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# SIMULATION OF HYSTERESIS BAND CURRENT CONTROL FOR GRID CONNECTED SOLAR PHOTOVOLTAIC INVERTER

Chinmay D. Shukla[1]

[1]*Electrical Engineering Department, Dr. S. & S. S. Ghandhy College of Engineering & Technology, Surat*

**Abstract**— *This paper discusses use of hysteresis band current control technique for grid connected Half bridge inverter for Solar Photovoltaic applications. The simulation of half bridge inverter employing HBCC is carried out using PSIM software. After simulation control strategy for the inverter has to be selected and implemented. The use of this inverter can be made for grid tied applications. The Hysteresis Band Current Control method for PWM inverters is very popular because of its simple implementation, fast transient response, direct limiting of the device peak current and practical insensitivity of dc link voltage ripple that permits a lower filter capacitor.*

***Keywords***- *PV generation plant, Hysteresis Band Current Control, Grid tied Inverter, Solar Array, MPPT, IGBT*

## I. INTRODUCTION

The reserves of coal, oil and natural gas are diminishing day by day and it has become imperative to exploit the non- conventional energy sources. The obvious choice amongst the renewable sources is the sun's energy –The Solar Energy, as it is the cleanest of all, in abundance and an everlasting source of energy. The maturity and continuous improvement in the photovoltaic systems and power electronics has made the power conversion more efficient. The PV systems have the further merits of flexibility and simplicity, being of modular structure. The grid connected PV systems do not require battery for storage of electricity which reduces the system cost. The PV generation plant does not have a specific geographic requirement for its installation as in wind farms or micro/small hydropower generation plants. Photovoltaic energy systems consist of arrays of solar cells which generate electricity from irradiated light. The solar field and Building Integrated Photovoltaic (BIPV) systems [1], are some cases where the site flexibility advantage can be exploited. The entire PV system can be thought of as a network of small dc sources with power conditioning interfaces employed to increase efficiency and reliability of the system. Power electronic circuits play an important role in PV systems to interface the dc output of the PV system to grid or the load. This is also only possible by using dc-dc-ac and dc-ac-ac conversion using different inverter topologies.

## II. BASIC ARRANGEMENT OF GRID TIED PV INVERTER

The grid connected PV generation plant comprises of Solar Array, MPPT, dc-dc Boost converter and an inverter. In order to extract maximum power form the PV module, MPPT is used along with a Boost converter to obtain a regulated dc bus voltage. The regulated dc bus voltage is then applied to the main inverter which converts the dc into ac. Figure 1 shows the basic arrangement of grid tied single phase photovoltaic inverter.

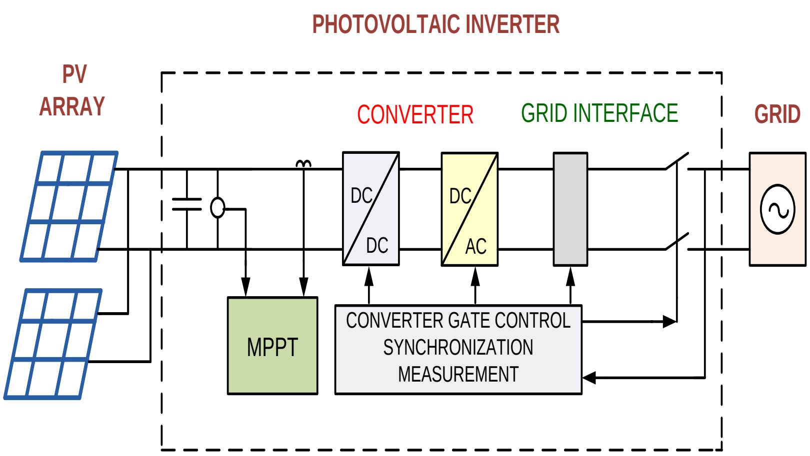


***Fig. 1 Basic arrangement of Single Phase Grid-tied PV inverter***

The PV array converts the solar energy into electrical energy which has a dc voltage. The unregulated dc is regulated by means of an MPPT, which takes voltage and current reference as shown. The output of MPPT is fed to dc-dc boost or Buck Boost converter. Sometimes the MPPT and dc-dc converter appear as a single block. The regulated dc from the

 

converter is fed to the inverter to convert it finally into ac. The grid interface is done after sensing the actual inverter current and the grid voltage. The controlling circuit maintains the control of synchronizing, protection and measurement functions. The inverter plays a major role in the proper functioning of the grid connected PV system. The inverter has to convert the dc to ac and also to maintain output power quality assurance, various protection and control functions. The desirable features of inverter include low cost, high efficiency, high reliability & tolerance over a wide range of input voltage variations and low component count. The Buck converter gives an output less than the input while the Boost converter gives higher output than the input it receives. Different configurations are used in different applications and these do have relative merits and demerits. There are different ways in which the inverters can be configured for PV applications. As the application changes, the mode of connecting PV panels with each other and the grid also changes.
Day by day newer techniques are being invented to make the maximum utilization of Solar Power, the major area of research being inverters and their topologies.

## III. CONTROL STRATEGIES FOR INVERTERS

The control of the inverter plays a major role in the satisfactory functioning of the grid connected inverters. The main consideration for the inverters for grid connectivity applications is the measurement of phase of the grid voltage and grid current and then the generation of pulses of the inverter such that the inverter voltage and current are in phase with each other. The control of inverter may be done by either using PLL, hysteresis current control or using a ZCD circuit. Out of these three methods hysteresis current control technique is discussed here.

### 3.1. Hysteresis Current Control for Grid Connected Inverter

Hysteresis current control is a method of controlling a voltage source inverter where the actual current $I_{actual}$ is compared with a reference current $I_{ref}$ on instantaneous basis. The proposed controller is shown in Figure 2[2], which is designed for a half bridge single phase voltage source inverter.

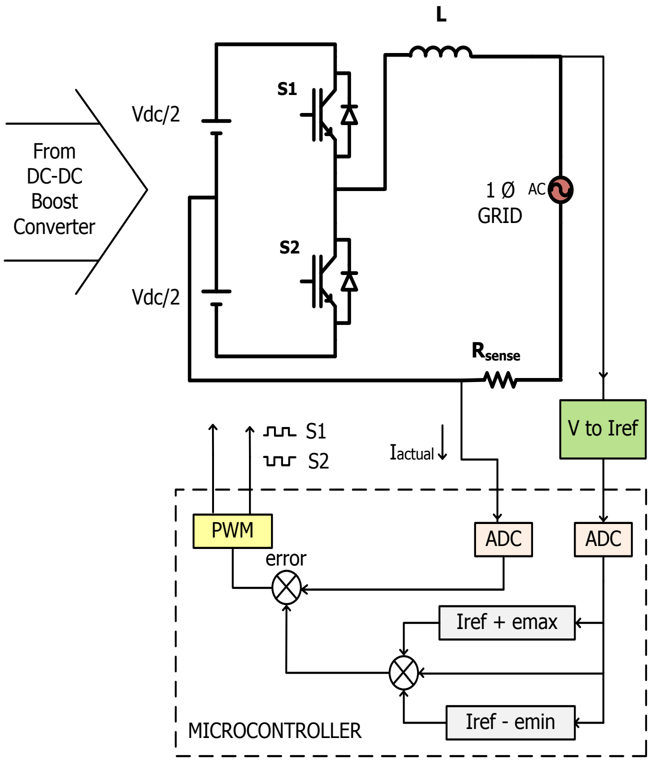


***Fig. 2 Hysteresis current control for grid connected inverter***

The actual current $I_{actual}$ through the inductor L is sensed and compared with two reference currents, forming the upper current reference and the lower current reference viz. $I_{ref\ upper}$ which is $I_{ref} + e_{max}$ and $I_{ref\ lower}$ which is $I_{ref} - e_{min}$. The current references are tapped directly from the grid, the grid voltage being converted into current of suitable value that matches the $I_{actual}$. This arrangement ensures that the current produced by the PV inverter is in phase with the grid voltage and also achieves unity power factor. The simulation of a half bridge inverter circuit was carried out using PSIM software. The actual current signal has to be tapped from the load circuit by using a current sensing resistor $R_{sense}$ and also conditioned to make it compatible with the microcontroller. The two signals $V_{grid}$ and $I_{actual}$ fed to the ADC of the microcontroller wherein the control algorithm has to be written using C language, the flow chart of which is shown in Figure 3.

 

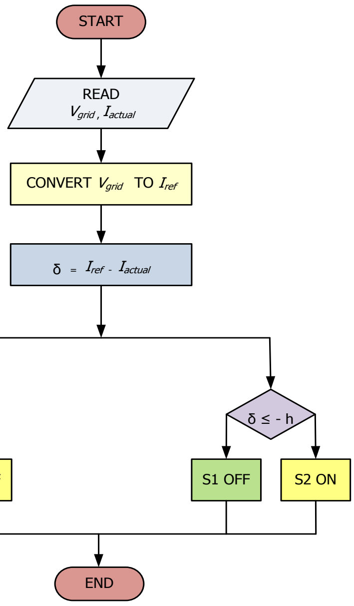


***Fig. 3 Flowchart of hysteresis band current control***

The error signal defined by δ which is the difference of the actual and reference current signals,

$\delta = I_{ref} - I_{actual}$

where $I_{ref}$ = reference current signal which is proportional to grid voltage

$I_{actual}$ = actual current sensed by current sensing resistor

The maximum and minimum values of error signals will be + h and –h. When the actual current reaches the upper Hysteresis band; $\delta \leq -h$ , the lower switch S2 will be turned ON to force the current down and similarly when the actual current reaches the lower band the upper switch; $\delta \geq +h$, S1 will be turned ON.

### 3.2. Simulation and Results of HBCC Inverter

The simulation of single phase half bridge HBCC inverter for grid connectivity was carried out using PSIM software. The simulation circuit and the results are presented here.

#### 3.2.1 Simulation Circuit

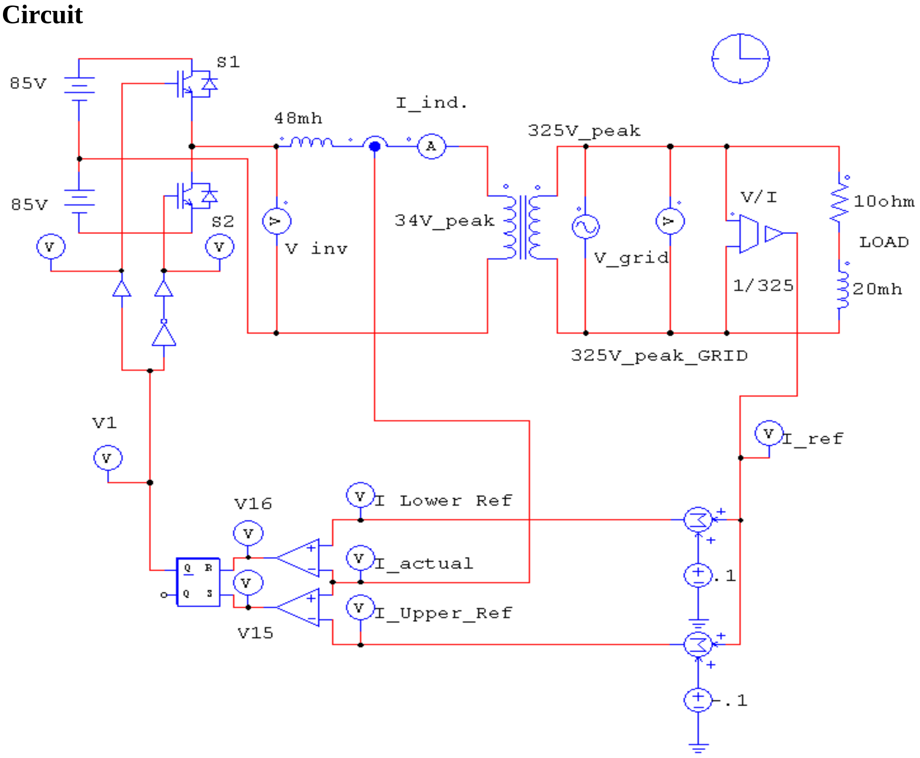


***Fig. 4 Simulation circuit of Grid connected HBCC half bridge inverter***

Figure 4 shows the simulation circuit of single phase half bridge HBCC inverter. The ac output of the inverter circuit is 24 Volts (rms), the grid voltage is 230 Volts (rms) and hence the peak value of grid voltage is taken 325 Volts.

The *rms* value of fundamental component is given by the equation mentioned below [3].

$$V_{01} = \frac{2V_d}{\sqrt{2}\pi} = 0.45V_d \qquad \text{------- 1}$$

$V_d$ of 85 volts dc gives 38 volts as the fundamental component of the inverter output voltage which needs to be slightly greater than the grid peak voltage on inverter side which is 34 Volts ac. The inductor value was varied from 24 mH to 48 mH and both give satisfactory switching of the devices to give the desired output current waveform. The voltmeters V_inv and V_grid measure the inverter output voltage and the grid voltage, while the ammeter I_ind measures the actual inductor current. An R-L load has been connected to the grid. The grid voltage has been converted into current signal by dividing it by 325 to obtain a reference current value of 1 ampere which is I_ref. This reference current is used to create hysteresis band by adding and subtracting a known value which here is taken as +/-10% to give sufficiently visible band in the output waveform. The logic circuit using S-R flip-flop compares the actual current every instant with the reference current and it issues pulses to both the IGBTs such that the actual current traverses the path within the hysteresis band formed around the reference current. The pulses issued to the lower switch S2 are inverted to those issued to the upper switch S1.

### 3.2.2 Simulation Results

The simulation results of the circuit discussed in the previous section are shown here.Figure 5 shows the inverter output voltage and the grid voltage which is used as the reference to drive the inverter to produce sinusoidal voltage. The fundamental component of the upper waveform which is the inverter output voltage can be recovered to obtain a sine wave.

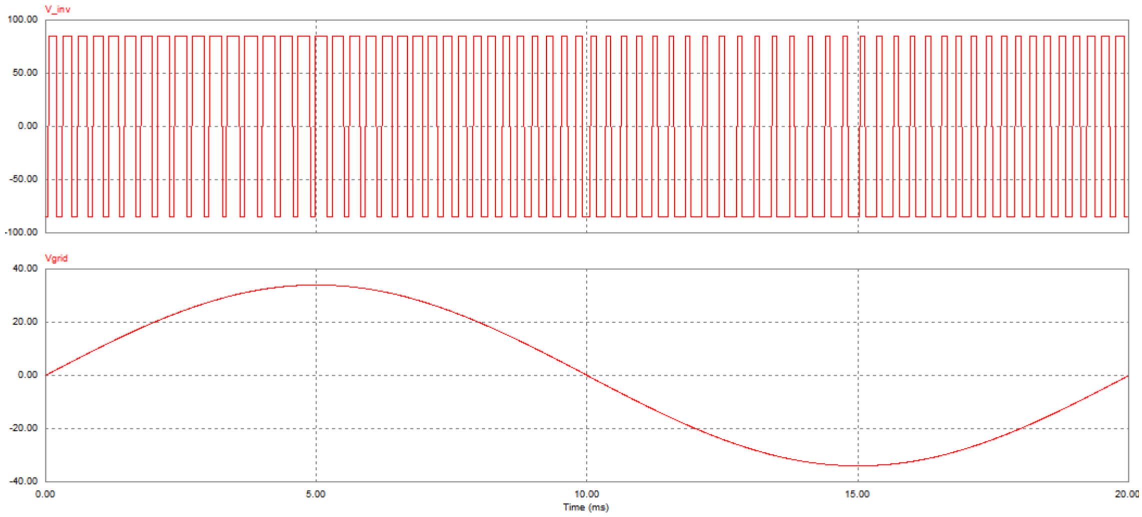


***Fig. 5 Inverter output voltage and the reference grid voltage***

Figure 6 shows the hysteresis current band obtained by switching the IGBTs S1 and S2 such that the actual current flowing to the load switches between the upper and the lower reference current values. The upper waveforms depict the current signals while the lower is the inverter output voltage. The actual current waveform can be seen to vary within the upper and the lower reference current waveforms.

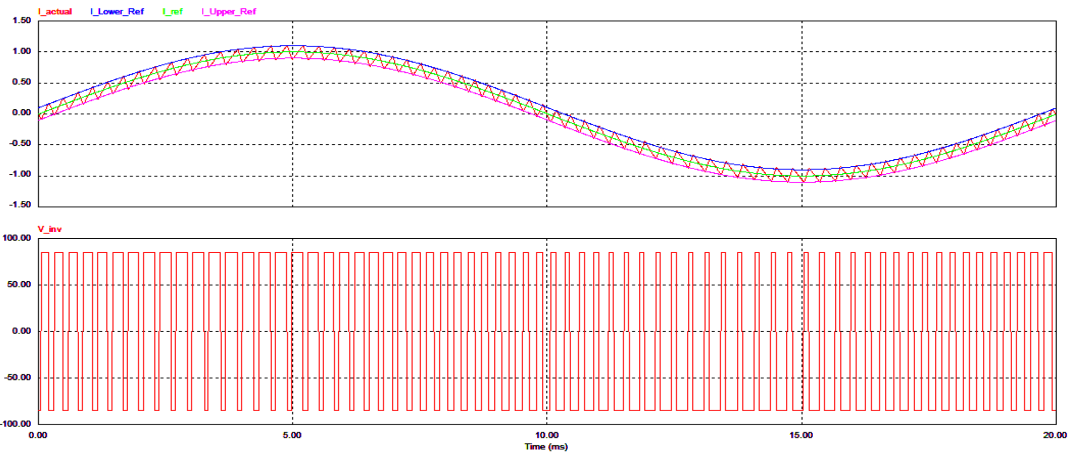


***Fig. 6 Current and voltage waveforms of HBCC inverter***

*The Figure 7 shows the simulation of a*ctual current waveform and the switching pulses issued to the upper and the lower switches S1 and S2 respectively of the HBCC inverter. It is observed that the actual current rises when upper switch is ON. When the current reaches upper limit the lower switch S2 is turned ON and S1 is turned OFF.

 

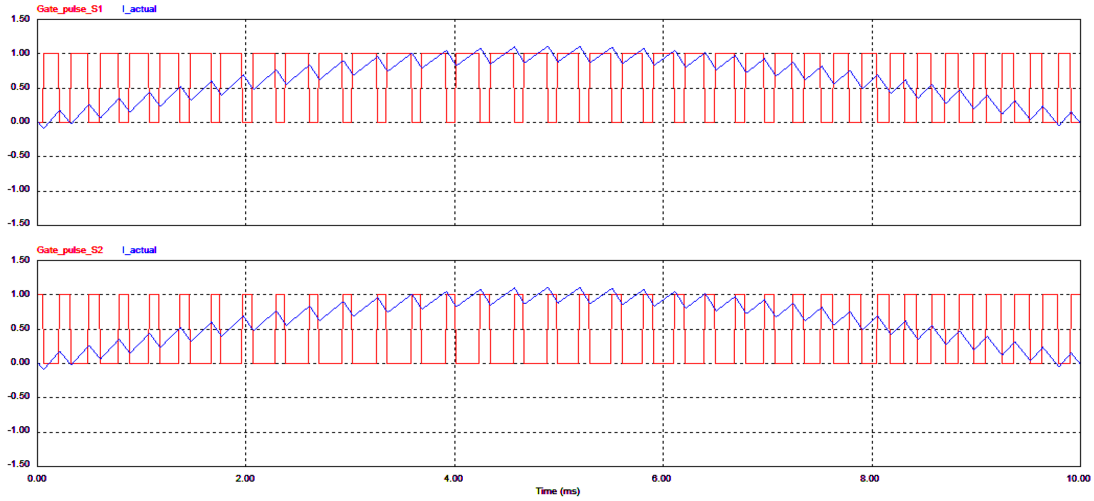


***Fig. 7 Actual inverter current and Gating signals to switches S1 and S2***

## IV CONCLUSION AND FUTURE SCOPE OF WORK

The solar energy for generation for electricity being a clean, unlimited and sustainable source is becoming popular day by day. The role of Power Electronics in harnessing PV power is crucial as the PV output needs to be modified a lot in terms of several electrical parameters and with the increase in research work in the power electronics area adds an impetus to increase the utilization of solar PV power. The simulation of hysteresis band current control technique was done and gating signals to be fed to the gates of power semiconductor devices of half bridge inverter were simulated. The hysteresis current control technique is advantageous over the technique using PLL as it uses fewer components and thus it reduces circuit complexities. The hysteresis control technique is better and effective as the reference signal is sensed directly from the grid. First the grid voltage is sensed and adjusted to desired value before converting it into a current signal which becomes the reference current signal. This ensures that the current produced by the PV inverter is in phase with the grid voltage. And thus helps achieve unity power factor. The actual implementation of the circuit using a DSP processor or a microcontroller can be done as future work.

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