International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249-8958 (Online), Volume-8 Issue-5, June 2019

Real time Analysis and Simulation of five level Grid Connected H-Bridge Inverter using FPGA Based Controller

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***Abstract:** In this paper FPGA based controller is developed for a cascaded 5-level H-bridge inverter inject active power to the grid through renewable sources. It reduces stress level on the different switches. Harmonic distortion and EMI in H-bridge Inverter cause by the different switching of power electronic devices. A capacitor, boost converter, three phase full bridge inverter and a filter add up to form a total five level inverter. The renewable energy source act as a input to the boost converter. The boost converter output is supplied to the capacitor which in turn is connected to the full bridge inverter. The switching action of the switches in five level H-bridge inverter is according to the controller action to give a five level AC voltage. The five level inverter output current is controlled to get the sinusoidal current in phase with the voltage of the utility in order to inject power in the grid. A prototype is developed so as to verify the performance of the cascaded five level H-bridge inverter with a grid connected renewable energy system. The results of the experiment show that the system gives the expected performance.*

***Keywords:** H bridge , Multilevel Inverter, DC-AC power*

I. INTRODUCTION

Cascade H-bridge multilevel inverter have many advantages as compare to the different multilevel topologies found in the literature such as flying capacitor and diode clamped. Some of the important feathers of H Bridge Inverter are its modular structure, generation of low harmonics content which reduces the filtering requirement. The main aspect of the system integrated to grid is to generate the proper power factor as per the grid demand. Here a control strategy is proposed for a grid connected photovoltaic system with a five level H-bridge inverter. The proposed scheme has much advantage over the traditional system. In general two level inverter are used for the connection but it has a limitation in THD and voltage rise. The five level H-Bridge does not have this problem as it reduces the THD and DC capacitor add up the voltage for high power application. Multilevel Inverter technology is the one of the emerging technology in the field of medium voltage application. The figure 1 shows three phase cascade H- bridge multilevel inverter.

Manuscript published on 30 June 2019.
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Cascade Multilevel Inverter has a series connection of H-bridge Inverter with a separate DC source. As the number of level is increased in a multilevel inverter, the quality of output is improved in term of THD , which reduces the filter component size and cost. The remaining part of the paper is followed by mathematical modeling in section 2 then the control of three phase 5-level inverter in section 3.The simulation results and the real time implementation result is discussed in section 4 .The end section discuss the conclusion of the paper.

II. MATHEMATICAL MODELING OF GRID CONNECTED INVERTER

In this section, the mathematical model of the grid connected inverter is presented. The five level cascade inverter consist of two full bridge having 4 switching devices in each module. In each module full bridge will have 16 possible combination. Out of these 16 possible states, 4 inverter states will make bidirectional flow of current and the inverter output is fixed. Each modulecreates three different voltage levels in steps to get the AC output. The series combination gives us the five levels AC output of the inverter.

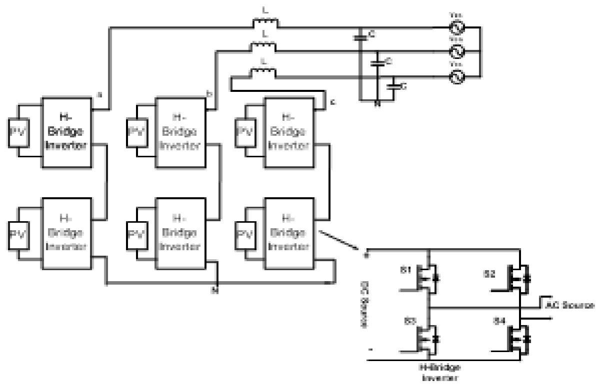

Fig.1. Grid Connected Five level H-bridge

Each voltage is determined by section of the PV plant. Here number of DC source.N_{DC}Required for good operation of the system is given by

$$N_{DC} = \frac{3}{2}(L_n - 1), \quad (1)$$

Where$L_n$represents the number of levels in phase voltage

$$L_n = 2S_{HB} + 1, \quad (2)$$

$S_{HB}$is the number of series connected H-bridge of each phase.

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Park transform can be used to transform the αβ into dq synchronous frame

$$\begin{bmatrix} e_d \\ e_q \end{bmatrix} = \begin{bmatrix} \cos\ \omega t & \sin\omega t \\ -\sin\ \omega t & \cos\ \omega t \end{bmatrix} \begin{bmatrix} e_\alpha \\ e_\beta \end{bmatrix} \quad (3)$$

$$\begin{bmatrix} e_d \\ e_q \end{bmatrix} = \begin{bmatrix} \cos\omega t & \sin\ \omega t \\ -\sin\ \omega t & \cos\omega t \end{bmatrix} \begin{bmatrix} V_\alpha \\ V_\beta \end{bmatrix} - \begin{bmatrix} \cos\omega t & \sin\ \omega t \\ -\sin\ \omega t & \cos\omega t \end{bmatrix} \begin{bmatrix} L\frac{di\alpha}{dt} \\ L\frac{di\beta}{dt} \end{bmatrix} \quad (4)$$

$$= \begin{bmatrix} V_d \\ V_q \end{bmatrix} - L\frac{d}{dt}\begin{bmatrix} i_d \\ i_q \end{bmatrix} - R\begin{bmatrix} i_d \\ i_q \end{bmatrix} + \omega L\begin{bmatrix} i_q \\ -i_d \end{bmatrix}$$

$$\begin{bmatrix} V_d \\ V_q \end{bmatrix} = L\frac{d}{dt}\begin{bmatrix} i_d \\ i_q \end{bmatrix} + R\begin{bmatrix} i_d \\ i_q \end{bmatrix} + wL\begin{bmatrix} -i_q \\ i_d \end{bmatrix} + \begin{bmatrix} e_d \\ e_q \end{bmatrix} \quad (5)$$

Were e_d and e_q are park transformation of grid voltage and V_d,V_q are park transformation of inverter voltage.

III. PROPOSED CONTROL SCHEME

The control of VSI can be categories as current control and voltage control. The voltage control technique use the phase angle between the grid voltage and the inverter output voltage for controlling the power flow. The current controller of a VSI is the most important part in controlling the Inverter which is connected to the grid. The control scheme of a current control PWM has the main task to flow the reference signals as shown in figure 2. This is done by comparing the command signal i_{Aa} ,i_{Ba},$i_{Ca}$and the instantaneous value of the phase current measured i_A ,i_B, i_C. The current controller generates the switching signal S_A ,S_B, S_C for the three phase inverter so that the current error can be reduce ε_A ,ε_B, ε_C.

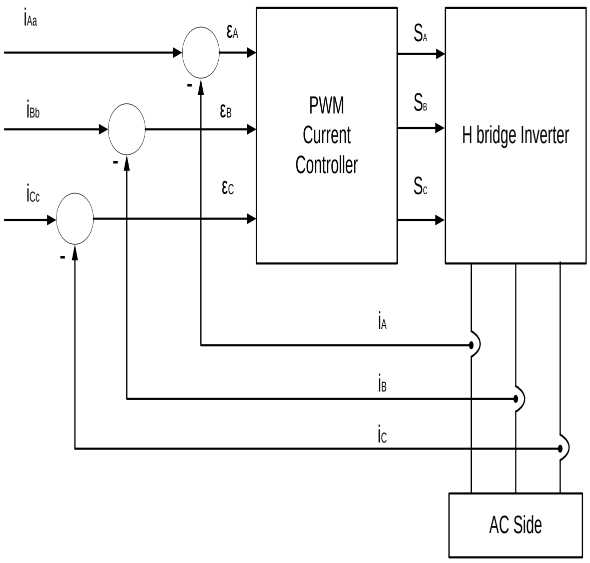

Figure 2. Block diagram Current control

The grid voltage must be synchronized with the inverter output voltage. The PLL is used to extract the phase angle of the grid voltage.

IV. RESULTS

4.1 Simulation analysis

To obtain the synchronous control the feedback variable ie three phase current and voltage are converted into dq reference frame which is obtain by using park transformation. Two identical PI controller are used with proportional (Kp) and integral (Ki) component. To set the value of Kp and Ki to get the ideal response from the control system is called tuning . Here Ziegler Nickolas tuning rules are used to guess the parameter value for fine tuning. The optimum value of PI controller are chosen as Kp =0.1 and Ki=0.001

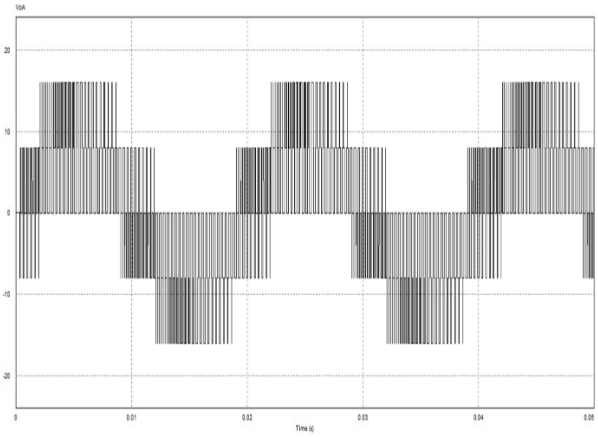

Figure3. Inverter phase voltage without filter

Figure 3 shows the simulation results of the voltage waveform of the inverter without using LC filter were as the Figure 4 shows the voltage waveform of the inverter after the use of LC filter. The output is nearly sinusoidal with small ripple.

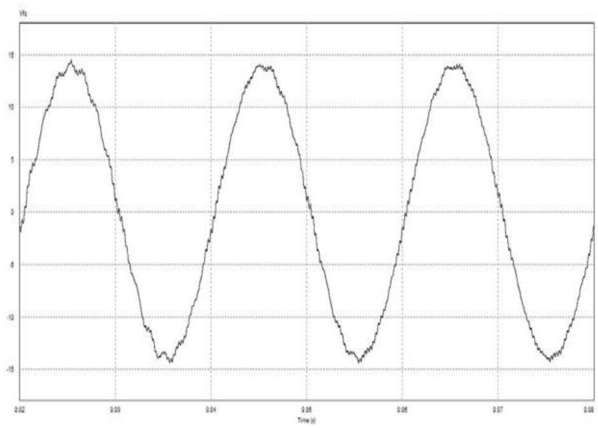

Figure4. Inverter phase voltage with LC filter

4.2 Prototype development and Experimental verification

A three phase 2KW five level cascade H-bridge inverter with driver and isolation circuit is implemented for the experimental set-up. The system proposed was tested in the laboratory on an equivalent PV source. The DC power supply was used as a replacement for PV array. Figure 6 shows the multilevel output voltage. The use of FPGA shows a very high-speed control loop resulting in significantly improved performance.

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If required computational speed and switching frequency can be increase. Therefore the output waveform has very limited harmonic content and hence a small value output filter is sufficient for fulfilling EMI rules which can reduce the size and cost. Figure 5 shows the THD value is around 4.4% in five level grid connected inverter.

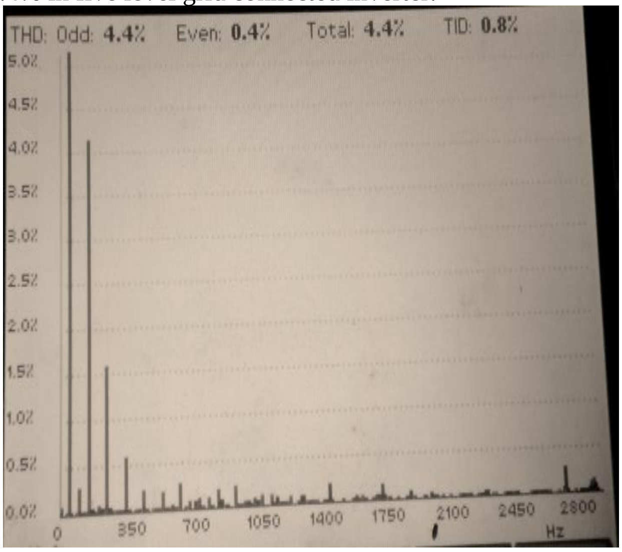

Figure 5. THD Analysis of five level inverter

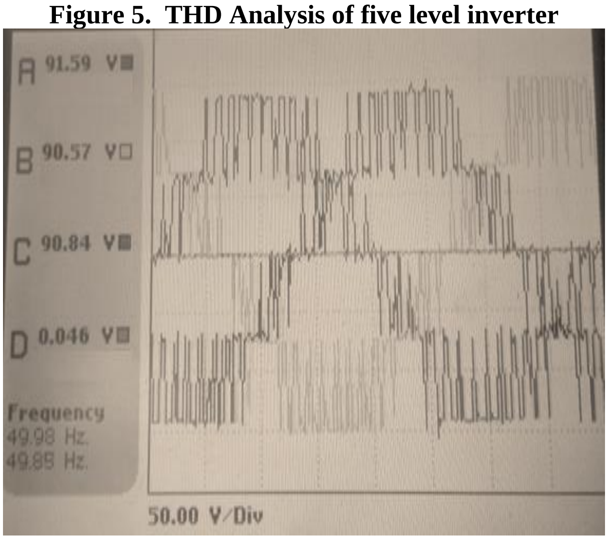

Figure 6. Three phase Five level Inverter output voltage

V. CONCLUSION

A novel three phase 5 level multilevel cascaded H-bridge inverter for PV application has been designed and analyzed its performance on MATLAB. A prototype is developed in the laboratory. Its performance on accurate electric power generates and lowers the filter dimension. FPGA background is used for programming purpose which has a fast response time.

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