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Hysteresis Current Control Based H- Bridge Inverter for Grid Integrated PV System

Burla Sridhar[1], Dr. S. P. Shukla[2], Dr. Ritesh Dash[3]

[1]PhD scholar, Electrical Engineering, BIT, Durg, Chhattisgarh, India.

[2]Professor, Electrical Engineering, BIT, Durg, Chhattisgarh, India.

[3]Associate Professor, EEE, REVA University, Benguluru, Karnataka, India,

burlasridhar@gmail.com, sp.shukla@bitdurg.ac.in, rdasheee@gmail.com

Abstract

A grid integrated PV system is examined in the quickly expanding field of green energy utilisation. The power inverter is typically used to connect the PV system to the AC electricity grid. Hysteresis current controller application to the DC/AC power inverter is the suggested better control strategy to control power inverter switching and to improve the current received by the grid. The DC/DC converter and additional filter that are typically used in grid-integrated PV systems can be lessened with this method. The applied control approach reduces the harmonics that are usually produced in grid-integrated PV systems' power grids without filters. This can also aid in removing the controllable DC voltage from the inverter's input side, controlling power factor at the moment of grid integration, and overcoming obstacles during the synchronisation of the grid voltage and the power inverter voltage prior to the inverter's integration with the grid. The suggested controller's usefulness is demonstrated by the results that the proposed control strategy in MATLAB Simulink produces.

1 INTRODUCTION

With the huge production and demand of power electronic devices for the usage in renewable power generation and also the cost cut in the PV modules, PV systems are growing rapidly specially in the countries located in the equatorial region with the large availability of solar energy. The Standalone off grid applications were very popular in the early 90's, distributed generation and grid integrated small and large PV systems are increasing nowadays with enormous merits. This decreases the use of storage ultra-capacitors and batteries, which at the same time reduces the overall cost of renewable energy installations [18].

Figure 1 shows a single line diagram for a grid integrated PV system. The PV structure is connected to the grid with the help of power inverter. The main function of the inverter is to convert DC power from the PV system to AC power that is transferred to the grid as per the requirement of the grid. The major limitations of the grid integrated PV system are that it leads to the problems related to the power quality, safety and efficiency of the grid [14, 19]. They may contain harmonics due to various modulation techniques, voltage and frequency fluctuations, power flow control, islanding etc, which are reviewed for the significant values of grid integrated PV systems.

The researchers work focused on improving the efficiency of the PV system and power electronic integration for the improvement of the usefulness of the renewable energy generation. The two main fields of research that are being published are Maximum Power point tracking (MPPT) algorithms to extract the maximum power by the PV modules and to use the power inverters and filters to enhance the power quality of the energy that is sending to the grid [6, 19].

Corresponding author details:

Burla Sridhar, PhD scholar
Electrical Engineering, BIT, Durg, Chhattisgarh, India
Email: burlasridhar@gmail.com

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The researchers are working on both the fields of grid integrated PV systems. The MPPT techniques is used to calculate the phase angle between DC/AC inverter voltage and grid voltage for optimal slope of power load line which is linked with maximum power point at the PV modules [4, 19]. The switching controller of PWM inverter uses voltage and power control methods. Most of the researcher still working on the problems for better power quality and stability of grid integrated PV systems [6, 16].

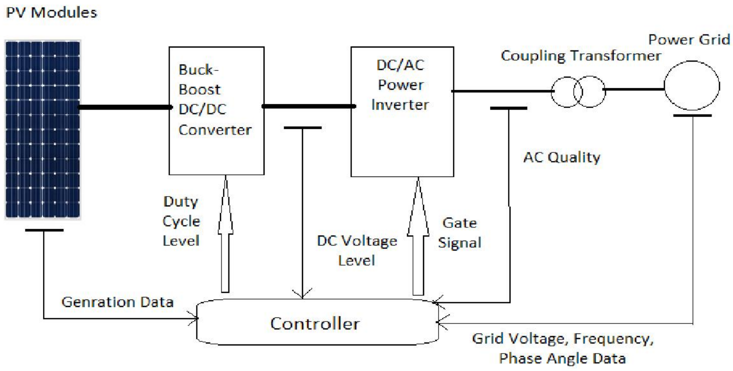

Figure 1: A Typical Grid Integrated PV System

This paper is mainly concentrated on an H-bridge inverter which is gated by the output of hysteresis controller in-spite of using conventional PWM current controller. Hysteresis controller reduces the complexity and permits fast operation by taking less time and computational resources. The hysteresis controller might deliver sinusoidal AC current which is close to reference sinusoidal current on the grid side [5]. This also helps to make effort in extraction of maximum power from MPPT technique [9, 15]. By applying such hysteresis controller, the main idea is to reduce harmonics into the grid without additional filter, remove the DC voltage controller and controlling the power factor level at the point of grid integration, reducing the limitations in matching the inverter output voltage with grid voltage where inverter works on direct PV-grid integration [12]. This paper has divided in following main segments: segment 2 limelight the functions of main blocks. Segment 3 on the numerical aspects in MATLAB Simulink and segment 4 shows the system results and conclusion.

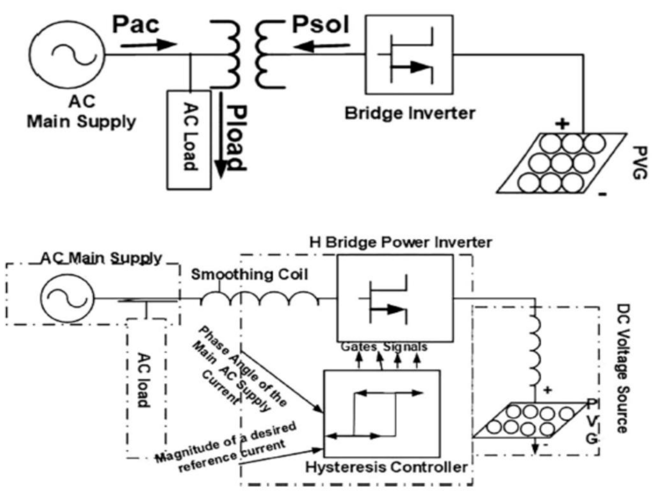

Figure 2: Single line diagram and detailed circuitry

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2 PROPOSED SYSTEM DESCRIPTION

Figure 2. demonstrates the proposed system in a single line diagram with four main blocks of the system: i) a power grid as AC source with 50 Hz frequency, ii) AC load at point of common coupling (PCC) iii) an H-bridge with a transformer (i.e. smoothing reactance in series) iv) PV system as a DC voltage source. The circuit diagram states the hysteresis controller to control the inverter, describes the PV module and accountability of the hysteresis controller block.

2.1 PV module

The array of solar cells is connected in series and parallel combination to generate the desired DC voltage and current in the PV module. The magnitudes of current and voltage depends load connected to the output of PV system. The details of the description are spoken in many textbooks of physics [9-13]. The model is taken from Akbaba's model and Ig- Vg relation is given as

$$Ig = (Voc - Vg)/ (A + BVg^2 + CVg) \quad \text{Eqn. (1)}$$

A, B and C are the coefficients and the values depends on current insolation or irradiation level. Voc is the open circuit voltage, Vg is the PV panel terminal voltage and Ig is the current brought by the PV module when the loop is completed by the load [2, 10]. The table 1 given below shows the parameters of A, B, C and Voc with the system data used for simulation.

Ig-Vg characteristics is given by the graph for three insolation levels. The equation of the power delivered is expressed by:

$$Pg = VgIg = Vg(Voc - Vg)/(A + BVg^2 + CVg) \quad \text{Eqn. (2)}$$

The Figure 3, shows the graph for three insolation values for the Ig-Vg and Pg-Vg characteristics. In this paper, hysteresis controller performance is also examined to tract the maximum power points.

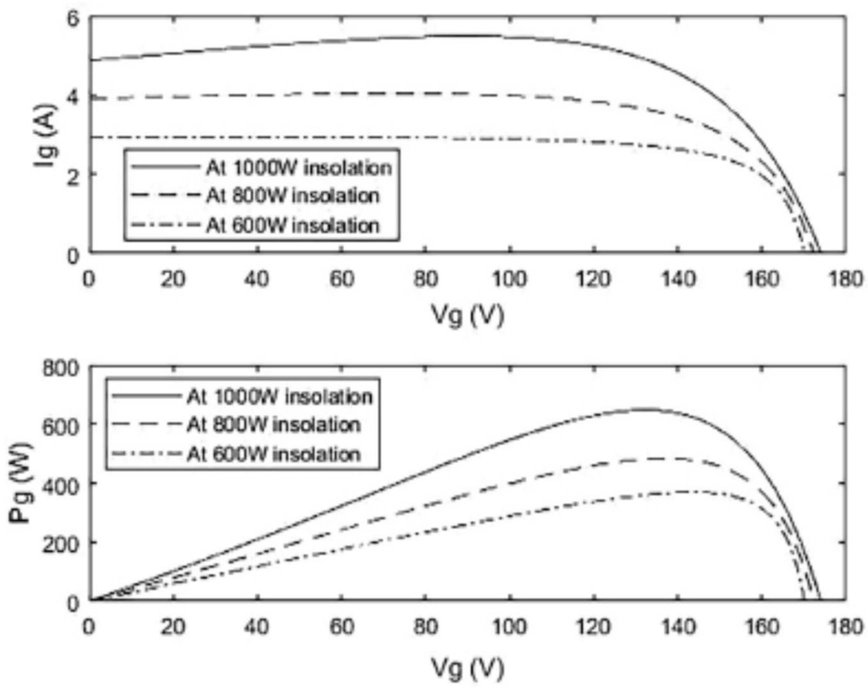

Figure 3: Ig-Vg and Pg -Vg characteristics of PV system

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Table 1: Data used in the simulation

Power grid Voltage RMS Voltage 240V		Frequency 50 Hz		Phase Angle Variable	
Transformer Turns ratio 240 V/ 100 V		Inverter Smoothing inductance Leakage inductance Lp = Ls = 1mH		L1 = 20 mH	
Photovoltaic System data					
Insolation Level (W/m^2)	Voc (V)	A (ohm)	B (1/AV)	C (1/A)	Max Power (W)
1000	174	35.714	4.987 * 10^{-4}	0.2716	648
800	172,3	44.191	2.922 * 10^{-4}	0.2896	484
600	172.1	58.174	1.223 * 10^{-4}	0.3510	370
Hysteresis controller Band 0.05 A					

2.2 H- Bridge Inverter

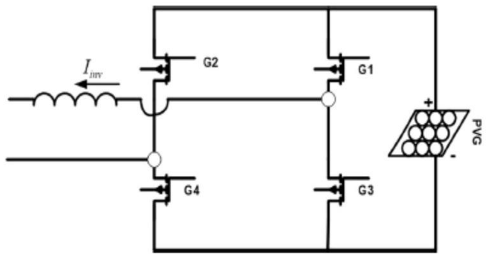

Figure 4: H-bridge Power Inverter

The single-phase H-bridge power inverter is made up by connecting four power MOSFETS or Insulated Gate Bipolar Transistors (IGBTs) shown in Figure 4. The switches G1, G2, G3, G4 works in a particular sequence. When G1 and G4 are working, G2 and G3 are in off condition and vice- verse. The sum of transformer leakage reactance and additional filtering inductance signifies by inductance shown in Figure 2.

2.3 Hysteresis Controller

The proposed hysteresis controller is shown in the block diagram in Figure. 5. It is having two stages; one discovers the reference current (I_{ref}) which would have the time varying sinusoidal waveform with the frequency equals to the grid frequency and in phase with the grid AC current [19]. To get the maximum power point value from the PV system, the reference current magnitude (I_m) is chosen and as the insolation level changes the maximum power points change and thus the reference current adjusts itself accordingly. Hence a time varying reference current is required. The required reference current magnitude (I_m) is arranged as per the imitated insolation levels in the simulation to get the maximum power point values from the PV system. The first stage in Figure. 5 (a) also senses the phase angle of the AC current which is required to ensure that the AC grid current and the inverter output are in phase with each other. The reference AC current is expressed by

$$I_{ref} = I_m \, Sin(\omega t+\phi) \qquad \text{Eqn. (3)}$$

An AC grid current waveform of the fundamental frequency is required from the inverter. The quality improvement of the inverter current is also studied as the main objectives. As in figure 5(a) the inverter current I_{inv} is continuously monitored and fed to the subtractor block.

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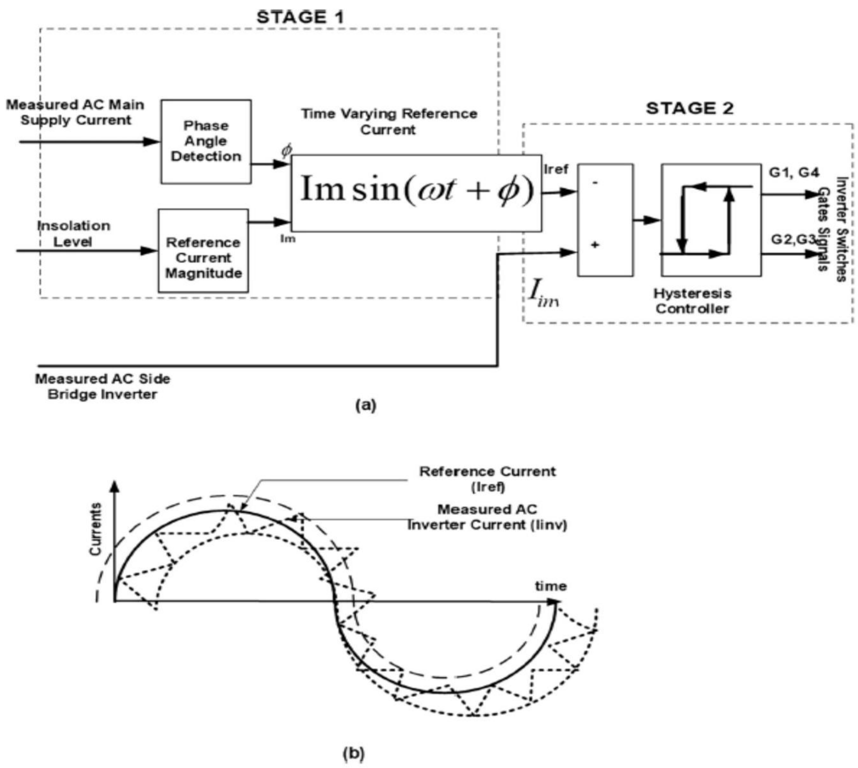

Figure 5: Hysteresis controller (a) block diagram (b) Performance waveform

The next stage of figure 5(b) is hysteresis controller block. The ($I_{inv} - I_{ref}$) is the input signal to the hysteresis controller block. If the difference exceeds the certain limit the output status changes from high to low or low to high. If not exceeded the hysteresis limits the output remains at its pre-current status. The probable waveforms are shown by the curves in figure 5(b). The gate signals of the switches of the inverter works according to output of the hysteresis controller.

3 SYSTEM ROUTINE ASSESSMENT

The data in table 1 fed in the integrated model designed in MATLAB Simulink had been studied and assessed. The hysteresis band is selected between the ripples generated in the inverter current I_{inv} and the switching frequency of the inverter switches. To minimize the ripples in the inverter AC current I_{inv}, the hysteresis band is set to 0.05. More than 0.05 value of hysteresis band will produce more ripples at the cost of low switching frequency and high switching frequency at less than 0.05 of hysteresis band [8]. In this paper, three insolation values at 25 degrees Celsius are taken and the performance was examined. The performance is examined under following conditions:

i) The sending end power is measured at various stages i.e. at inverter input, inverter output and at the grid.
ii) The generated reactive power is measured at the grid and also monitored the power factor at the grid side bus.
iii) The difference of the real power generated at the PV system and the maximum power that can be generated.
iv) Observing continuously the waveforms of the reference current *(I_{ref})* and the inverter current *(I_{inv})*.
v) Calculating the currents at the AC load, output of inverter and the PV system along with total harmonic distortion (THD) factor.

Figure 6(a) shows the active powers for the three insolation values.

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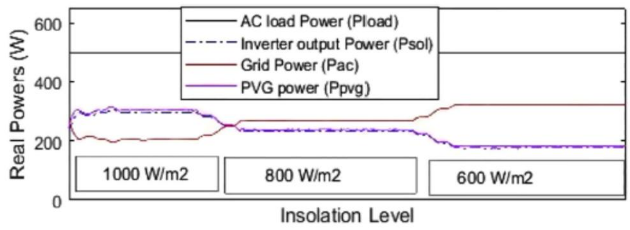
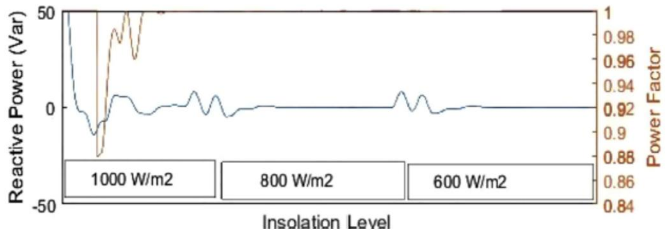


(a)



(b)

Figure 6: Measured powers (a) active power (b) reactive power and power factor at AC main grid bus.

To get the constant active power at AC load, the active AC power at the inverter output matches the active power from the grid power. Higher the insolation level, higher will be the percentage of AC power at load drawn from the inverter.

The reactive power from the AC grid and the power factor level are shown in figure 6 (b). At steady state conditions, almost zero reactive power and unity power factor is drawn from the AC grid under certain insolation levels. The AC resistive load was taken as constant 500 W. Table 2 gives the values of powers at various stages in grid integrated PV system. If maximum power is drawn from the PV system, the quality of the sinusoidal waveform weakens [10]. Figure 7 explains the waveforms of reference current and the inverter current at different insolation levels.

Table 2: System active power performance

Powers	Insolation levels at 25 degrees Celsius		
	1000 W/sq. m	800 W/sq. m	600 W/sq. m
AC load power Pload (W)	500	500	500
Inverter AC Power Pinv (W)	295.57	232.89	176.29
Contribution to the AC load	59.11%	46.58%	35.25%
Grid Power Pac (W)	204.52	267.21	323.78
Contribution to the AC load	40.89%	53.42%	64.75%
Power drawn from PV system	303.28	239.25	181.88
Percentage of the PV system Power	46.80%	49.43%	49.16%

The inverter AC instantaneous limits between upper and lower values due to the hysteresis controller characteristics. In this case, the Total Harmonics Distortion factors (THD) for all the AC currents are measured. Table 3 shows the levels of THD (%) in different currents. The THDs are below the allowable standard limits. The AC currents are nearly harmonic free not to be worried for the higher order harmonics inserted in to grid integrated PV systems.

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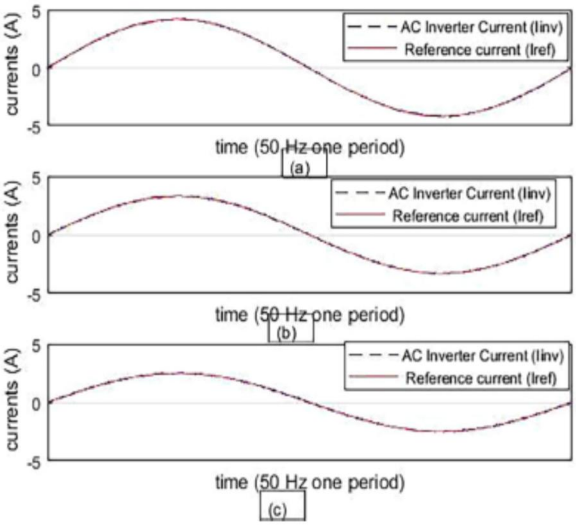

Figure 7: Inverter AC side current waveform at insolation levels: (a) 1000 W/sq. m (b) 800 W/sq. m (c) 600 W/sq. m

Table 3: Total Harmonic Distortion (THD) factor

Powers	Insolation levels at 25 degrees Celsius		
	1000 W/sq. m	800 W/sq. m	600 W/sq. m
AC inverter current	1.1246 %	1.1560 %	1.5941 %
AC grid current	1.7232 %	0.9854 %	0.7630 %

4 CONCLUSION

H-bridge inverter is explored for the grid integrated PV system. This alternative strategy is different from the conventional integration techniques. The hysteresis current controller used with H-bridge inverter avoids the DC voltage controller and additional filters as found in the conventional grid integrated PV systems. The hysteresis current controller in this grid integrated PV system helps in conditioning the inverter AC current according to the grid AC current. The hysteresis controller works for the generated sinusoidal waveforms at the inverter AC side in spite of variable insolation levels at the input of PV systems, synchronizing the inverter AC current and grid AC current and to control the power factors at the grid AC bus shown through the simulation results. The simulation also shows that more power from the PV system may distort the inverter AC sinusoidal waveforms.

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