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# IMPLEMENTATION OF MULTI LEVEL INVERTER TOPOLOGY WITH REDUCED SWITCHES FOR GRID INTERCONNECTION OF PV SYSTEMS

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**Abstract**- This Renewable energy sources (RES) gain an importance in recent decades because they are pollution free, easily erectable, and limitless. Among RES, Photovoltaic systems are mostly used as they are light, clean and easily installable. Normally PV cells converts sunlight into electricity in the form of dc. A suitable converter is usually needed to convert the dc power into ac power, which is then injecting into the power grid. The Multilevel Inverters [MLI] can be used to convert the dc into ac for integration of renewable energy sources into the conventional grids. But the conventional MLIs such as Diode Clamped MLIs requires extra diodes in conjunction with the active switches, Flying capacitor MLIs requires extra Capacitors and control also difficult if the levels increases and the Cascaded H-bridge MLIs requires separate dc sources which limits its use. This paper proposes a new type of multi level Inverter which converts the dc into ac using less number of switches when compared to conventional multilevel Inverters. The proposed Inverter can be used to integrate the Photovoltaic system into Grid, with satisfying the grid requirements such as phase angle, frequency and amplitude of the Grid voltage. Seven level, Eleven level, thirteen level and Twenty one level proposed MLI is simulated using Matlab/Simulink environment and the corresponding results are presented in this paper. MATLAB/SIMULINK

## I. INTRODUCTION

Over the past few years, technological advances in power electronics and increasing demand for energy have contributed to rapid development of power generation based on renewable energy sources as like the Photovoltaic (PV), Wind and Fuel cell (FC) based renewable energy technologies [1-3]. One of the problems focused in the research is the constraint of power electronic switches. If the power electronic devices which can prolong high voltage are used in the inverter, their switching frequency is restricted. Hence, the device voltage must be reduced to use high-speed switching devices. A multilevel inverter can reduce the device voltage and the output harmonics by increasing the number of output voltage levels. Further, increase in number of isolated DC sources in order to increase the number of output voltage levels leads to additional system complexity especially in PV and FC fed inverter topologies. In single-phase multi-level inverters, the most widely used techniques are cascaded H-bridge (CHB), diode-clamped and capacitor-clamped types [7-9]. This paper proposes a latest MLI which is used to convert DC to AC using reduced number of switches, when compared to conventional MLI. By this less number of switches, switching losses can be avoided [4-5]. Basically Inverter is a device that converts DC power to AC power at desired output voltage and frequency. Demerits of inverter are less efficiency, high cost, and high switching losses. To overcome these demerits, we are going to multilevel inverter. The term Multilevel began with the three-level converter. The concept of multilevel converters has been introduced since 1975 [6]. The cascade multilevel inverter was first proposed in 1975. In recent years multi level inverters are used high power and high voltage applications. Multilevel inverter output voltage produce a staircase output waveform, this waveform look like a sinusoidal waveform. The multilevel inverter output voltage having less number of harmonics compare to the conventional bipolar inverter output voltage. If the multilevel inverter output increase to N level, the harmonics reduced to the output voltage value to zero. The multi level inverters are mainly classified as Diode clamped, Flying capacitor inverter and cascaded multi level inverter. 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 [7-9].There are two PWM methods mainly used in multilevel inverter control strategy.In addition, many other techniques also exist. In particular, among these techniques, CHB single phase inverters have drawn attention because of their modularized circuit layout and simplicity. A variety of modulation techniques can be applied to CHB inverters. By increasing the number of cascaded H-bridges [10-11], the number of levels in CHB inverters increases. Generally if the number of output voltage levels is increased, then the number of power electronic devices and the number of isolated DC sources is also increased. This makes a CHB inverter further complex. In this paper, a novel multilevel inverter with minimum number of power electronic switching devices is proposed which is a modified version of the multilevel inverter using series/parallel conversion of DC sources. In the proposed Multilevel Inverter three similar Cascaded H-Bridges are used, each Bridge carries an auxiliary switch which will be Bidirectional in nature. The proposed multilevel inverter topology can be extended for the application of grid connected photo voltaic systems, hybrid electric vehicles, etc. Furthermore, theoretical analysis, numerical simulations and experimental results are also presented to demonstrate the validity of the proposed single phase cascaded multilevel inverter.

## II. MULTILEVEL INVERTER

The general structure of proposed new multilevel inverter is shown in the fig.1. It consists of a one H-bridge inverter and 'N' number of cascaded cells, which are having a dc rating of V dc. The number of levels can be given by the formula:

$$\text{Number of Levels} = [n\,(n+1) + 1] \quad (1)$$

Where n= Number of cells excluding the H-bridge. For generating + V dc we need turned on switches S I and S2, for -V dc, switches S3 and S4 has to be turned on, and for zero voltage either switches Sl and S3 or switches S2 and S4 has to be turned on.

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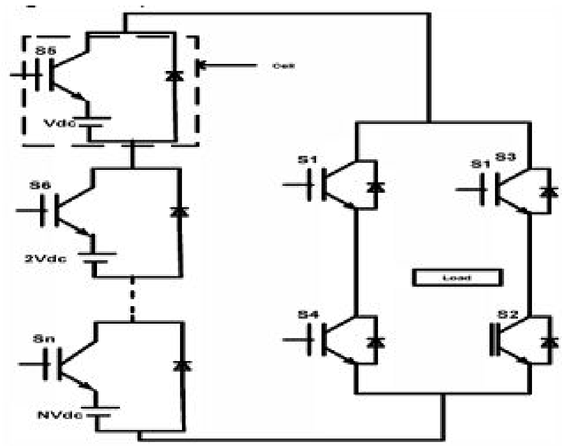


Fig.1 General Structure of proposed new multilevel inverter

### A. Seven Level Proposed Multilevel Inverter

The seven levels proposed inverter uses only six switches compared to cascaded H-bridge inverter which uses ten switches and three separate dc sources. But in proposed inverter, the requirement of separate dc sources is only two and the switching losses are also low. Using proper switching sequence proposed circuit generates seven levels in output voltage [7]. Table I shows the switching sequence used for creating seven levels for the output voltage. The output waveform has 7 levels: ± 3Vdc, ± 2Vdc, ± Vdc and 0. Circuit diagram of proposed seven level multilevel inverter is shown in fig.2.

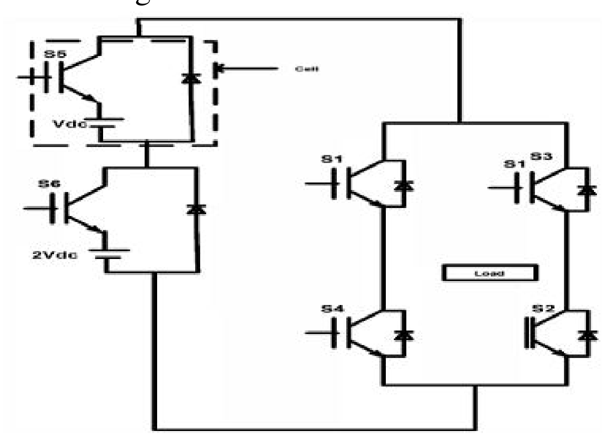


Fig.2. Circuit diagram of seven level proposed inverter

For generating seven levels, the proposed inverter uses two cells that mean it contains two switches and two diodes in addition with the one H-bridge. The output voltage waveform of the ideal seven level inverter is shown in fig .3.

Table 1: Switching Sequence for Proposed Seven Levels Inverter

| Sw1 | Sw2 | Sw3 | Sw4 | Sw5 | Sw6 | Load Voltage |
|---|---|---|---|---|---|---|
| On | On | off | off | On | off | $V_{dc}$ |
| On | On | off | off | off | On | $2V_{dc}$ |
| On | On | off | on | On | On | $3V_{dc}$ |
| off | On | off | On | off | off | 0 |
| off | off | On | On | On | off | $-V_{dc}$ |
| off | off | On | On | off | On | $-2V_{dc}$ |
| off | off | On | On | On | On | $-3V_{dc}$ |

### B. Thirteen Level Proposed Multi level inverter

The thirteen level proposed inverter uses only seven switches compared to cascaded H-bridge inverter which uses twenty four switches and six separate dc sources. But in proposed inverter, the requirement of separate dc sources is only three and the switching losses are also low. Using proper switching sequence proposed circuit generates seven levels in output voltage. Table 2 shows the switching sequence used for creating thirteen levels for the output voltage.

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Table 2: Switching Sequence for Proposed Thirteen Level Inverter

| Sw1 | Sw2 | Sw3 | Sw4 | Sw5 | Sw6 | Sw7 | $V_{load}$ |
|---|---|---|---|---|---|---|---|
| On | On | off | off | On | On | On | $6V_{dc}$ |
| On | On | off | off | off | On | On | $5V_{dc}$ |
| On | On | off | on | On | off | On | $4V_{dc}$ |
| On | On | off | off | off | off | On | $3V_{dc}$ |
| On | On | off | off | off | On | off | $2V_{dc}$ |
| On | On | off | off | On | off | off | $V_{dc}$ |
| off | On | off | On | off | off | off | 0 |
| off | off | On | On | On | off | off | $-V_{dc}$ |
| off | off | On | On | off | On | off | $-2V_{dc}$ |
| off | off | On | On | off | off | On | $-3V_{dc}$ |
| off | off | On | On | On | off | On | $-4V_{dc}$ |
| off | off | On | On | off | On | On | $-5V_{dc}$ |
| off | off | On | On | On | On | On | $-6V_{dc}$ |

Circuit diagram of proposed thirteen level multilevel inverter is shown in fig.4

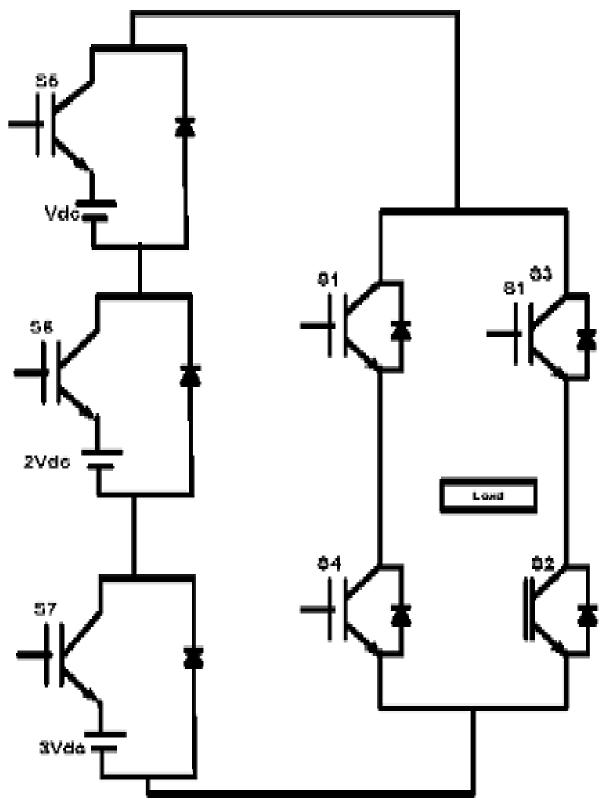


Fig.3. Circuit diagram of thirteen level proposed inverter

The output waveform has 13 levels: ± 6Vdc, ± 5Vdc, ± 4Vdc± 3Vdc, ± 2Vdc, ± Vdc and 0.

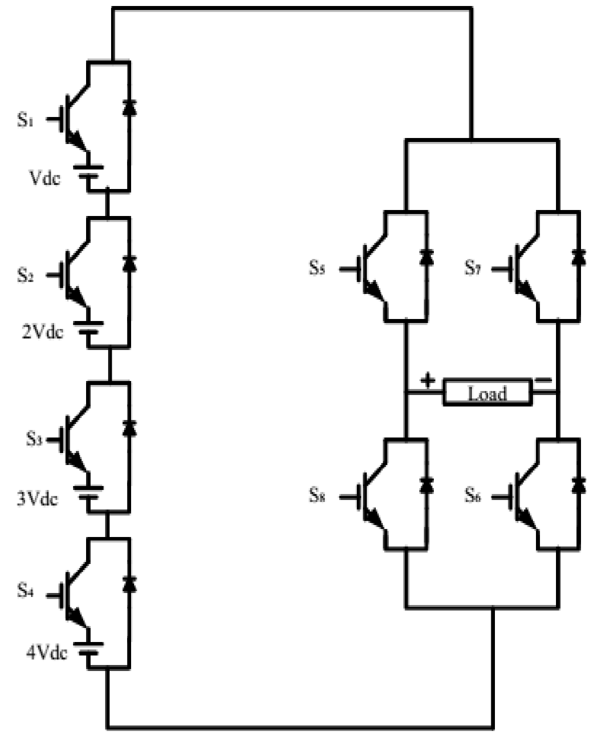


Fig.4.Circuit diagram of 21 levels proposed inverter

Table 3: Switching Sequence for Twenty One Level Inverter

| Sw1 | Sw2 | Sw3 | Sw4 | Sw5 | Sw6 | Sw7 | Sw8 | $V_{Load}$ |
|---|---|---|---|---|---|---|---|---|
| On | On | On | On | On | On | Off | Off | 10Vdc |
| Off | On | On | On | On | On | Off | Off | 9Vdc |
| On | Off | On | On | On | On | Off | Off | 8Vdc |
| Off | Off | On | On | On | On | Off | Off | 7Vdc |
| Off | On | Off | On | On | On | Off | Off | 6Vdc |
| On | Off | Off | On | On | On | Off | Off | 5Vdc |
| Off | Off | Off | On | On | On | Off | Off | 4Vdc |
| Off | Off | On | Off | On | On | Off | Off | 3Vdc |
| Off | On | Off | Off | On | On | Off | Off | 2Vdc |
| On | Off | Off | Off | On | On | Off | Off | Vdc |
| Off | Off | Off | Off | On | On | Off | Off | 0 |
| On | Off | Off | Off | Off | Off | On | On | -Vdc |
| Off | On | Off | Off | Off | Off | On | On | -2Vdc |
| Off | Off | On | Off | Off | Off | On | On | -3Vdc |
| Off | Off | Off | On | Off | Off | On | On | -4Vdc |
| On | Off | Off | On | Off | Off | On | On | -5Vdc |
| Off | On | Off | On | Off | Off | On | On | -6Vdc |
| Off | Off | On | On | Off | Off | On | On | -7Vdc |
| On | On | Off | On | Off | Off | On | On | -8Vdc |
| Off | On | On | On | Off | Off | On | On | -9Vdc |
| On | On | On | On | Off | Off | On | On | -10Vdc |

Table 4: Comparisons between Different Topologies

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| TOPOLOGY | NUMBER OF SWITCHES for 7-level | NUMBER OF SWITCHES for 13-level | NUMBER OF SWITCHES for 21-level |
|---|---|---|---|
| Diode Clamped MLI | 12 | 24 | 40 |
| Flying capacitor MLI | 12 | 24 | 40 |
| Cascaded H-bridge MLI | 12 | 24 | 40 |
| Proposed MLI | 06 | 07 | 08 |

## III. GRID TIED PV SYSTEM

The block diagram of the proposed grid connected PV system is shown in the figure. It consists of a PV system, proposed multi level inverter to interface with the grid.

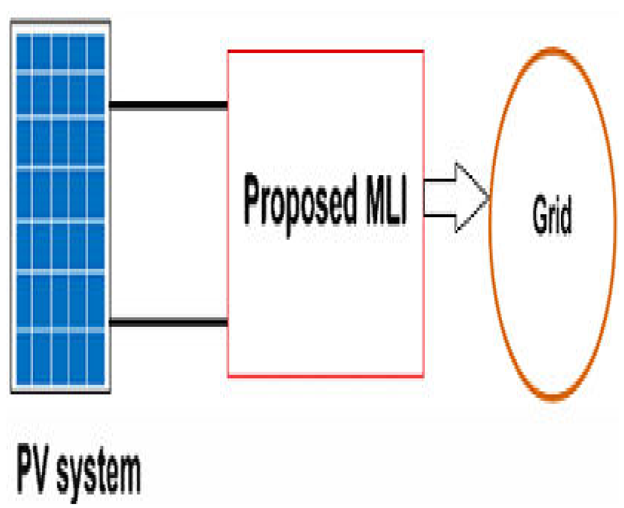


Fig.5.Grid tied photovoltaic system (PV)

From fig.5 the PV cell directly converters the solar energy into electricity in the form of dc [8]. The voltage obtained from the PV is converted into ac using the proposed inverter. Finally the proposed inverter is connected to the power grid with satisfying the grid requirements such as phase angle, frequency and amplitude of the grid voltage.

## IV. MATLAB/SIMULINK RESULTS

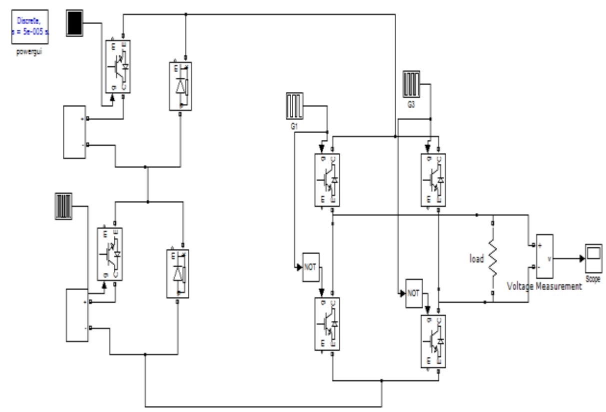


Fig.6. Matlab/Simulink diagram of proposed seven level MLI

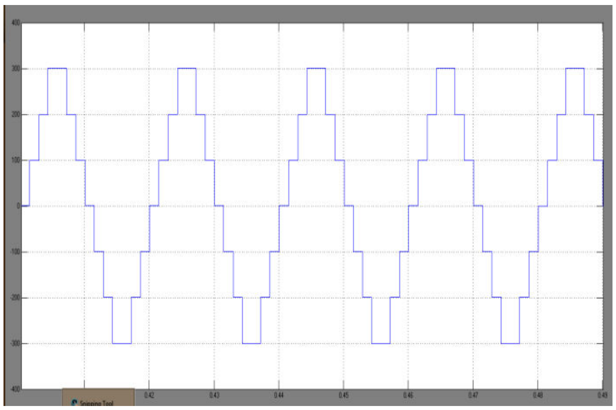

Fig.7. Proposed seven level inverter output voltage

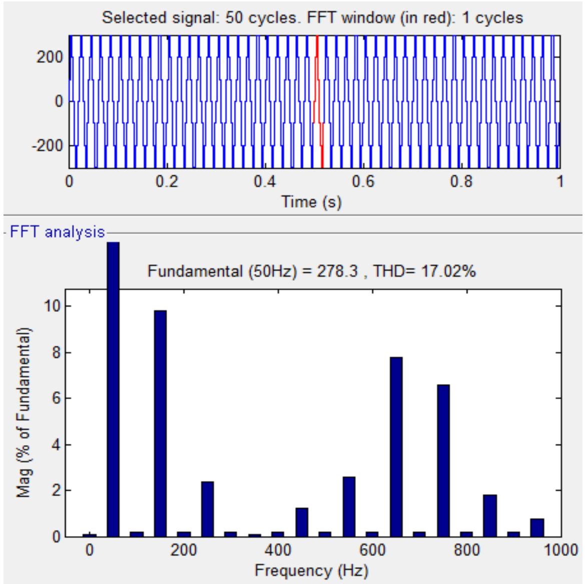


Fig.8 THD plot of 7-level inverter

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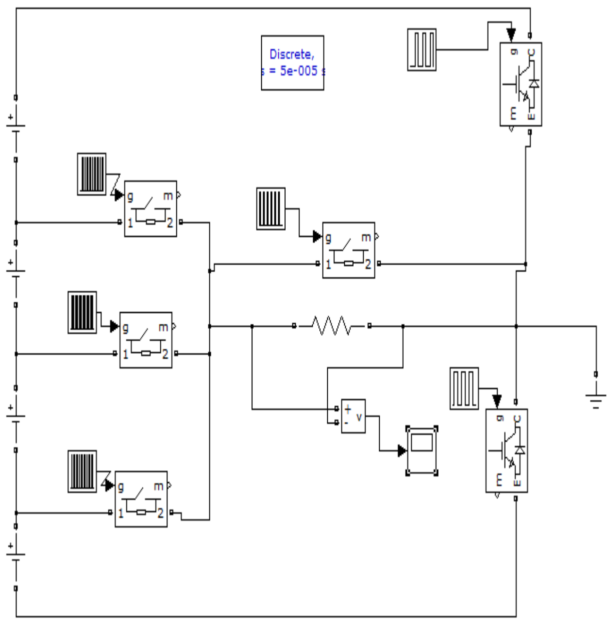


Fig.9.Matlab/Simulink diagram of proposed seven level MLI with 6 switches

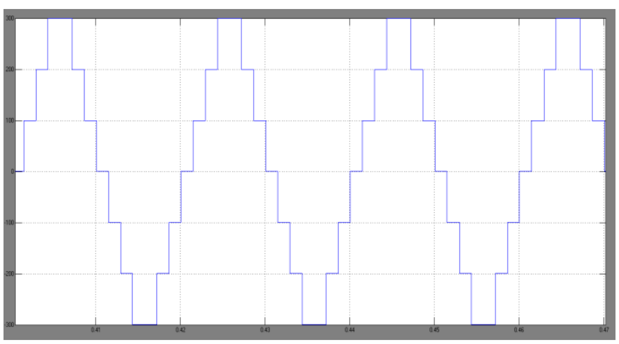

Fig.10. Proposed seven level inverter output voltage

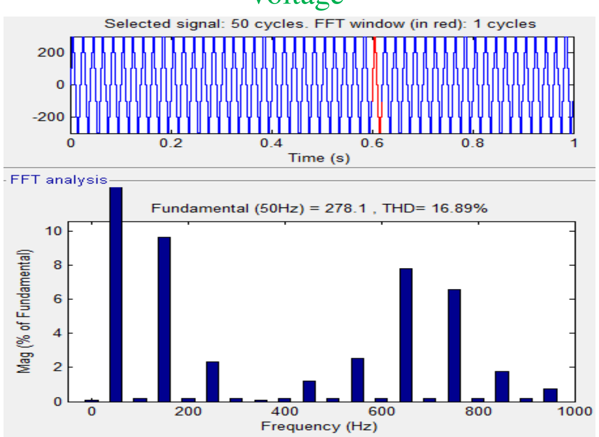


Fig.11 THD plot of 7-level inverter with 6 switches

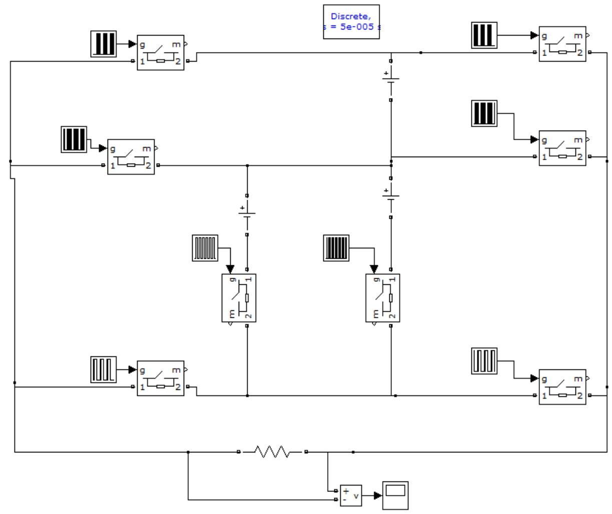


Fig.12. Matlab/Simulink diagram of proposed Eleven level MLI

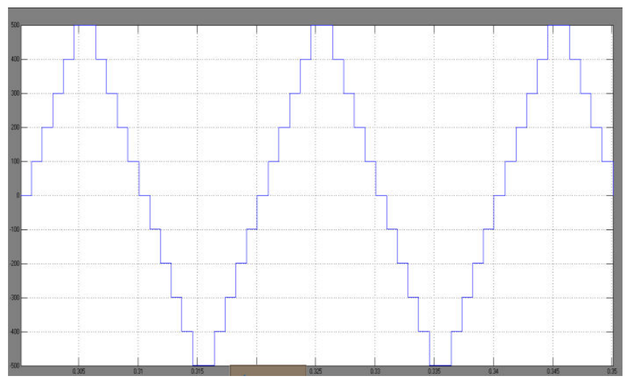

Fig.13. Proposed eleven level inverter output voltage

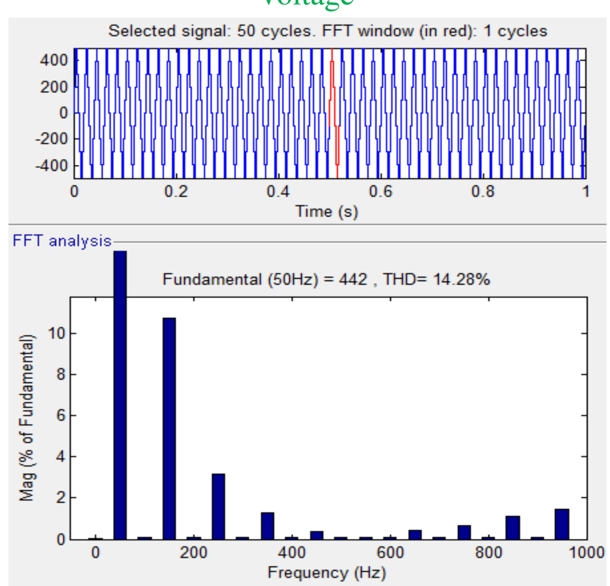


Fig.14 THD plot of 11-level inverter

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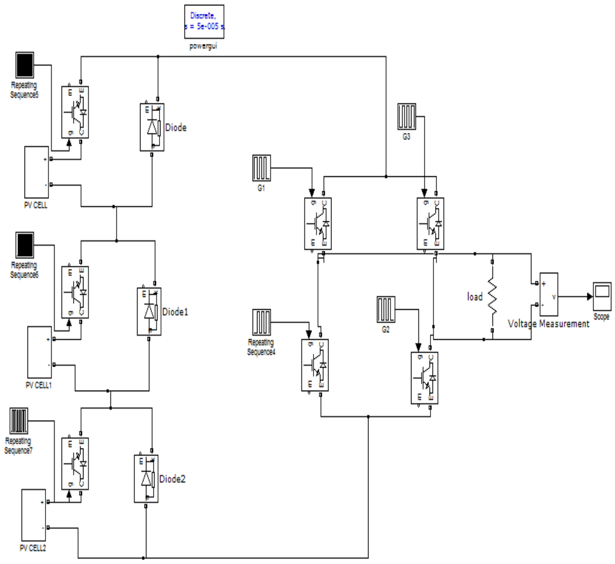


Fig.15 Matlab/Simulink diagram of proposed 13 level inverter

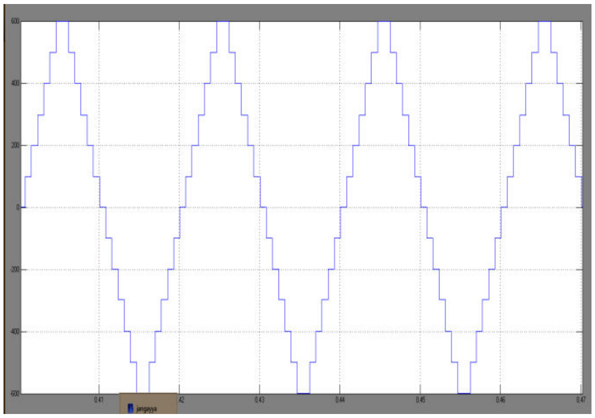

Fig.16 13-level inverter output voltage

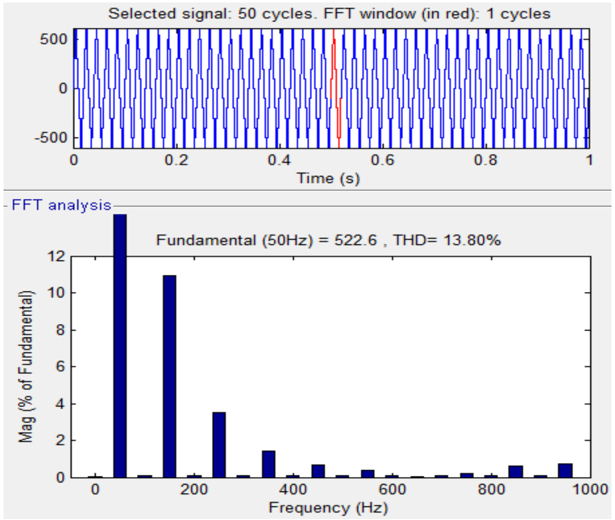


Fig.17 THD plot of 13 level inverter

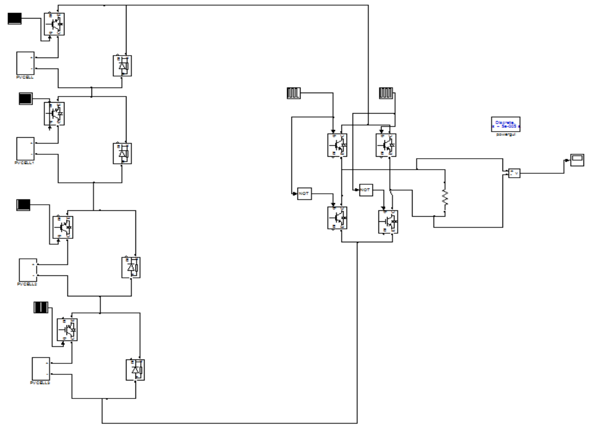

Fig.18 Grid Connected PV system based on Multilevel Inverter without twenty one level with grid connected.

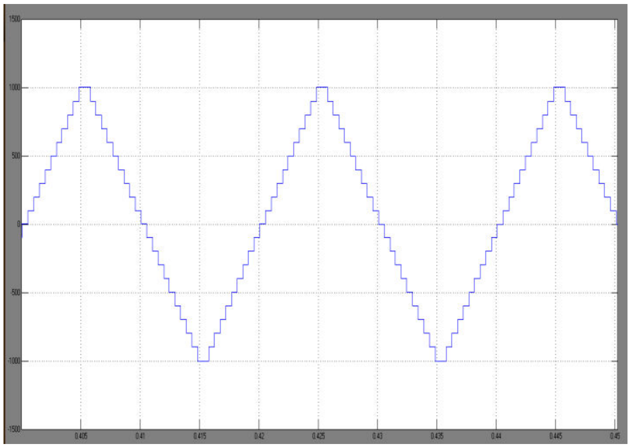

Fig.19 Twenty one level inverter output voltages of without grid connected.

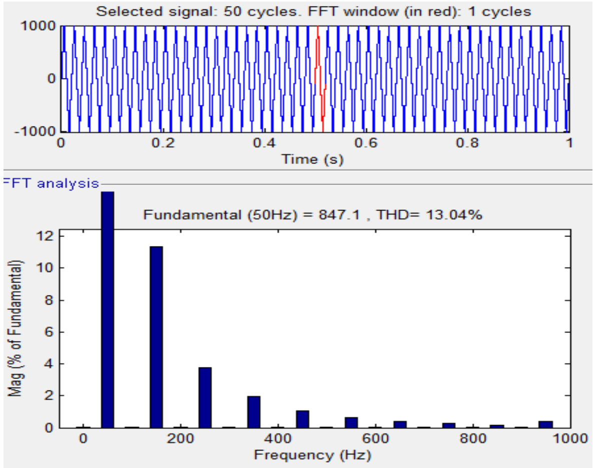


Fig.20 THD of the 21-level.

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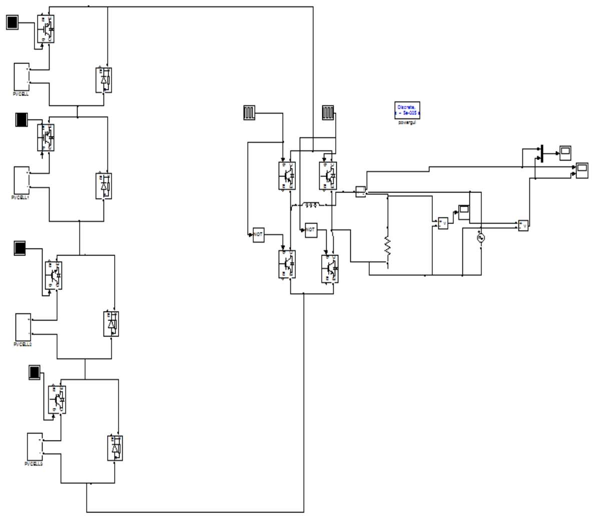
Fig.21 MATLAB/SIMULINK diagram of twenty one level with grid connected MLI.

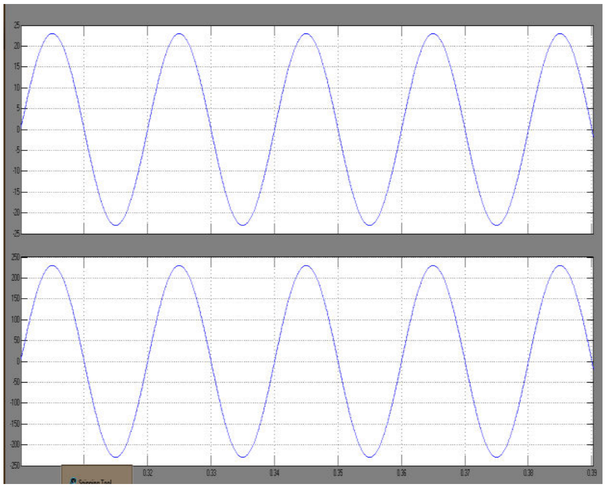
Fig.22 Grid current and voltage

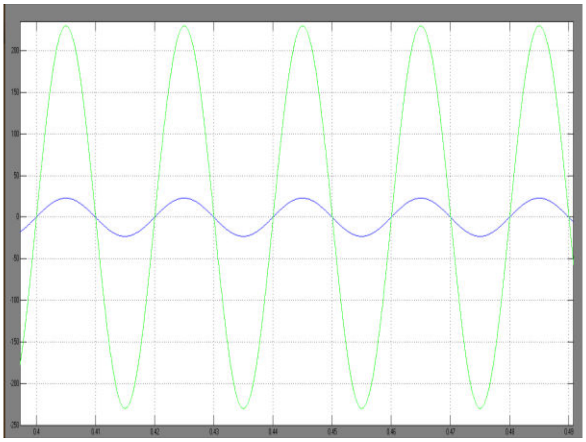
Fig.23 Power factor angle between voltage and current

## V. CONCLUSION

This paper has presents a novel single phase cascaded H-bridge Inverter with reduced number of power electronics devices and isolated DC sources. Simulations are carried out in MATLAB/Simulink. The performance of the suggested novel cascaded H-Bridge multilevel inverter is investigated in detail. The modulation waveform and the harmonic analysis are also presented for various values of modulation strategies. By properly adjusting the modulation index, the required number of levels of the inverter output voltage can be achieved. This proposed inverter system offers the advantage of reduced switching devices and isolated DC sources. A PV based modified MLI with reduced switches, integrated scheme for power grid is proposed in this paper. This topology eliminates the harmonics at the solar system by expanding and increasing the number of output levels with less number of switches, the initial cost is also reduced. Increasing the number of output voltage levels reduces the lower order harmonics and the THD. It's preferred that the output voltage has no lower order harmonics because their filtering is so hard. From the results grid voltage and grid connected current are in phase with each other.

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