

# Performance Estimation of Five Level Inverter for Solar Grid Connected System

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**Abstract:-**Reformations in electricity sector along with various renewable energy promotion policies have increased the importance of small grid connected photovoltaic (PV) systems utilizing single-stage single-phase inverters. To improve the performance multilevel inverter are preferred over two levels. This paper proposes a single-stage five level inverter for grid connected (PV) system. The output current of the inverter can be adjusted according to the voltage of the photovoltaic (PV) array. This control scheme is based on SPWM topology. Schemes based on SPWM which do not require the service of a phase locked loop for interfacing the inverter to the grid are increasingly being employed for such applications. Performance evaluation of the five-level inverter is done on MATLAB platform. The viability of the proposed scheme is confirmed by performing simulation and results validation.

**Keywords:** Five level inverter, Cascaded H-bridge inverter, SPWM, Solar PV array

## 1. INTRODUCTION

In recent years, reformations in electricity sector along with various renewable energy has been increasing interest in Electrical energy Generation. Solar Energy is one of the best alternatives among available renewable sources. Photovoltaic (PV) systems are ideal distributed generation (DG) units, and they offer many advantages such as no fuel costs, no pollution, no noise, and little maintenance. Solar photovoltaic arrays have been fastest growing energy sources in the world, and the growth is more penetrated in grid connected applications. Multi-level inverters have gained much attention in the application areas of medium voltage and high power owing to their various advantages such lower common mode voltage, lower voltage stress on power switches, lower dv/dt ratio to supply lower harmonic contents in output voltage and current. Comparing two-level inverter topologies at the same power ratings, multi-level inverter also have the advantages that the harmonic components of line-to-line voltages fed to load are reduced owing to its switching frequencies.

In this paper, the photovoltaic grid connected cascaded H-bridge five level inverter is proposed. Five Level inverter topology have two cascaded inverters and SPWM controlled technique. Fig. 1 shows the proposed five level inverter topology for grid connected PV system. Two individual PV arrays are connected with two cascaded IGBT H-Bridges to the grid. Performance of proposed inverter is verified with exhaustive simulation results on MATLAB Simulink platform.

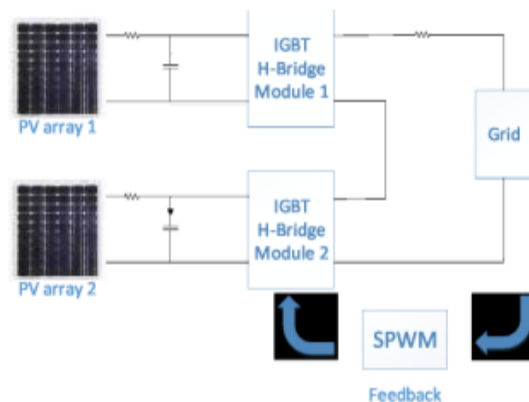


Fig. 1 Proposed Cascaded H-Bridge Inverter

## 2. FIVE LEVEL INVERTER TOPOLOGY

The most common MLI topologies classified into the three types are 1) Diode clamped Multi - level inverter (DCMLI), 2) Flying capacitor MLI (FC-MLI), 3) Cascaded HBridge MLI (CHB-MLI), 4) Hybrid MLI. The hybrid and asymmetric hybrid inverter topologies have been developed according to the combination of existing multilevel inverter topologies or applying the different DC bus levels respectively. Among with these types of MLI, Cascade Multi level inverter is very much suitable for solar grid integration application. Several modulation and control techniques have been developed for multi level inverters including selective harmonic elimination PWM (SHE-PWM), sinusoidal PWM (SPWM), space vector PWM (SVM), and similar variations of the three main algorithms. SPWM control method is very popular in industrial applications owing to its harmonic reducing opportunities by using several phase shifting options on carrier signal. In the SPWM, a sinusoidal reference voltage waveform is compared with a triangular carrier waveform to generate gating signals for the switches of inverter. Several multicarrier techniques have been developed to reduce the THD ratios, based on the classical SPWM with triangular carriers. Another alternative modulation technique is SVM strategy, which has been used appropriately in five level inverters. The SVM and SHEPWM methods are fundamental frequency switching methods and perform one or two commutations of the power semiconductors during one cycle of the output voltages to generate a staircase waveform. This paper presents the multi level inverter topologies and their control methods according to Solar Grid integration application, based on a well surveyed literature summary. A comprehensive study has been performed on commonly used and hybrid multilevel inverters and the most appropriate SPWM control scheme

## 3. CONFIGURATION OF PROPOSED CASCADED H-BRIDGE FIVE LEVEL INVERTER

Cascade Five level inverters consists of a series of H-bridge cells to synthesize a desired voltage from two separate DC sources (SDCSs) which may be obtained from PV array, batteries or fuel cells. All these properties of cascade inverters allow using various pulse width modulation (PWM) strategies to control the inverter accurately. Hence cascade H-Bridge five level inverter is very best suitable for solar grid connected system.

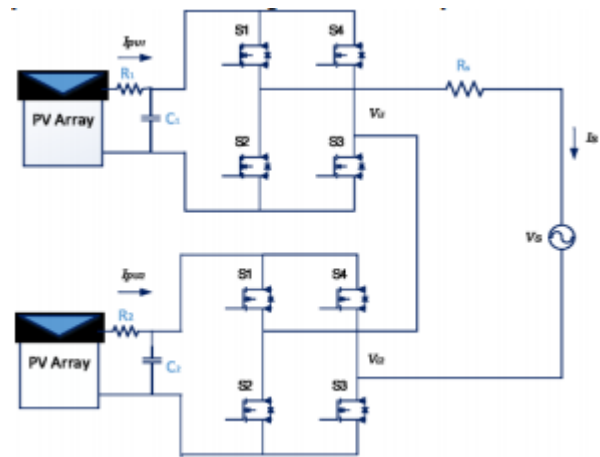


Fig. 2 Five Level Topology for Grid Connected System

The proposed inverter includes two H-bridge and four SPWM switching signals to the each bridge shown in Fig.2. Two different Equivalent model of PV Array is act as DC source of inverter. This two H-bridge connected in cascade connection and Output of inverters is directly fed to AC source. By different combinations of the four switches in each H-bridge, five output voltage levels can be generated,  $V_s, V_s/2, 0, -V_s/2, -V_s$ . A cascaded five level inverter with 2 input sources will provide five levels to synthesize the AC output waveform. This five level voltage waveform enables the reduction of harmonics in the generated current, reducing the requirement of output filters. As shown in Fig. 1, the cascaded multilevel

inverter is connected to the grid. PV power is delivered to the load grid according to the system operation conditions.

#### 4. SPWM CONTROL TOPOLOGY

The sinusoidal SPWM is most widely used PWM control method due to many advantages including easy implementation, lower harmonic outputs according to other techniques, and low switching losses. In the SPWM, a sinusoidal reference voltage waveform is compared with a triangular carrier waveform to generate gate signals for the switches of inverter. Several multicarrier techniques have been developed to reduce the THD ratios, based on the classical SPWM with triangular carriers.

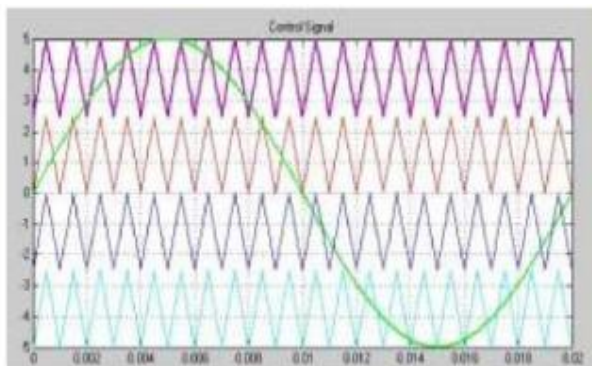


Fig. 3(a) Modular control strategy (control Waveform)

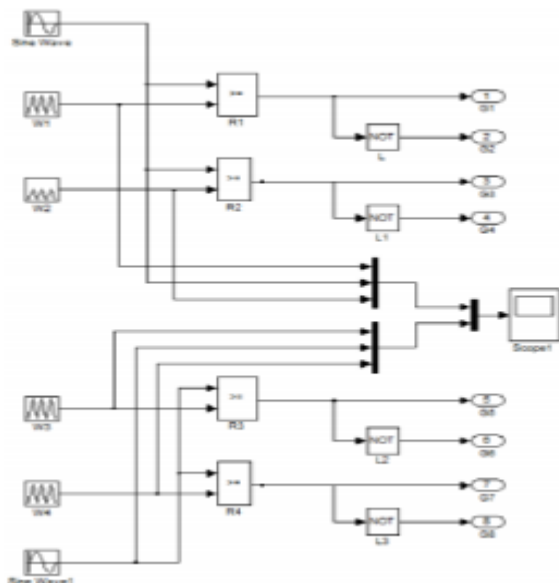


Fig. 3 (b) Modular control strategy (Block diagram)

In SPWM control, a high frequency triangular carrier signal is compared with a low frequency sinusoidal modulating signal in an analog or logic comparator devices. The frequency of modulating sinusoidal signal defines the desired line voltage frequency at the inverter output. The modulation algorithm has been performed in SPWM modulator block to generate 4 separate SPWM pulses for individual H Bridge.

#### 5. SIMULATION SETUP

In order to verify the performance of proposed cascaded H-bridge five level inverter, detailed simulation studies are carried out on MATLAB-Simulink. Simulation model of the proposed system is simulated in Matlab Simulink software as shown in Fig. 4 and modular controller of the proposed system is shown in Fig.3 (a). According to specification of PV array solar insolation is set at 1000W/m<sup>2</sup>. At 1000W/m<sup>2</sup> insolation, the output of PV array will be 115 Volt which will be fed to cascaded H-bridge inverter. Two individual cascaded H-bridge inverters are used for grid integration. Output of two cascaded H-bridge Inverters is 230V AC and will be directly connected to grid utility. This inverter output is controlled by modular control strategy. Two individual modular controllers are used for both inverters. Modular controller is shown in Fig. 3(b) IGBT switches for inverter topology. The detail parameters of the inverter chosen for the purpose of simulation and controller are as follows:

Solar Insolation: 1000W/m<sup>2</sup>

Nominal Solar array voltage: 115 Volts

Resistance R1, R2: 1.5 Ohm, 10 Ohm

DC link Capacitor: 2200  $\mu$ f

Grid Voltage: 230 Volts

Filter fundamental frequency: 50 Hz Simulation model of proposed five level inverter fed solar grid

connected system is shown in Fig. 4. DC link capacitor C1 and C2, resistances R1 and R2 is used for interconnection of PV array and Cascaded H-bridge

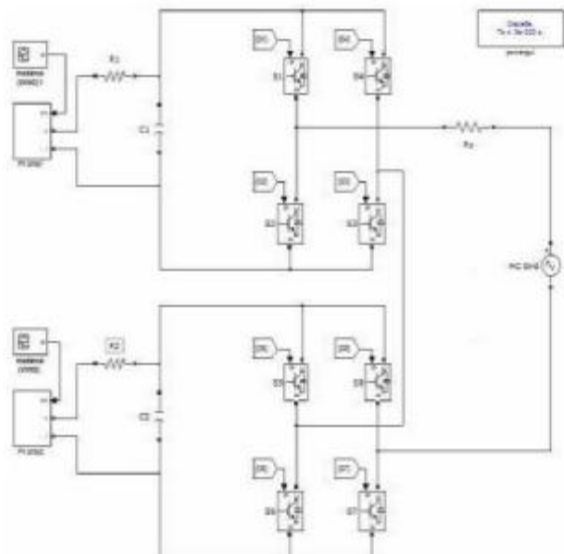


Fig. 4 Simulation model of proposed system

## 6. RESULTS AND DISCUSSION

MATLAB simulation set up of five level inverter is shown in Fig.4. Output PV array is connected to the Inverter and it is directly integrated with DC link Voltage Fig. 4(a) to (d) show the simulated waveforms of the DC link voltage, Output voltage, output current, and AC grid voltage. This DC link voltage shows output of one solar equivalent circuit model. Output voltage and output current of five level inverter is settle down after the 2 to 4 msec is shown in Fig. 4(b) and (c).

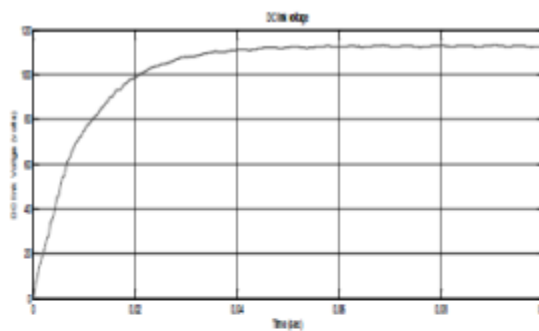


Fig. 4 (a) DC Link Voltage

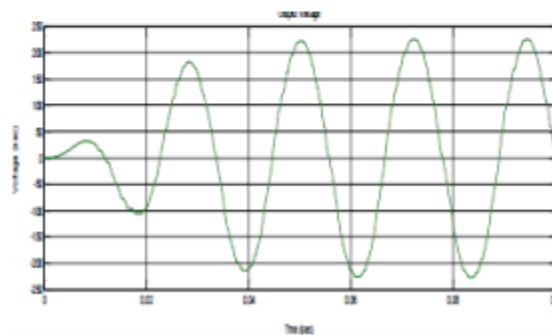


Fig. 4 (b) Output voltage of Inverter

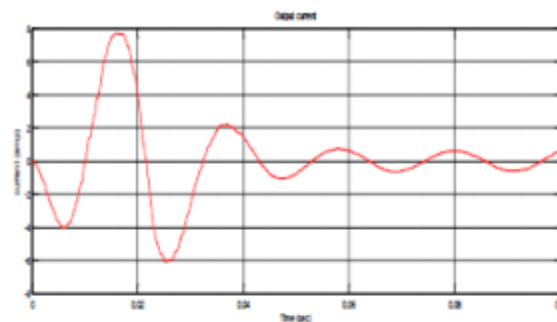


Fig. 4 (c) Output current of Inverter

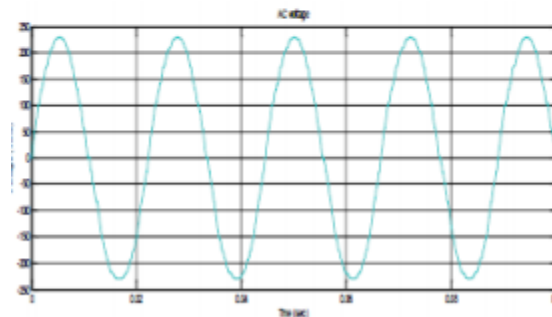


Fig. 4 (d) Grid Voltage

Solar Five level inverter is required 2 to 4 msec for PV grid integration with Single phase supply. This results

clearly shows the solar grid integration is based on cascaded H-bridge inverter based on SPWM control technique

## 7. CONCLUSION

In this paper, simplified Single phase cascaded H-bridge Five-level inverter used for solar grid integration application has been presented. The performance Evaluation of the five-level inverter is done on Matlab platform. And comparing its simulated voltage waveform with respect to the conventional single phase cascaded H-bridge inverter. So control strategy based on SPWM topology is very simple technique for grid integration. For solar PV array integrated to grid, only 2 to 4 msec are required. This is follows under the Voltage level and phase angle between voltage and current

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