# COMPARATIVE ANALYSIS OF THREE PHASE 5-LEVEL AND 9-LEVEL MULTILEVEL INVERTERS FOR GRID CONNECTED PV SYSTEM.

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***Abstract: - Photovoltaic energy conversion becomes main focus of many researches due to its promising potential as source for future electricity and has many advantages than the other alternative energy sources like wind, ocean, biomass, geothermal etc. In Photovoltaic power generation multilevel inverters play a vital role in power conversion. The three different topologies, diode-clamped inverter, capacitor-clamped inverter and cascaded h-bridge multilevel inverter are widely used in these multilevel inverters. Among the three topologies, cascaded h-bridge multilevel inverter is more suitable for photovoltaic applications since each photo voltaic array can act as a separate dc source for each h-bridge module. This paper presents a comparison of three phase cascade h-bridge 5-level and 9-level multilevel inverters for grid connected photovoltaic application using phase shifted pulse width modulation scheme. Multilevel inverters are basically used for high power applications as it helps in getting improved output waveform, nearly sinusoidal. As the levels obtained by multilevel inverters increased, harmonic content reduced but with this merit there are certain problems offered by it so to study this trade-offs the theoretical study made in this paper considers comparison of grid connected 5-level and 9-level cascaded h-bridge multilevel inverters.***

***Keywords: – Power Quality, Grid Connected PV Systems, Multilevel Inverter, Cascaded H-Bridge Multilevel Inverter, Phase Shifted PWM Technique.***

## 1. INTRODUCTION

In the recent years, the demand for clean and green energy requires high quality output power with low switching losses. It is also seen that the soft switching technology develop showing that the demand further increases by improving efficiency. This trend is expected to continue in coming years because the energy produced by renewable sources is expected to satisfy 20% and 50% of the total needs in 2020 and 2050 respectively. It is also witnessed that among these renewable energy sources, solar photovoltaic energy is found to be a promising energy.

Inverters are needed to convert the direct current electricity produced into alternating current electricity required for loads. Multilevel inverter promises a lot of advantages over conventional inverter especially for high power applications. Some of the advantages are that the output waveform were improved since multilevel inverter produced nearly sinusoidal output voltage waveforms, hence the total harmonic distortion also low, reduced switching losses and the filter needed to smooth the output voltage is small; hence, the system is compact, lighter and much cheaper. There are different types of multilevel circuits involved. The first topology introduced was the series H-bridge design followed by the diode clamped converter, which utilized a bank of series capacitors. A later invention detailed the flying capacitor design in which the capacitors were floating rather than series-connected. Another multilevel design involves parallel connection of inverter phases through inter-phase reactors. In this design, the semiconductors block the entire dc voltage, but share the load current. The cascaded multilevel control method is very easy when compare to other multilevel inverter because it doesn't require any clamping diode and flying capacitor. These designs can create higher power quality for a given number of semiconductor devices than the fundamental topologies alone due to a multiplying effect of the number of levels. There are several pulse width modulation (PWM) techniques are known. Here, we concern only in phase shift PWM topologies in this paper.

## 2. H-BRIDGE INVERTER

The H-Bridge inverter is as shown in the fig. 1. Here the switches s1 and s2 are used to get positive voltage and switches s3 and s4 are used to get negative voltage. By using this single h-bridge we get only three levels (0, +V, -V) of voltage. To get more levels we should connect these h-bridge inverters in series.

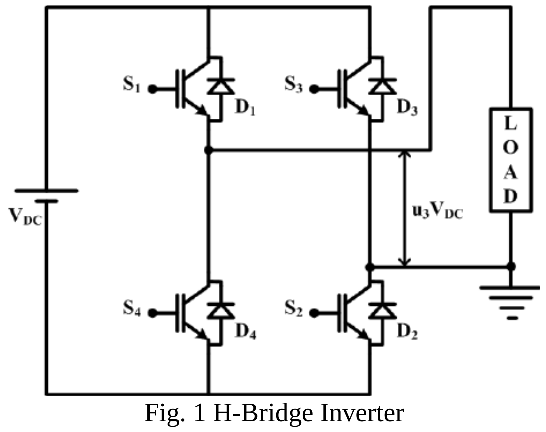


Fig. 1 H-Bridge Inverter

## 3. DESIGN OF THREE PHASE FIVE-LEVEL INVERTER

As we already discussed to get more than three levels of voltage we should connect h-bridge inverters in series as shown in the fig. 2. The main advantages of the cascaded h-bridge multilevel inverters are its ability to offer improved regulation of the dc bus voltage and its structure, which is modular to simplify control as well as maintenance. From the figure you can observe that for three phase inverter three sets of five level inverters are used. The cascades single phase H-Bridge multilevel inverter uses different single phase h-bridge ones, each with an independent dc voltage source. The different legs of a cascaded h-bridge multilevel inverter can have different levels of voltage that are switched by the individual single phase h-bridge inverters, where three levels of voltage can be obtained. The ac outputs of the single phase h-bridge inverters in each leg are connected in series such that the synthesized voltage waveform is the sum of the h-bridge inverters outputs. Table 1 shows the switching sequence of five level inverter. Same switching sequence is applicable for all phases with 120 degree phase shift. For 9-level inverter we use four h-bridge inverters in each phase.

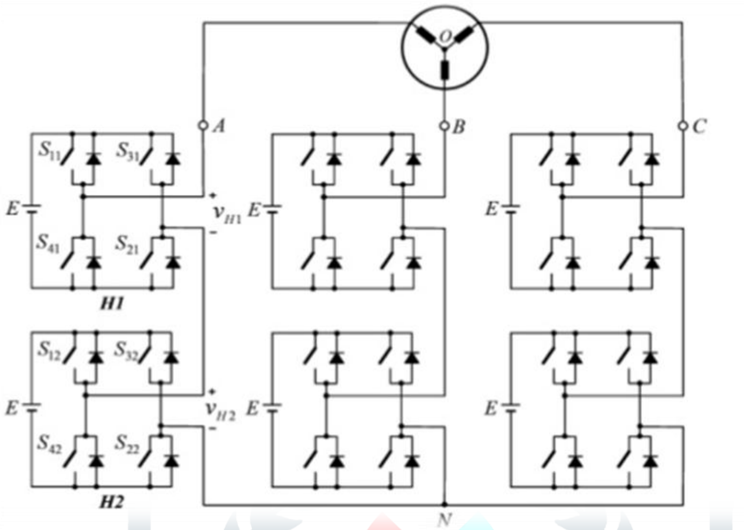


Fig. 2 Three-Phase 5-level H-Bridge Inverter

| Voltage | S11 | S21 | S31 | S41 | S12 | S22 | S32 | S42 |
|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| E | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2E | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 |
| E | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| -E | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 |
| -2E | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 |
| -E | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

### *3.1 Modulation techniques for INVERTERS*

The main advantage of PWM is that power loss in the switching devices is very low. When a switch is off there is practically no current, and when it is on and power is being transferred to the load, there is almost no voltage drop across the switch. Power loss, being the product of voltage and current, is thus in both cases close to zero. The carrier-based modulation schemes for multilevel inverters can be generally classified into two categories: **phase-shifted** and **level-shifted** modulations. Both modulation schemes can be applied to the CHB inverters. Here we will discuss about phase-shifted modulation scheme. In phase shifted carrier pulse width modulation all the triangular carriers have the same frequency and same peak-peak amplitude .But there is a phase shift between any two adjacent carrier waves. For m Voltage levels (m-1) carrier signals are required and they are phase shifted with an angle of θ = (360°/m-1). The gate signals are generated with proper comparison of carrier wave and modulating signal. Figure 3 shows two level PSCPWM scheme. From figure 3 you can observed that carrier wave and sine wave are compared to get pulses. To get pulses for five level inverter the second carrier waveform (for h-bridge2) is shifted by 90 degrees.

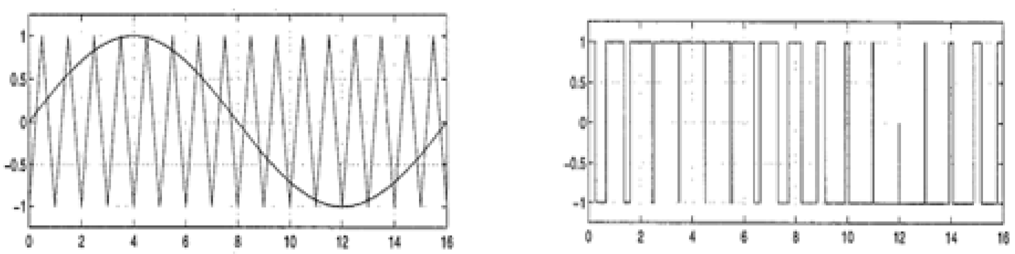

Fig. 3 Two-level PSCPWM

## 4. BLOCK DIAGRAM OF PV SYSTEM CONNECTED TO GRID

Block diagram shows grid connected photovoltaic system. Here two more components dc-dc converter, MPPT and Phase locked loop are used. **Maximum power point tracking** is a technique used commonly in photovoltaic solar systems to maximize power extraction under all conditions. PV solar systems exist in many different configurations with regard to their relationship to inverter systems, external grids, battery banks, or other electrical loads. Regardless of the ultimate destination of the solar power, though, the central problem addressed by MPPT is that the efficiency of power transfer from the solar cell depends on both the amount of sunlight falling on the solar panels and the electrical characteristics of the load. As the amount of sunlight varies, the load characteristic that gives the highest power transfer efficiency changes, so that the efficiency of the system is optimized when the load characteristic changes to keep the power transfer at highest efficiency. This load characteristic is called the maximum power point and MPPT is the process of finding this point and keeping the load characteristic there. **DC-DC** converter is used to control the dc link voltage. **Grid synchronization** is one of the most important issues of the distributed power generation system (DPGS) connected to utility network. Converter interfaced DG units must be synchronized with the utility system. Grid synchronization is a challenging task especially when the utility signal is polluted with disturbances and harmonics or is of a distorted frequency. A phase detecting technique provides a reference phase signal synchronized with the grid voltage that is required to control and meet the power quality standards.

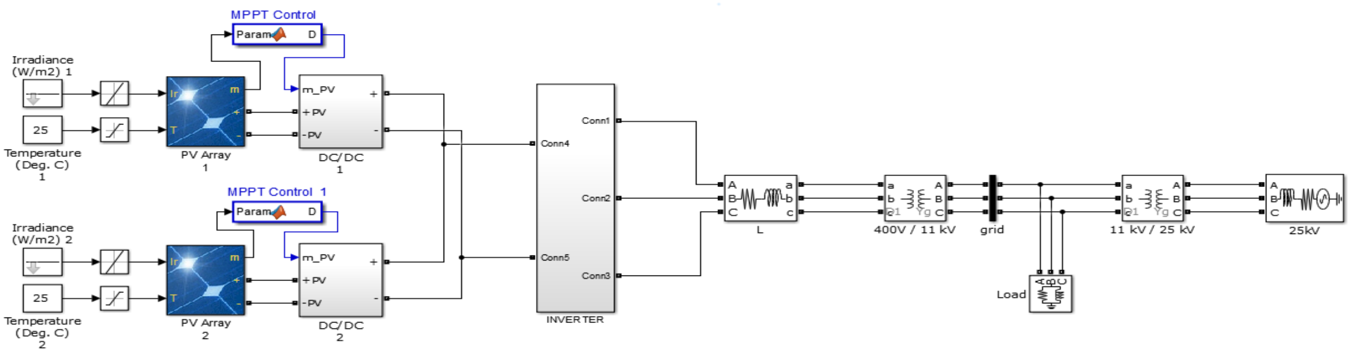


Fig. 4 Block Diagram of GRID-TIED PV SYSTEM

## 4. PERFORMANCE GRAPH AND RESULTS

MATLAB/Simulink is utilized to create the simulation model three phase inverter. All these results are done by continuous simulation type. Fundamental output voltages can be controlled by changing a modulation index M of referent signal; also, the fundamental output frequency can be adjusted by changing frequency of the referent signal. The simulation results of the 5-level and 9-level cascaded h-bridge multilevel inverters are as shown in the fig. 5-12.

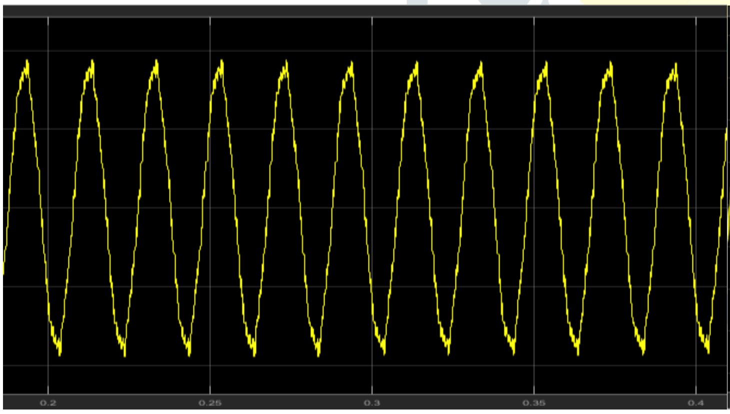

Fig. 5 Phase voltage of 5-level inverter

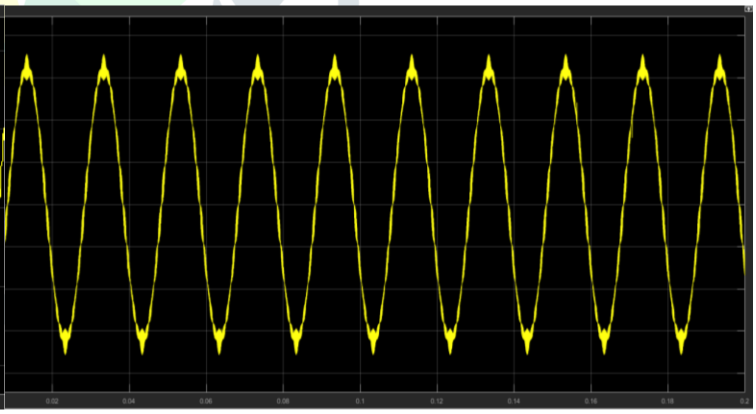

Fig. 6 Phase voltage of 9level inverter

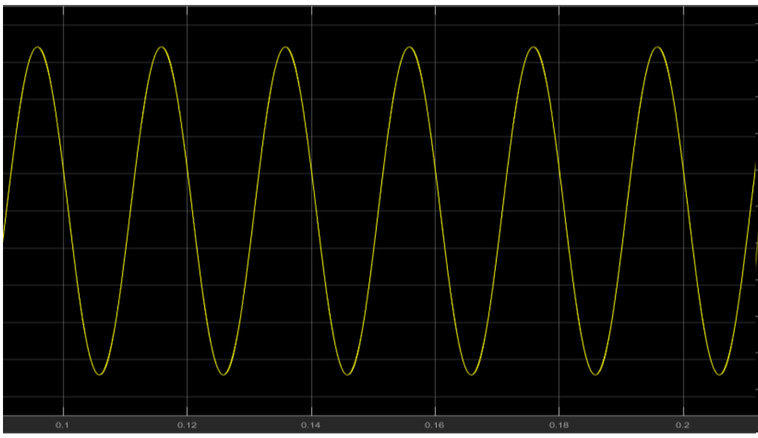

Fig. 7 Phase current of 5-level inverter

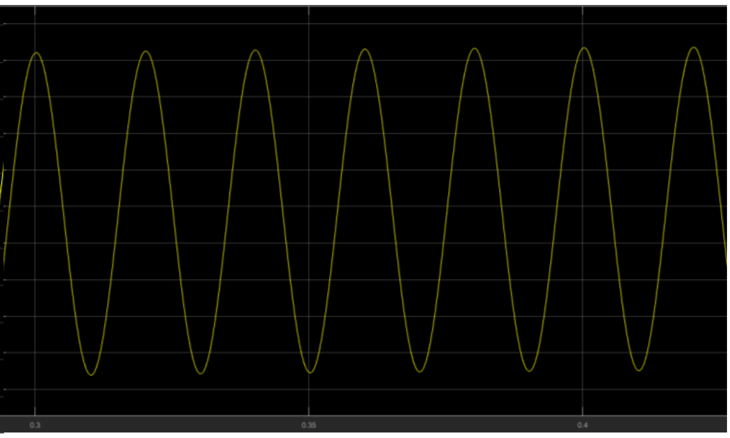

Fig. 8 Phase current of 9-level inverter

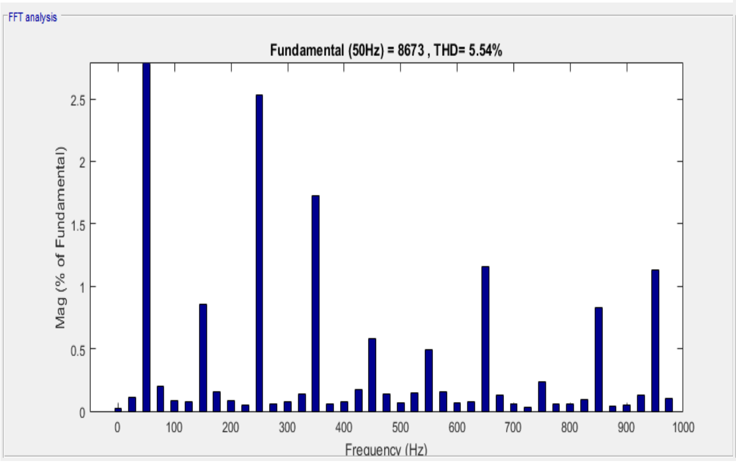


Fig. 9 FFT analysis of (voltage) 5-level inverter

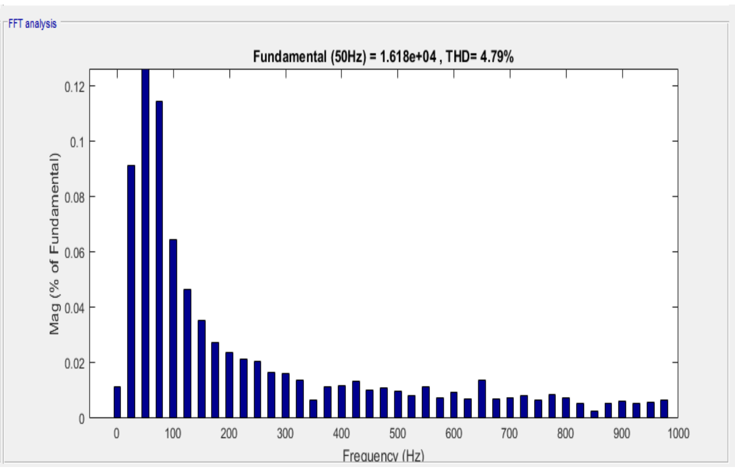


Fig. 10 FFT analysis of (voltage) 9-level inverter

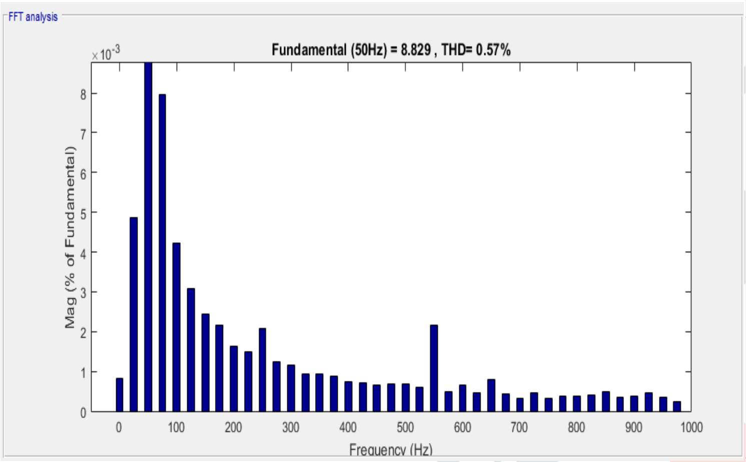


Fig. 11 FFT analysis of (current) 5-level inverter

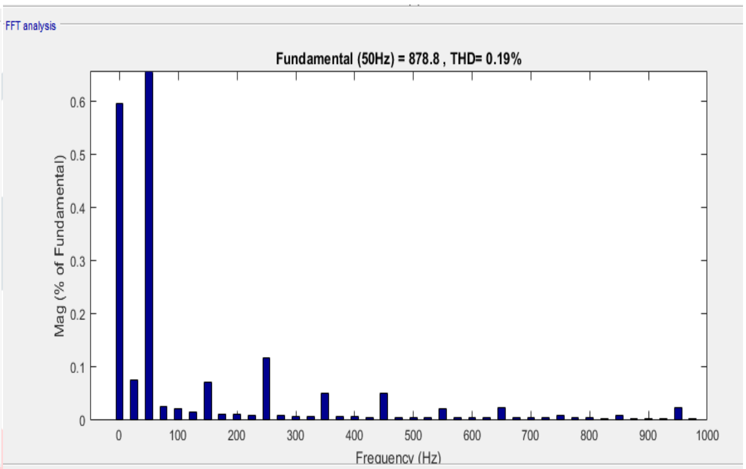


Fig. 12 FFT analysis of (current) 9-level inverter

The graphs shown from 5 to 12 shows the performance of 5-level and 9-level inverter. By taking reference from IEEE standards the voltage THD (total harmonic distortion) at PCC (point of common coupling) should be less than 5%. For 9-level inverter if we use transformer then at point of common coupling the output waveform THD is 4.79% so no need to use filters but for 5-level inverter the THD is 5.54% (>5%) so we should use filter. On comparing 9-level with 5-level we observed that as the levels of voltage increases then the total harmonic distortion will be decreased.

## 5. CONCLUSION

Thus we have studied 5-level and 9-level cascaded h-bridge multilevel inverters and observed that at point of common coupling the total harmonic distortion for five level is 5.54% and for nine level is 4.79%. As the levels of voltage increases, the total harmonic distortion decreases but the complexity of the circuit is increases. This problem will be solved in future by using new topology for same output and level.

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