

Cost Effective Advanced Inverter for PV System

^[1]Jijo Balakrishnan, ^[1]Saritha .M, ^[1]Kannan .S.A, ^[1]Renjith .G, ^[2]Anandu Chandran, ^[2]Anukrishnan .B,
^[2]Kokila .V, ^[2]Chaithanya .G.S, ^[2]Saranya .S.R

¹Assistant Professors, College of Engineering, Perumon, Kollam, Kerala, India

²B.Tech Scholars, College of Engineering, Perumon, Kollam, Kerala, India

ABSTRACT: Electricity is one of the most important and indispensable forms of energy. The present scenario highly demands exploitation of efficient and reliable alternatives to cope the ever-increasing power demands. A Grid connected photovoltaic generation system as a renewable energy power generation technology is the most mature of them. This paper presents the concept of an S3 inverter for grid connected PV applications. A DC-DC converter with voltage multiplier circuits is introduced to perform the boosting action. The DC-AC inverter uses only three switches for inverting the DC output which helps reduce the switching losses. Finally the simulation results of various stages using MATLAB has been included in this paper.

KEYWORDS: MPPT, Islanding protection

I. INTRODUCTION

With the increasing concerns on environmental protection and energy conservation, the development of renewable energy resources such as wind, biomass, PV systems etc have taken on an accelerated pace. Photovoltaic (PV) system has recently become an essential target all over the world with the advantages of scalability in power, simple installation, small amount of modularization and maintenance. However, the inability of renewable energy systems for supplying high quality electric power to AC loads in standalone mode and for injecting sinusoidal current into the grid at high power factor in grid-connected mode necessitates a high-performance inverter. The conventional inverter topologies using four switches for inverting the DC output and transformer for stepping up the voltage has associated problems of core saturation, reduction in power factor, switching losses etc. Therefore, in order to overcome these drawbacks, a new voltage source inverter topology is presented in this paper. The proposed system comprises mainly of a PV module, a buck conversion stage and DC-AC inversion stage. There are two main requirements for solar inverter systems: harvest available energy from the PV panel and inject a sinusoidal current into the grid in phase with the grid voltage. A Maximum Power Point Tracking (MPPT) algorithm is used to harvest energy from the PV module. The meaning of the MPPT is to make the PV system work on the MPP, which enable the efficiency of the PV system highest. The perturbation and observation algorithm (P&O) for MPPT is employed here. The output voltage of PV module is too low, so it cannot be transferred to the grid and large output current will be difficult to the system. So a high efficiency step up transformer is employed to boost the PV output to a desirable value. However a DC-AC inverter section is required for connection to the grid. It employs three semiconductor switches, in which one is operating at high frequency and the rest are operating at fundamental frequency. A control circuit provides PWM signals for the switches of two stages and it will adjust the duty cycle for MPPT of PV panel.

II. RELATED WORK

1. PHOTO-VOLTAIC PANEL

Photovoltaic power generation system (PV system) is a device which converts the solar power into electrical energy by solar cells using the principle of photovoltaic effect. Because the output of a single solar cell is very low (0.5-0.7V), number of solar cells have to be connected in series and in parallel to be used in practical applications. Solar module thus formed should be strengthened by some supported substrate and covered by tempered glass to offer protection.

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The equivalent circuit of a single solar cell is shown in Fig 1. It consists of a photo current, a diode, a parallel resistor expressing leakage current, and a series resistor showing internal resistance to the circuit.

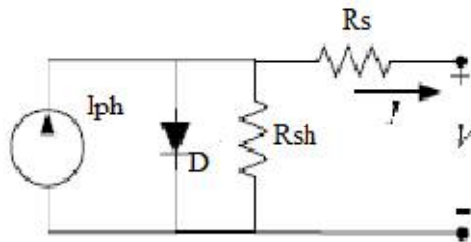


Fig.1: Solar cell model

Where,

R_s = series connected resistance,

R_{sh} = shunt connected resistance.

A PV array is a group of several PV cells which are connected in series and in parallel to produce the required output voltage and current. The equivalent circuit of a PV array is shown in Fig 3.

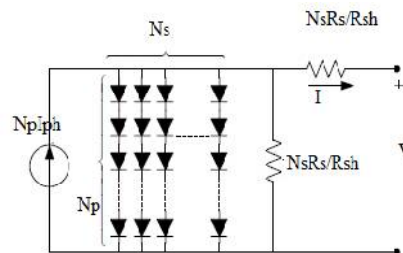


Fig.2: Equivalent circuit of a PV array

Where,

N_p = number of parallel connected cells

N_s = number of series connected cells

The solar module is modelled using the following set of equations,

$$I_{ph} = [I_{SC} + K_1(T_c - T_{Ref})]H \quad (1)$$

$$0 = I_{SC} - I_{RS} [\exp(\frac{V_{oc}}{V_t})] \quad (2)$$

$$V_t = \frac{N_s k T_c A}{q} \quad (3)$$

$$I_S = I_{RS} (\frac{T_c}{T_{Ref}})^3 \exp[\frac{q E_G (T_c - T_{Ref})}{T_{Ref} T_c k A}] \quad (4)$$

$$I = N_p I_{ph} - N_p I_S [\exp(\frac{q(V + I R_{SM})}{N_s k T_c A}) - 1] \quad (5)$$

$$R_{SM} = \frac{N_s R_s}{N_p} \quad (6)$$

Where,

I_{ph} = Light generated current or photocurrent,

K_1 = cell's short circuit temperature coefficient,

T_c = cell's working temperature,

T_{ref} = cell's reference temperature,

H = solar insolation in kW/m^2 ,

I_{sc} = cell's short circuit current ,

I_{rs} = cell's reverse saturation current,

V_{oc} = open circuit voltage,

I_s = cell saturation or dark current,

k = Boltzmann's constant ($1.38 \times 10^{-23} J/K$),

q = electronic charge ($1.6 \times 10^{-19} C$)

A = ideal factor

E_g = band gap energy of semiconductor material

| Characteristics | Specification |
|------------------------------------|---------------|
| Peak power | 60W |
| Short circuit current (I_{sc}) | 3.8A |
| Open circuit voltage (V_{oc}) | 21.1V |
| Voltage at peak power | 17.1V |
| Current at peak power | 3.5A |

Table 1: Specifications of PV model

The above given equations can be used to govern the PV panel of required output . It depends on the solar radiation intensity, the number of solar cells in the panel and the photon current from the panel. Using the above equations PV model is built using Matlab/Simulink

2. MAXIMUM POWER POINT TRACKING

Solar cells have a complex relationship between temperature and total resistance that produces a non-linear output efficiency which can be analysed based on the I-V curve. It is the purpose of the MPPT system to sample the output of the PV cells and apply the proper resistance (load) to obtain maximum power for any given environmental conditions. Thus it is crucial to figure out the maximum power point (MPP). MPPT implementations utilize algorithms that frequently sample panel voltages and currents, then adjust the duty ratio as needed. Microcontrollers are employed to implement the algorithms. The different algorithms used are perturb and observe, incremental conductance method, constant voltage tracking, fuzzy logic control, neural network etc.

In perturb and observe (P&O) method, the controller adjusts the voltage by a small amount from the array and measures power; if the power increases, further adjustments in that direction are tried until power no longer increases. This is most common, although this method can result in oscillations of power output. It is referred to as "hill climbing" method, because it depends on the rise of the curve of power against voltage below the maximum power point, and the fall above that point. Perturb and observe is the most commonly used MPPT method due to its ease of implementation. Perturb and observe method may result in top-level efficiency, provided that a proper predictive and adaptive hill climbing strategy is adopted. The flowchart of P&O method is shown in Fig 3.

Here in this method at first the values of power and voltage are obtained from the PV panel. Then the system waits for the same at another instant. Thus two values of power and voltage are obtained. Now the difference between these values are calculated, and denoted as ΔP and ΔV . Then based on the values various conditions are checked. The output of the MPPT system is a signal of the required duty cycle D . For this at first the value of $\Delta P > 0$ is checked and if so go for $\Delta V > 0$ and if its true the value of D is reduced and if its not true D is increased. Else if $\Delta P < 0$ and $\Delta V < 0$ then D is decreased and else D is increased. The above given algorithm is implemented using the Matlab/Simulink. It obtains the

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inputs P and V values from the PV panel section and the various conditions discussed above are implemented with the help of SPDT (Single Pole Dual Throw) switches.

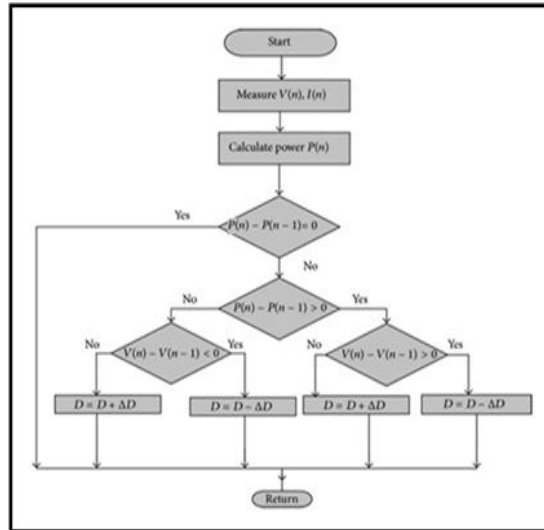


Fig 3: Flowchart of P&O method

The above given P&O algorithm is implemented using Matlab/Simulink and obtained the output duty cycle.

3. S3 INVERTER

The circuit diagram of proposed S3 inverter is shown in Fig. 4, in which a DC-DC conversion stage is coupled with a push-pull configuration employing center-tap transformer and operating at fundamental frequency/line frequency. The average output voltage of DC-DC conversion stage, V_c is a function of duty cycle, δ and input voltage, V_{dc} and is given as

$$V_c = \left(\frac{T_{on}}{T_{on} + T_{off}} \right) V_{dc}$$

$$V_c = \delta V_{dc}$$

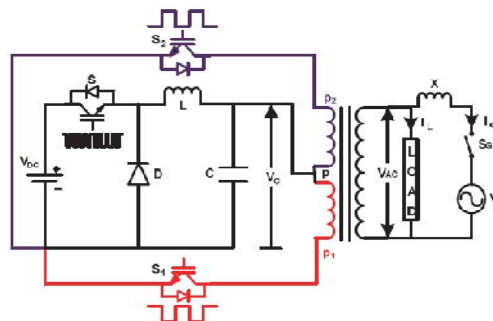


Fig 4: circuit of a S3 inverter.

For positive half cycle, S_1 is switched on along with continuous operation of S , the conduction path is $(V_c^+ - p - p_1 - S_1 - V_c^-)$ and for negative half cycle S_2 is switched on and the path is $(V_c^+ - p - p_2 - S_2 - V_c^-)$. At a time either S_1 or S_2 is at on condition. A circuit for the generation of switching pulses for the switches is shown in fig 5. The presented circuit consists of a phase shifting device, zero crossing detector, precision rectifier and a comparator. As shown in fig the reference sine wave extracted from the grid voltage is provided as input to the phase shifting circuit. The amount of phase shifting can be varied by adjusting the variable resistor R_v . The phase shifted sine wave acts as input to both

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precision rectifier and zero crossing detector. The output of precision rectifier is compared with a triangular wave for generating high frequency switching pulse for the operation of switch S. The output of zero crossing detector and its compliment serve as the switching pulses for S1 and S2.

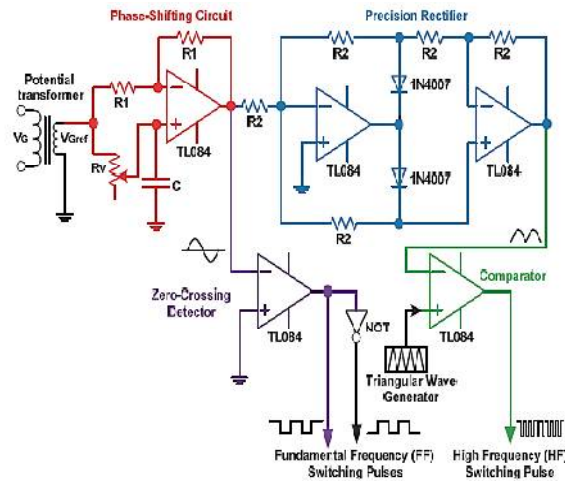


Fig 5: Switching pulse generator circuit.

The above given circuit of the inverter system is modelled using Matlab/Simulnk

III. EXPERIMENTAL RESULTS

Figures shows the results of MATLAB simulations of the above discussed circuits. Figs. 6 & 7 shows the simulation of PV and its output. Fig 8 shows the simulation of MPPT and Fig 9 & 10 shows that of the inverter and its output.

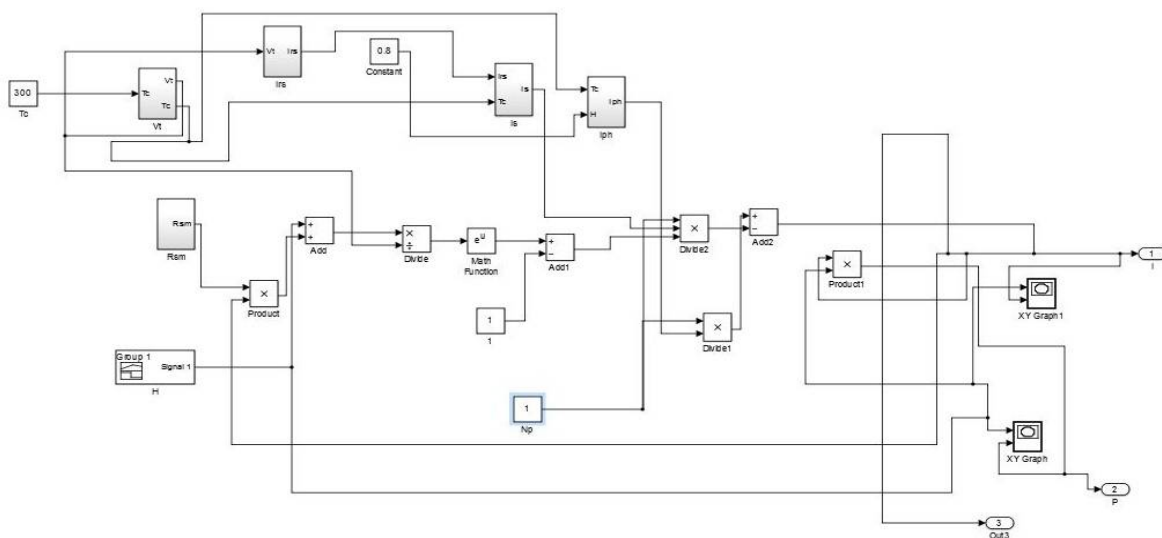


Fig 6: Subsystem of PV model

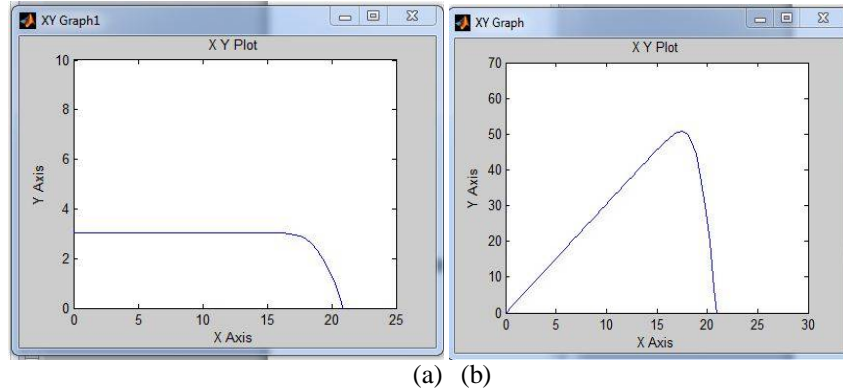


Fig 7 (a),(b): I-V and P-V characteristics of simulated PV module.

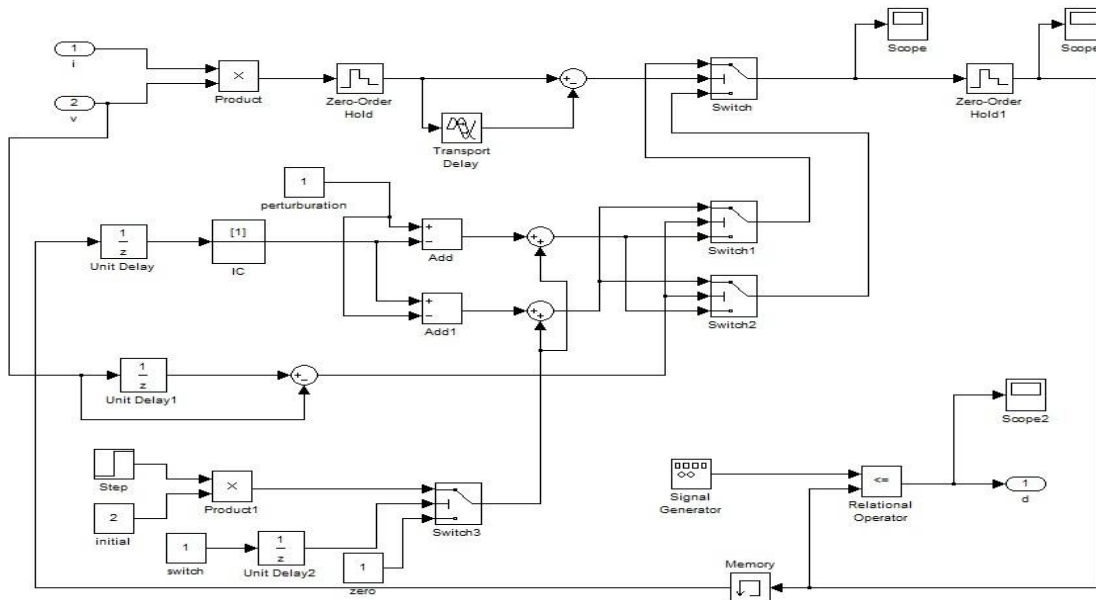


Fig 8: Simulation of MPPT using Matlab

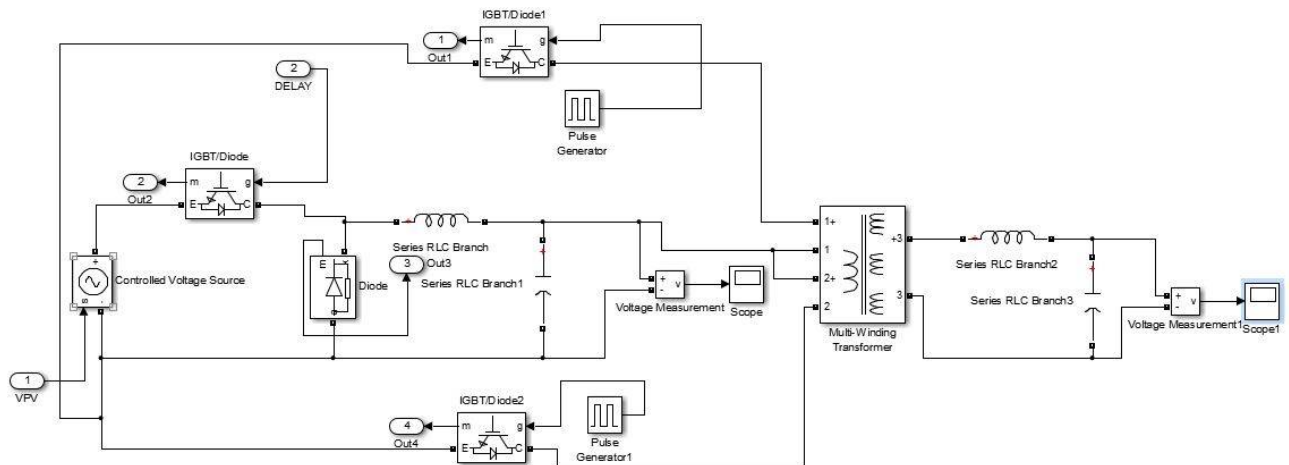


Fig 9: Simulation of S3 type inverter using Matlab

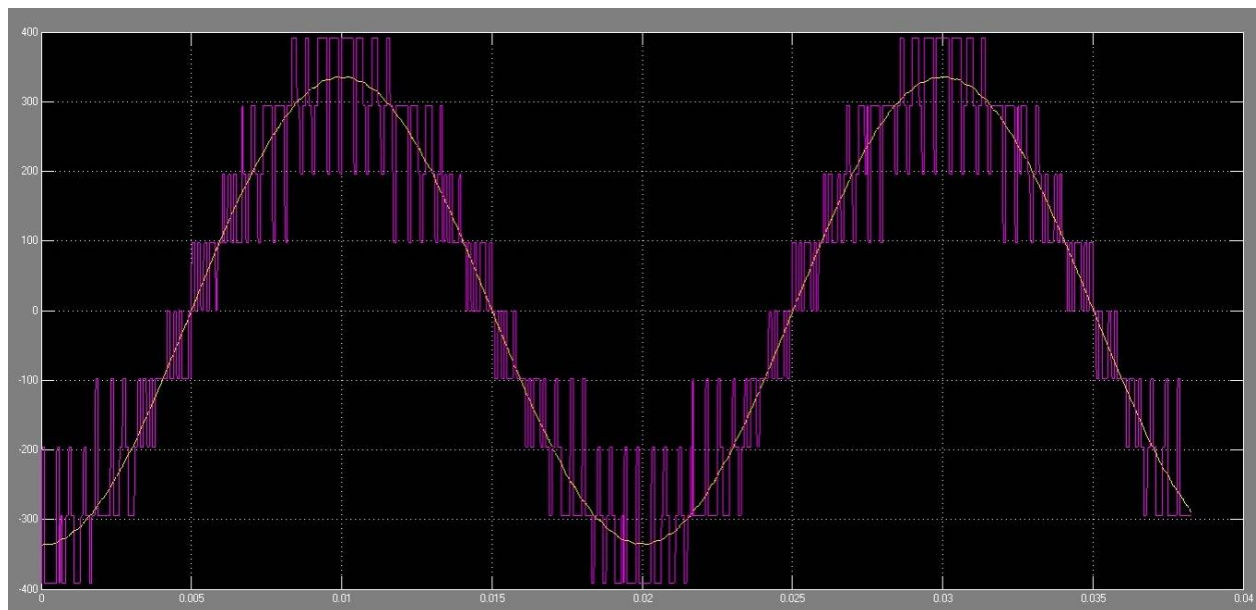


FIG 10: SIMULATED OUTPUT OF S3 TYPE INVERTER

IV. CONCLUSION

From the analysis of the conventional system, we identified the drawbacks of the PV integrated conventional Inverter system. In this proposed system, using the cascaded form of MPPT, proposed type inverter, Voltage stability and the reliability of the system is improved. In order to obtain constant output voltage from the PV irrespective of the varying solar radiation a better MPPT algorithm is imposed. To improve the power factor and to make the system suitable for micro-grids, a DC-Dc converter with voltage multiplier cells can be introduced. To overcome the switching losses a high efficiency advanced inverter is used. In order to achieve voltage stabilization AC-AC Buck/Boost converter can be employed. Better anti-islanding schemes can be enabled through controllers and relays for system protection.

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