A New Topology for Photo Voltaic Energy Conversion System

Sudhir Maurya and Abhik Banerjee

Abstract A new topology for solar photovoltaic (PV) energy conversion system is used in this paper. Various topologies are available nowadays which have several problems associated with using several blocks and in its performance analysis of the system from the stability point of view like DC-DC converter, low-frequency transformer, maximum power point tracking [MPPT] block, unfold circuit like push-pull circuit, etc. New types of topology for solar photovoltaic energy conversion systems have been shown which bypass the MPPT separate block units, unfold circuit, low-frequency transformer. By the use of current-controlled inverter integration of MPPT along with the DC-DC to AC conversion takes place inside a single block which reduces the number of blocks helping in getting a simple transformation block for the stability analysis. With the help of Phase Locked Loop (PLL) quadrature axis voltage can set to zero so that only direct axis voltage is used which corresponds to a single PI controller which again reduces one set point type tracking controller. Currents which are injected into the grid contains harmonics, THD generated form inverter is approximately 10% only, which can be further reduced by 5% by using simple suitable LC filter. MATLAB simulation depicts the whole work.

Keywords Current controlled inverter · Phase-locked loop · Integrated maximum power point tracking · Set-point controller

1 Introduction

MPPT controller (DC-DC circuit) can be of any type either isolated or non-isolated type. It ensures the load line attributes with respect to PV terminals so that maximum power can be drawn from the photovoltaic cell. An old topology that includes various

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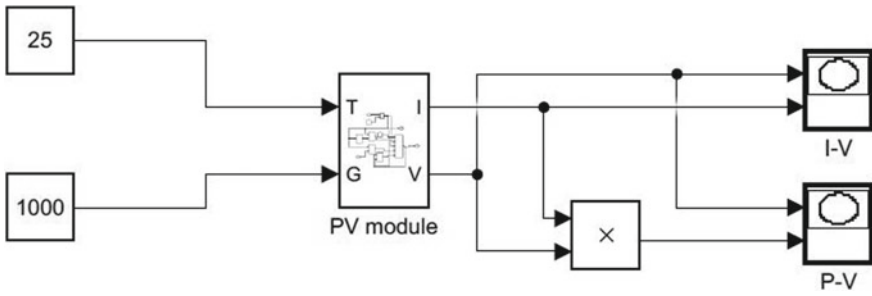S. Maurya
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Fig. 1 PV module

blocks like separate MPPT block, DC-DC converter (Buck–Boost), Unfold circuit, push–pull circuit, low-frequency transformer is used. In the new topology, DC-DC converter and unfolding circuit are replaced by a single power stage block called current controlled inverter. Low-frequency transformer which is present at the right side is shifted to the high-frequency side, i.e. into the dc-dc converter. Low frequency transformer is bulky to use in this circuit. Isolation of transformer from the circuit is necessary from any type of discharging of currents which leads to shock, for this flyback converter topology is used which is an isolated version of buck-boost topology. DC-DC converter is eliminated by the use of current-controlled inverter. Inverter is doing current control with the help of inductor current which is actually being pumped into the grid is being controlled, then the MPPT algorithm can be used for the terminal currents of the photovoltaic panel. The stability analysis of the terminal voltage can be seen in [1–3], similarly the terminal voltage of the photovoltaic can be measured and the power that is obtained can be pass through the maximum power point tracking algorithm. The output of the reference current for the inverter will be appropriately modulated in such a way that the desired current flows through it and maximum power will be achieve from the photovoltaic panel [4]. In [5, 6], the simulink model of hybrid system can be observed and also in this way this topology works, where is only one power stage which is coming between the photovoltaic module and the grid (Figs. 1 and 2).

2   Three-Phase Grid Connection

The three-phase inverter, there are six gates (let we are using IGBT or MOSFET, for this six gate drive terminals are required, gate drive is getting the control signal from PWM block for RYB phases [7]. Now the input to the PWM will be control signals coming from the output of controllers. Now, to control the inductor current that is being pumped into the grid. Again, with the help of a comparator an I_g reference can be compared. Now, it compare current with the value of i_g reference and then pass it to the controller block it could be PI controller. Each phase of the
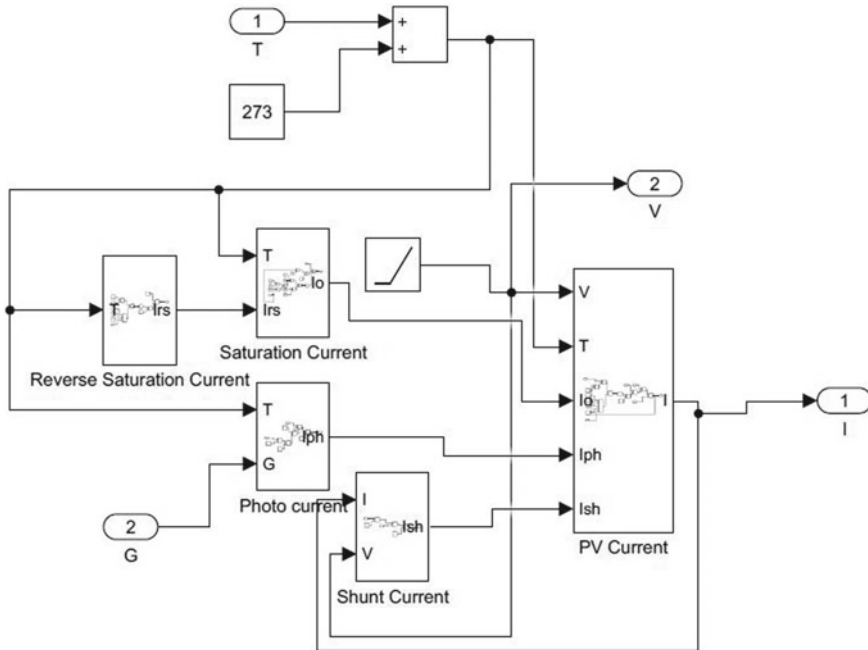
Fig. 2 PV module inside blocks

three phases are need to compare and control the output of controllers which will give it to the PWM block. So let us say each of the controllers is connected to PWM. Currents are sensed compared with a reference and based on the error the controller output will send the signal to the PWM which compares with the triangle carrier and then appropriately gives the PWM drive to each of the arms of the inverter with proper energy management [8]. These references i_{gR}^*, i_{gY}^*, i_{gB}^* are obtained from the MPPT algorithm. All the three currents are sensed by using a hall sensor or alternatively resistive shunt and differential amplifiers, instrumentation amplifiers can be used but hall sensor is better because it is contactless and has large bandwidth. V_T and I_T are measured by another hall sensor for MPPT block. Input to MPPT is V_T and I_T and output are i_{gR}^*, i_{gY}^*, i_{gB}^* (These are sinusoidal values).

3 Controller

However there are lots of drawbacks in this particular type of the circuit, first of all, the references i_{gR}^*, i_{gY}^*, i_{gB}^* are sinusoidal. They are not DC or setpoint value. The controller becomes a tracking controller it is no longer a setpoint controller reference current signal and feedbacks current signal all are AC sinusoidal in general.

Tracking controller needs to handle large signal deviation as the consequence the B.W of tracking controller will be lower compared to a similar setpoint controller, if i_{gR}^* and feedback signal have DC. So, design of tracking controller will be much more complex compare to a set point controller and DC to DC converter in power system [9]. It can also able to achieve intra cycle dynamics if one user setpoint controller but for the tracking controller only integral cycle dynamics can be achieved. Another problem is here three separate controllers one for each phase and the dynamics are coupled, so fining the three controllers simultaneously will become difficult as the dynamics are coupled. So those issues should be short out for the controller for three-phase photovoltaic grid-connected inverters [10] in the control methodology.

4 Current Controlled Inverter

Input to PWM is reference V_a, V_b, V_c (as desired) which will be compare with the carrier triangle which PWM has and then generate the necessary PWM signals (pulse). For the gate drive to switch ON and OFF accordingly and supply a voltage here such that i_a, i_b, i_c flows according to this control such that error just before PT is zero. Now to define ρ, angle between the d axis and α axis so that both coordinate systems rotates synchronously. α, β coordinate system has current space vector i_d get aligned along the current space vector that is i_q is equal to zero because i_d is aligned itself along grid current. We use V_a, V_b, V_c voltage waveforms to obtain ρ then i_d and i_q will be such that it will be with the respect to the voltage space vector as the d-axis and it has an advantage. Let we take angle ρ between V_α and α axis also V_g is not along V_d and V_q is not equal to zero. Then we get some error the PT activates and PI controller will work in such a way that error to PI tends to zero. Then V_q is equivalent to V_q^* which is equal to zero and d-axis will go and aligned along V_g voltage space vector and such a value of ρ (ρ will increase while aligning) will come up because of control action such that V_q is equal to zero here. In this way, ρ gives the value of difference between d_q axis and $\alpha\beta$ coordinate system such that d-axis aligned along the voltage space vector.

So, it becomes a robust mechanism because it is a close loop system and then there is PI component that has a history in it which will have a filtering effect on harmonics, surges, spikes, and uncertainties. So by incorporating this modification into our entire three phase grid-connected inverter block diagram, it will be a completely workable solution like other PV inverters used in [11, 12]. So we modify ρ-generation block.

5 SPWM (Unipolar PWM Technique)

According to IEEE—5/19/992-for household appliances total harmonic distortion (THD) is less than five percent. So we can just attach a simple AC filter like LC filter in order to reduce harmonics which is injected into the grid without using complex

AC filter also we can make THD less than five percent or by using base works as a filter. This can be achieved by using a sinusoidal PWM technique in which we should use less filter (Fig. 3).

6 Detailed Comparisons of Older Photo-Voltaic Conversion Topology with Respect to New One

Various topologies are available in the past in which separate DC-DC converter [9] which can be of any type of isolated or non-isolated type are present whose work is just to match load line to the PV terminals in such a way that maximum power [13, 14] can be drawn from the PV cell. Unfolding circuit which is basically a two-way switch type which switches ON alternatively can be replaced by a more popular bridge stage which is decoupled from the isolating stage. In the new topology, DC-DC converter and unfolding stage are replaced by a single power stage which is called the inverter. This leads to an increase in the efficiency of this model. Power transformer is of low frequency which is bulky, heavy, and expensive, so in this electronic model, the transformer is shifted to DC-DC converter so that it can work as high switching frequency which thereby reduces its weight, size, and works with increased efficiency. System becomes more compact. This leads to transformerless interface. In this high-frequency isolation flyback converter topology which is the isolated version of the buck-boost topology that can handle the entire first quadrant of the curve of the PV module is used. Further, improve on this topology by the use of current-controlled inverter, DC-DC converter is eliminated which is doing the job of maximum power point tracking. MPPT is done by the current-controlled inverter [15] itself, there is inductor current which is pumped into the grid is being controlled, then the maximum point algorithm is used for the terminal currents and the terminal voltage of the PV panel are measured and power that is obtained is pass through the maximum power point tracking algorithm..

7 Proposed Model of PV Energy Conversion System in MATLAB

See Fig. 4.
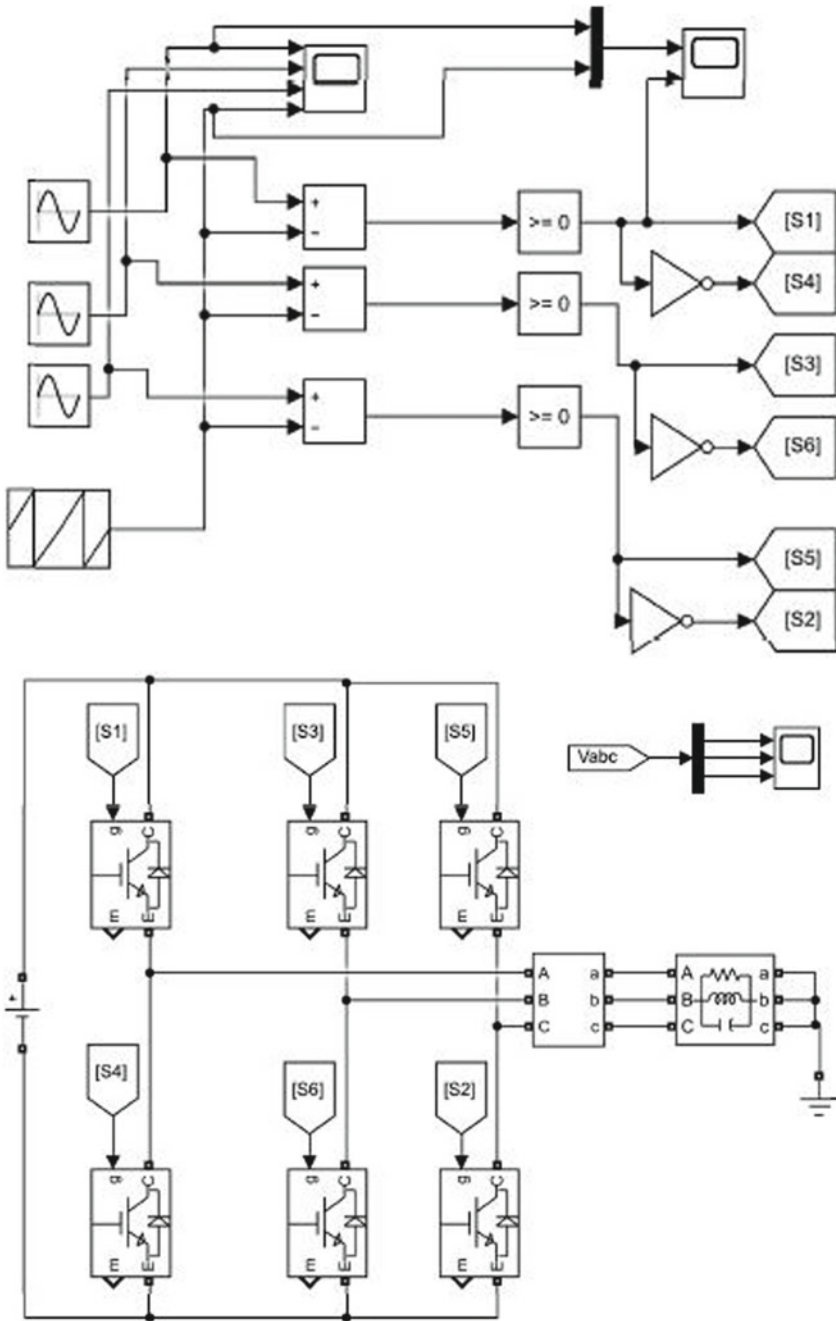
8 Simulated Result

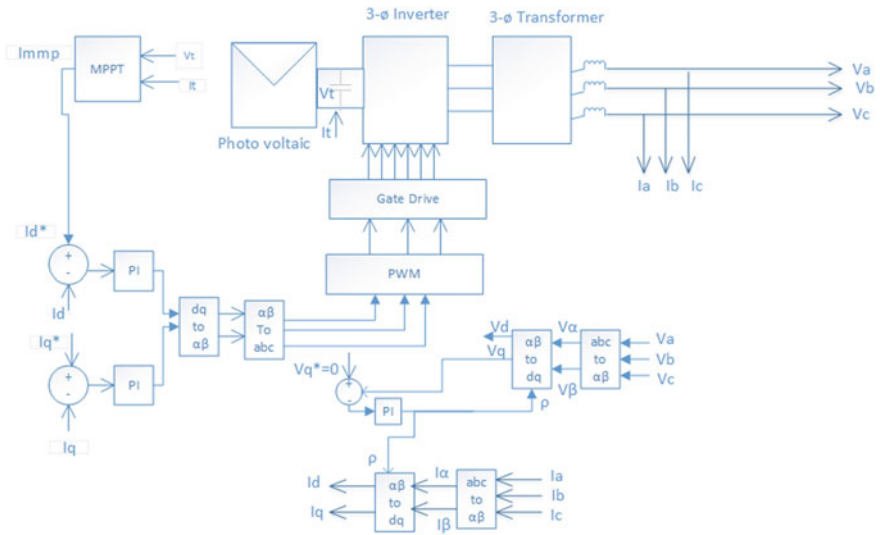See Fig. 5.

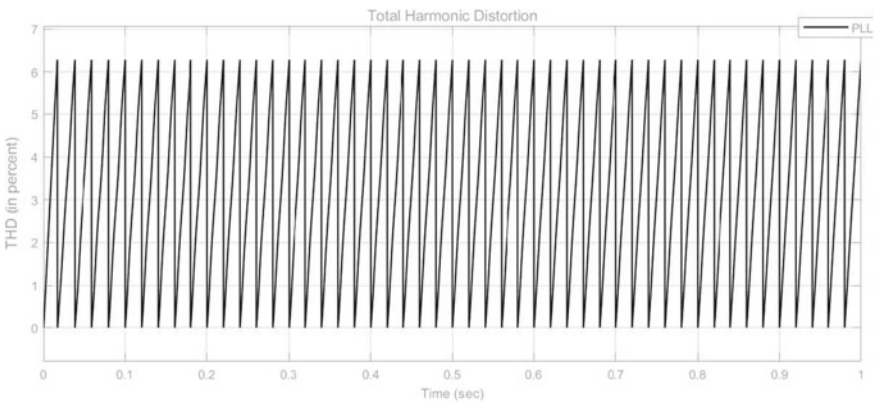**Fig. 3** Current-controlled inverter

Fig. 4 MATLAB simulation model

Fig. 5 PWM output

9 Parameters with Different Rated Values Used

See Table 1.

Table 1 Data sheet for PV module elements

Module type	BLD240-60P
Peak power	240 W_p
Maximum power voltage (V_{mp})	30.18 V
Maximum power current (I_{mp})	7.96 A
Open circuit voltage (V_{oc})	36.72 V
Open circuit current (I_{sc})	8.99 A
Cell η	16.50%
Module η	14.56%
Maximum system voltage	DC 1000 V
Temperature coefficient of I_{sc} α_I	+0.045%/K
Temperature coefficient of V_{oc} α_v	−0.34%/K
Temperature coefficient of P_{max} α_p	−0.47%/K
Series fuse rating	15 A
Cells	6 × 10 pieces polycrystalline solar cells series (156 mm × 156 mm)
Junction box	With 3 bypass diodes

10 Conclusion

Setpoint controllers only two have been used (while we need three for AC tracking type controller). Working with DC values is easy because it is difficult to compare changing values of magnitude of AC which is changing with respect to time with the reference values for comparison. MPPT is integrated into the invertors by removing the DC-DC converter and power block is simple (just has one power stage) so that the analysis from the stability point of view becomes easy and the efficiency of the model is increased. Robust Phase Locked Loop (PLL) based on ρ determination is done as the current is injected into the grid via current terminals contain harmonics. So getting ρ we converted current terminals into voltage terminals with the help of proper transformation. In PLL open-loop becomes closed-loop by doing certain modifications, in this way it becomes robust a robust mechanism there is proportional-integral (PI) component there is history in it which will filtering the effect on harmonics, surges and spikes.

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