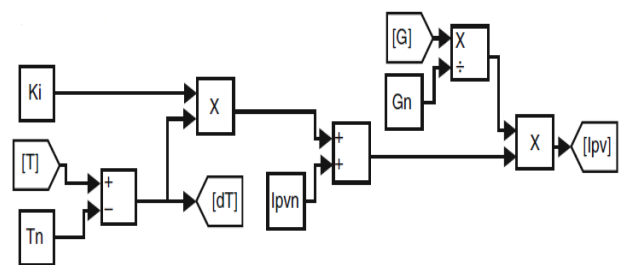


Fig-2: Simulink model of the solar PV array

The diode saturation current  $I_0$  is strongly dependent on the temperature so that the net effect of the temperature is the linear variation of the open-circuit voltage according to the practical voltage/temperature coefficient. The simulation model of the PV array is as shown in figure 2. The calculation of  $I_m$ ,  $I_{pv}$  and  $I_0$  are presented as separate sub-systems in Fig. 3(a),(b) & (c) respectively.



(a)



(b)

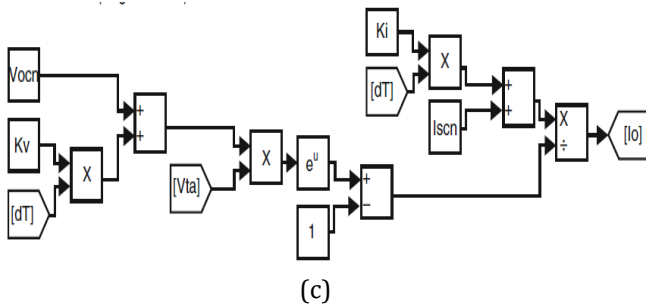


Fig-3: Calculation of  $I_m$ , (b) Calculation of  $I_{pv}$  and (c) Calculation of  $I_0$

The I-V and P-V curve curve of the simulated module is plotted as shown in figure 4 a & b respectively.

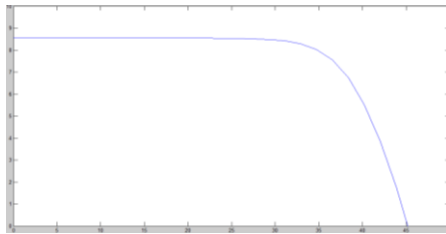


Fig-4: (a) I-V curve of the simulated model

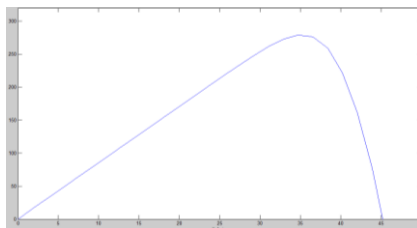


Fig-4: (b) P-V curve of the simulated model

### 3. MAXIMUM POWER POINT TRACKING

The output power of the solar PV array is not the constant as it's a function of the sun irradiation and temperature. To have the maximum efficiency from solar maximum output must have to extract by operating it at maximum power by varying the voltage of the system. Different kind of the topologies are presented out of these perturb and observe method is mostly used one. In this method the voltage of the system is change and the change in the output power is observed, if the change in power with respect to the change in voltage is positive then system continues to operate the same direction. The power at which the change in power with respect to the change in voltage is zero this point is called as maximum power point (MPP). This can be presented in terms of the flowchart as given in figure 5, and its simulated model is shown in figure 6.

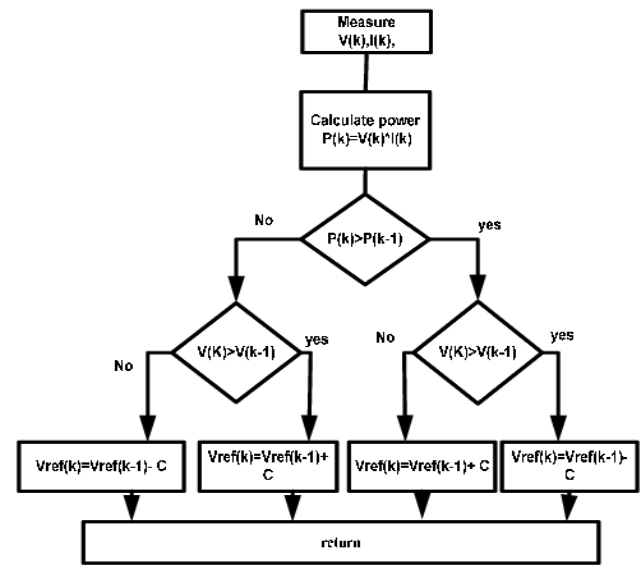


Fig-5: Flow Chart of P&O

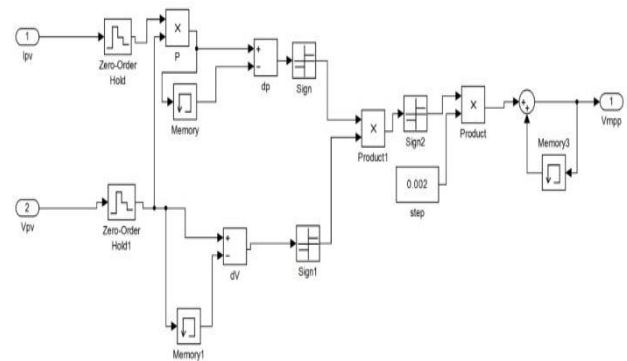


Fig-6: Simulink model of MPPT

### 4. BOSST CONVERTER

The dc voltage generated by solar PV is low and it changes with atmospheric condition, but the input to the inverter must be kept constant and its value is high. So the DC-DC boost converter is used in the system. It is composed of the inductor, diode, capacitor and power electronic switch. The configuration of the component is as shown in figure 7. There are two modes of operation of this kind of the converter. First one is the charging mode, in this mode only switch  $S_{B1}$  is in the ON state, the power developed by the solar is stored in the inductor  $L_B$ . Another mode of operation is discharging mode, here the  $S_{B1}$  is OFF and  $S_{B2}$  is in the ON state.

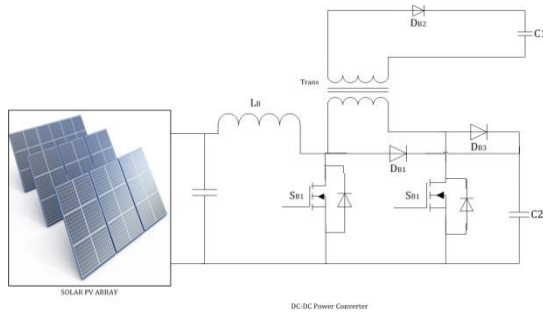


Fig-7: DC-DC boost converter

The power develops by the solar and the stored by the inductor is given to the capacitor C<sub>1</sub> through transformer and directly to the capacitor C<sub>2</sub>. These capacitors are connected in parallel through the transformer with multiple relations, so the capacitor circuit is simplified.

### 5. INVERTER

Inverter is the component which is used to convert the DC into AC with required frequency. This is the combination of the power electronics switches arrange in such manner to discharge the capacitor to produce the positive and negative cycle of the given DC supply. There are two types of the inverter two level and multilevel. All the inverter above two level are come under the category of multilevel inverter. The multilevel inverters are classified as Diode clamp, Flying capacitor and cascaded. Cascaded multilevel is mostly preferred for higher level as the number of capacitor, diode and switches required is less as compare to the other ones for the same level. As the components required are less cost of the system get reduce and losses due to this components also reduces specially the switching losses. Again the different arrangement are proposed cascaded inverter to reduce the number switches and capacitor in improve the efficiency of the system.

### 6. PROPOSED SYSTEM

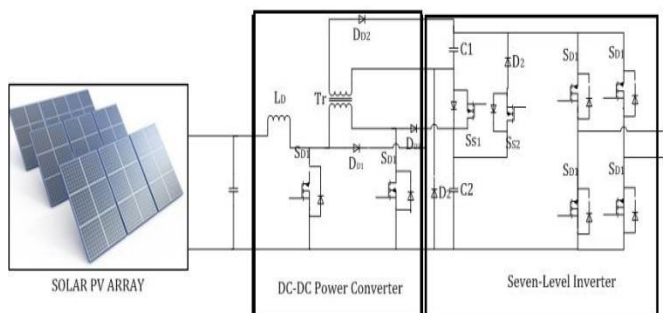


Fig-8: Solar power generation system

The proposed system consists of the PV array, DC-DC boost converter and new seven-level inverter. The output of solar PV is connected to MMPT in order to extract the maximum power for the solar. As the output voltage is low, boost converter is used between the solar output and inverter. The signal generated by the MPPT is again used to decide the switching the MOSFET. The boost converters convert the solar output into two independent voltages with multiple with the help of a transformer having the turn ratio 2:1. Discharging of the two capacitors is decided by the capacitor selection circuit. The outputs of the capacitor selection circuit are three level voltages depend upon the discharging while they are discharge in series or individually. These are converted into seven-level AC voltage with the help of inverter. The output is in phase with the utility voltage. As the number of capacitors used to produce three level voltage output are only two it become easy to control the discharging.

### 7. SIMULATION

The proposed inverter is design in MATABL Simulink. With the following parameter given in the table 1.

Table-1: Simulation parameter

Input voltage to the booster	70V
Boost inductor	1 mH
Boost capacitor (C <sub>1</sub> & C <sub>2</sub> )	1 uF
Booster	70 to 210 V DC
Switching frequency	15000 Hz
Filter inductor	1.5 mH
Output Voltage of inverter	230 V (rmp)

With the above parameter the simulation model is develop as shown in figure 9.

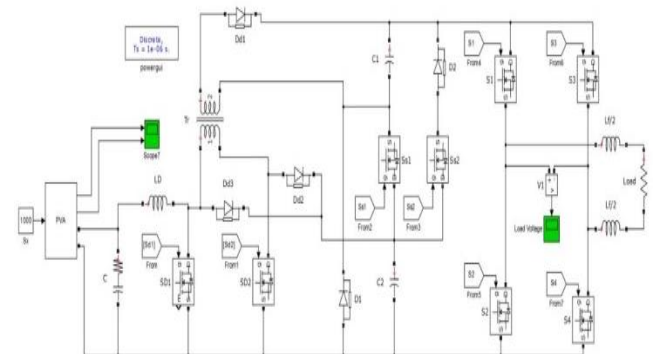


Fig-9: Simulink model of the inverter

The main objective of the simulation is to generate the output voltage of 230 V rms to maintain the output with varying input level of the solar the control system is design as shown in figure 10.

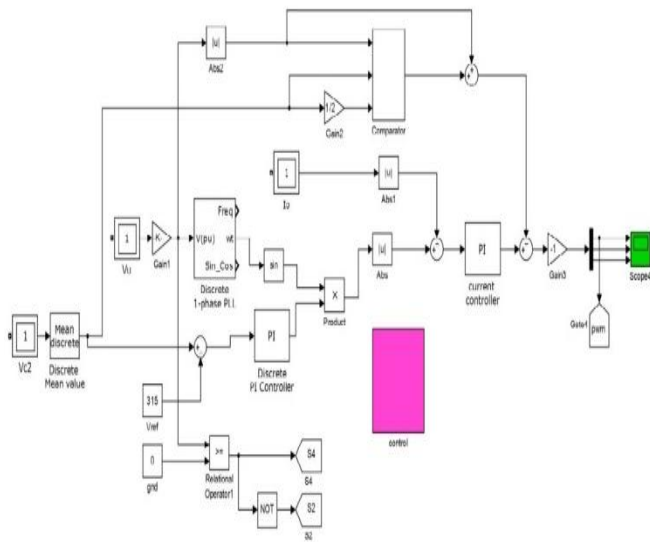


Fig-10: Control system of the inverter

Figure 10. Control system of the proposed inverter  
 In this the utility voltage and current are sense by the sensor. Voltage is converter into per unit with the help of the proper gain and send to the PLL to generate the pure sinusoidal waveform. The voltage of the capacitor C2 is sense, subtracted from the reference voltage and output is feed to the PI controller. The PLL and PI controller output is multiplied and its absolute value is subtracted from the absolute values of the current and result is given to the Current controller. The voltage of the capacitor C2 and its half value is compare with the utility voltage compare result is subtracted from the current controller output to generate the PWM signals, which are given to the Power electronics switches.

### 8. RESULT

The output voltage and the current of the simulation is given in the figure 11 and 12 respectively. The switching wave forms of the power electronics switch are shown in figure 13.

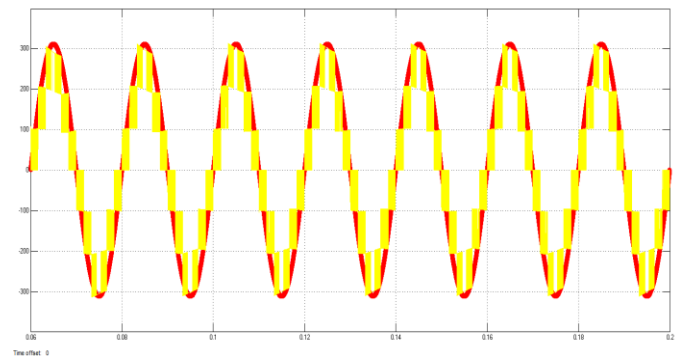


Fig-11: Output voltage of the inverter

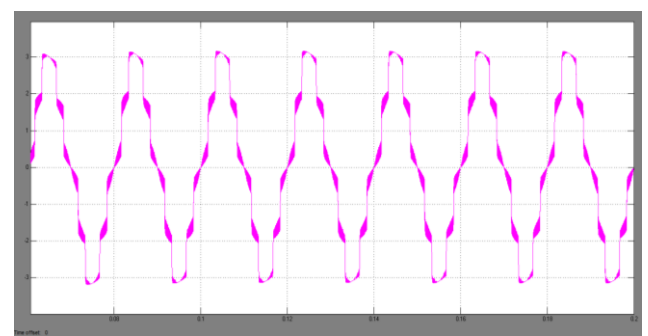


Fig-12: Output current of the inverter

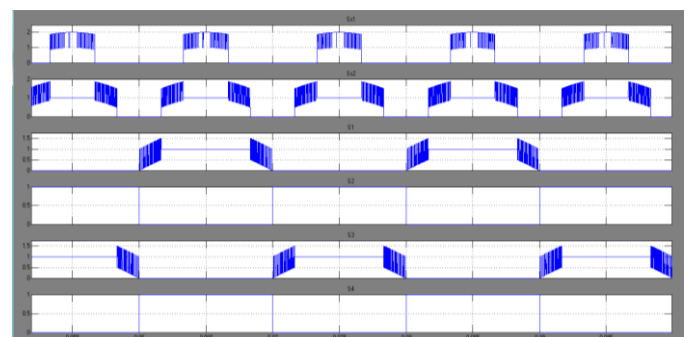


Fig-13: Switching sequence of the power electronics switch

### 9. CONCLUSION

The above graph shows simulation result obtained from the proposed Seven-level inverter. The voltage and current graphs shows the both are in phase, yielding the power factor of the system. Only two capacitors are used to generate the three-level DC voltage, which makes the capacitor selection circuit simple. From switching graph of the power electronics switch, the seven-level output is produced only with the help of the six power electronics switches out of which only one switch is operating at high frequency. The switching losses of the system get reduced improving the overall system efficiency.

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