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Smart Grid Integrated Five Phase Five Level Multilevel Inverter for Photovoltaic Conversion

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Abstract: - Grid-based solar power systems offer an excellent a way to meet the increasing needs, especially smart grids. In this context, this article presents a system that uses multi-level inverters to extract photovoltaic energy, convert it, and feed it into the smart grid. Cascade H-bridge inverters combined with smart grids improve performance in areas, such as efficiency, better tracking of maximum power, lower harmonic distortion, and less stress on power conversion.

Keywords: Photo voltaic (PV), DC –DC converters, polyphaser inverters, power grid

1. INTRODUCTION

Industrial and scientific developments over the next few years will make photovoltaic devices more efficient, starting a cycle of increased production and lower costs that continues today. Photovoltaic costs are falling as industry increases production and gradually develops new technologies. Grid-connected photovoltaic systems in particular must provide maximum power, ensuring that energy is delivered to the grid. To ensure that maximum power is extracted maximum power point (MPP) is tracked by employing MPPT algorithm. By employing this algorithm, losses and total harmonic distortion (THD) [1]. Furthermore, because the PV panels are exposed to varying levels of irradiance and temperature, the photovoltaic systems have issues such as the potential to regain their prior performance under both normal and abnormal circumstances.

Initially this article focusses on boost converter which guarantees the input DC voltage to the inverter, which is the second step and converts it into appropriate AC voltage. To satisfy the necessary grid voltage, step up transformer is utilized. The various topologies of inverters have been introduced that can be used in Grid connected photovoltaic systems (GCPS) [2]. The photovoltaic systems are mostly used as they are pollution free, clean and abundant. Duty cycle is varied and MPPT optimizes the output at varied temperatures and irradiance levels. This article focuses on P&O MPPT algorithm to maximize the output.

In the research, many multilevel inverter topologies have been suggested. The majority of them are cascaded H-bridge, diode clamps, and flying capacitors. For specific reasons, cascaded H-bridge are most commonly utilized among them in grid-tied solar systems [6]. Cascade H-bridge inverters are preferred because of low total harmonic distortion (THD), their ability to operate at voltages (high and low), and noise-free input current absorption. Electric cars, continuous power transmission, and DC power applications are the main uses for cascaded H-bridge inverters. This paper focusses on Smart Grid integrated 5 phase 5 level cascade H Bridge MLI for photovoltaic conversion.

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2. TOPOLOGY OF THE CIRCUIT

2.1 Photo voltaic cell:

Solar energy is converted to electrical energy by exiting electrons present in silicon cells using the photons of light in photovoltaic cells. When solar radiation hits silicon atoms, photons of light energy are absorbed, then electrons are released. This flow of electrons causes the current to flow. It is fed to the inverter to be converted to AC and fed to the grid. The power output of a tiny solar cell can range from 1 to 2 W, depending on the material, including cadmium telluride, silicon, and gallium arsenide. The greatest power capacity of the module available on the market is 1KW; although larger capacities may be manufactured, handling more than 1KW modules will become difficult. Fig 1 explains the working principle of a photovoltaic cell

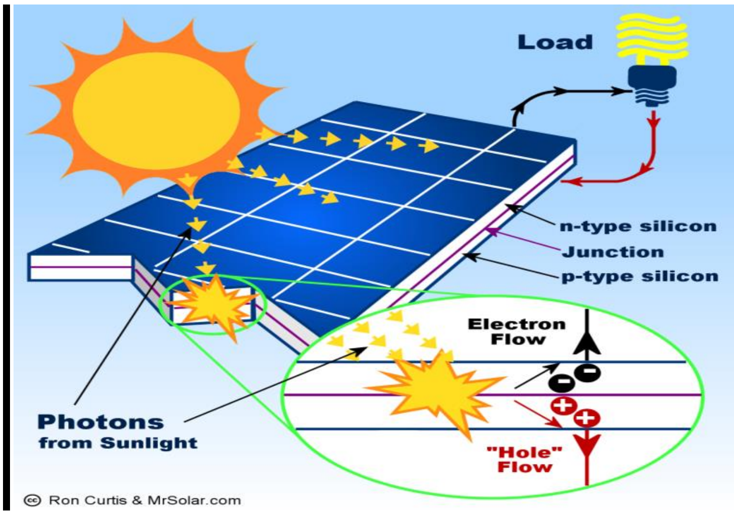

Fig.1. Working principle of PV cell

2.2 Hierarchy of PV cell

A unit composed of photovoltaic cells is called a photovoltaic module, and a series of photovoltaic modules is called a photovoltaic array. Fig 2 shows the hierarchy of PV cell

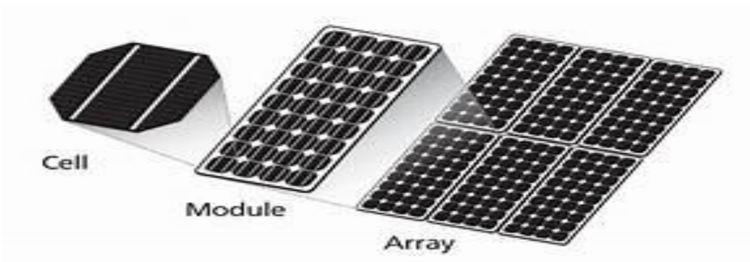

Fig.2. PV cell, PV module, PV array

The output power produced by a photovoltaic cell varies with different levels of irradiance and temperature. The performance of a photovoltaic cell is subjected to the percentage of conversion.

$$\eta = \frac{P_{max}}{EA_{cell}}$$

Where, η=efficiency of the PV cell

P_{max}=maximum power of PV cell

E=irradiation level.

The PV cell is simulated in MATLAB as shown below in Fig 3 and the characteristics is shown in Fig 4.

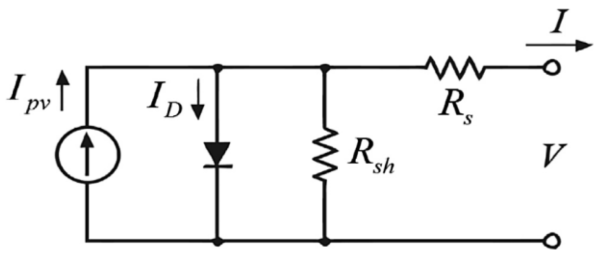

Fig 3: Electrical model of PV cell

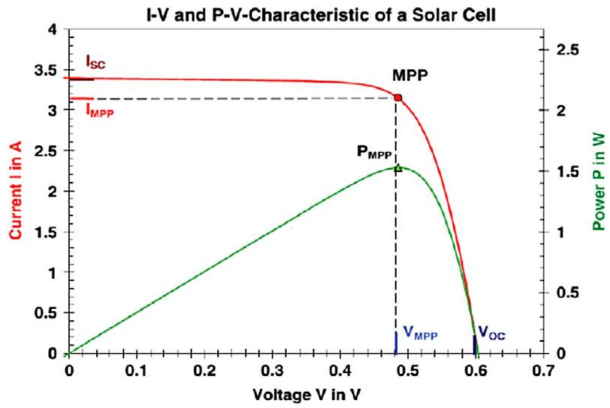

Fig 4: Characteristics of PV cell

2.3 Converter:

Converter is employed to boost the output obtained from PV.The PV panel output power varies with respect to duty cycle. The schematic of boost converter is presents in Fig.5.

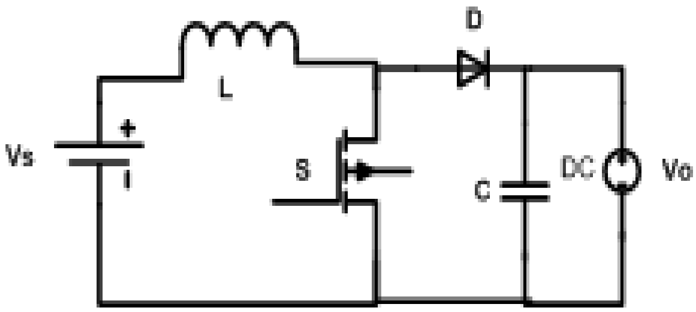

Fig.5. DC-DC Boost Converter

The input current is continuous which is very desirable for sources like photovoltaic or battery.

$$V_0 = \frac{V_s}{1 - D}$$

$$I_s = \frac{I_0}{1 - D}$$

D=duty cycle (0<D<1)

2.4 MPPT Controller:

To maximize the conversion efficiency of PV, MPPT is used. A typical PV panel converts 30-40% of the incident solar radiation which can be enhance to 93-97% by employing MPPTs. There are different tracking techniques like Perturb and observe(P&O), incremental conductance and constant voltage.

All the algorithms continuously track the panel voltages and currents; accordingly, the duty cycle is adjusted. These algorithms are implemented by microcontrollers. The working of P&O Algorithm is explained in Fig 6.

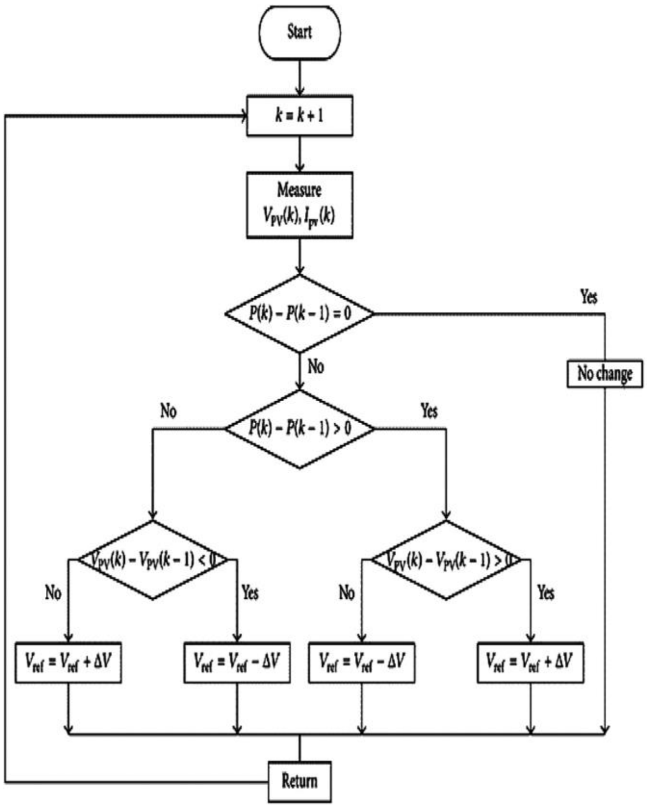

Fig.6. Flowchart of P&O Algorithm

2.5 Cascade H-Bridge Multilevel Inverter:

A voltage source inverter has two output levels, +Vdc/2 and -Vdc/2, and is suitable for low and high voltage applications. This type of two-phase inverters has some disadvantages, especially during high frequency operation. This disadvantage can be overcome by using multiphase inverters [7]. MLIs are the best alternative for grid connected PV systems. Multilevel inverters were introduced in 1975 as the best solution for medium and high conditions in industrial applications. This article employed cascade H-Bridge and employs lesser components in each level. It requires two separate DC sources. The combination of capacitor and transformer pair is H-bridge and each H-bridge needs a different DC voltage. A DC voltage source powers the H-bridges that are linked in series. The outputs are linked such that the total output is equal to the individual output [8]. Fig 7 displays the schematic design for the cascade H-bridge MLI circuit.

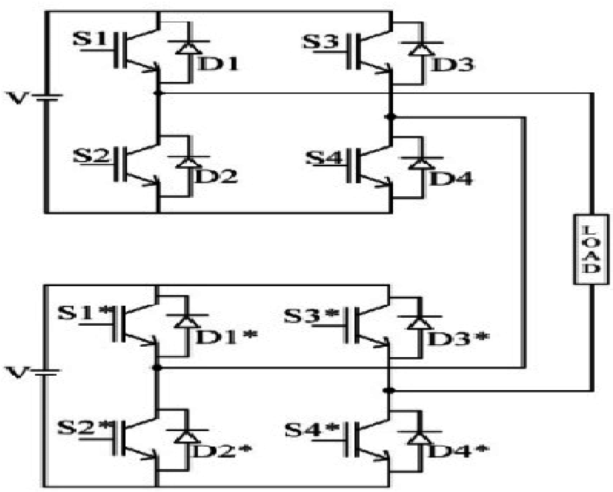

Fig.7. Cascade H-Bridge multilevel Inverter

The operation of the step-down H-bridge inverter depends primarily on the transformer. A special switch is activated by sending a pulse to the switch using pulse width modulation (PWM). To filter out the harmonics it is connected to the filter. The order in which the switches are rotated is shown in Table 1.

S_1	S_2	S_3	S_4	S_1*	S_2*	S_3*	S_4*	V_0
1	0	1	0	1	0	1	0	0
1	0	1	0	1	0	0	1	+V/2
1	0	0	1	1	0	0	1	V
0	1	0	1	0	1	1	0	-V/2
0	1	0	1	0	1	0	1	0
0	1	1	0	0	1	1	0	-V

Table1. Conducting sequence of Cascade H-Bridge inverter

3. IMPLEMENTATION OF THE PROPOSED CIRCUIT

The PV system is simulated in MATLAB with P&O MPPT to track the PV system and with a good efficiency of boost converter. The simulation results shows that capable of track the maximum power [3]. MLIs have lately gained popularity and advanced consideration in solar systems because of growing need for applications requiring medium and high power. [4],[5]. Fig 8 shows the Simulink model of cell whereas Fig 9 shows the characteristics of cell.

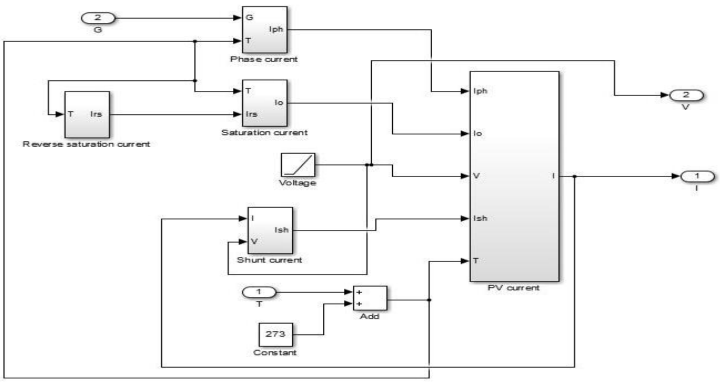

Fig 8: Simulink model of PV cell

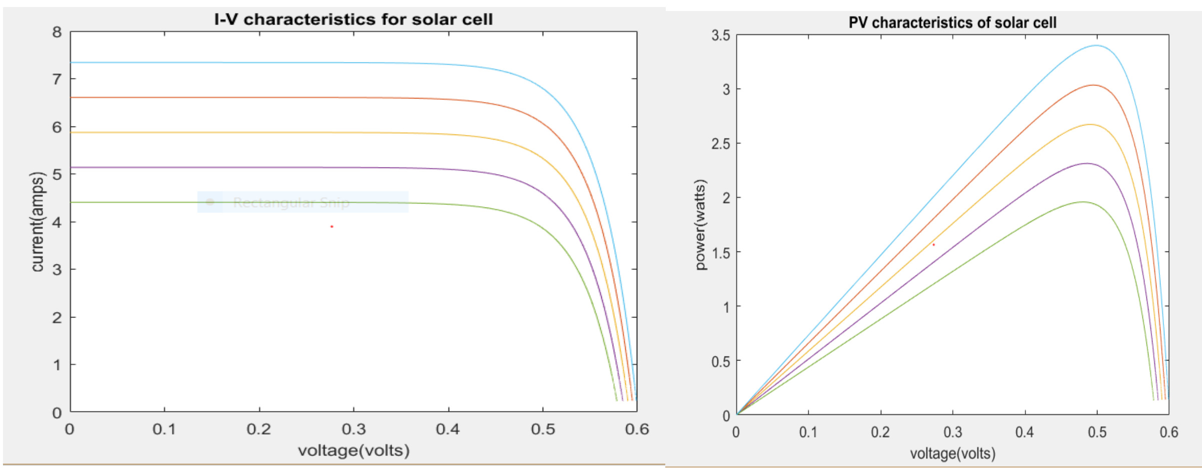

Fig 9: IV and PV characteristics of PV cell

The proposed five phase five level cascade H bridge MLI is implemented in MATLAB and is shown in Fig 10. Fig 11 shows 5 level output obtained from Cascade H bridge MLI.

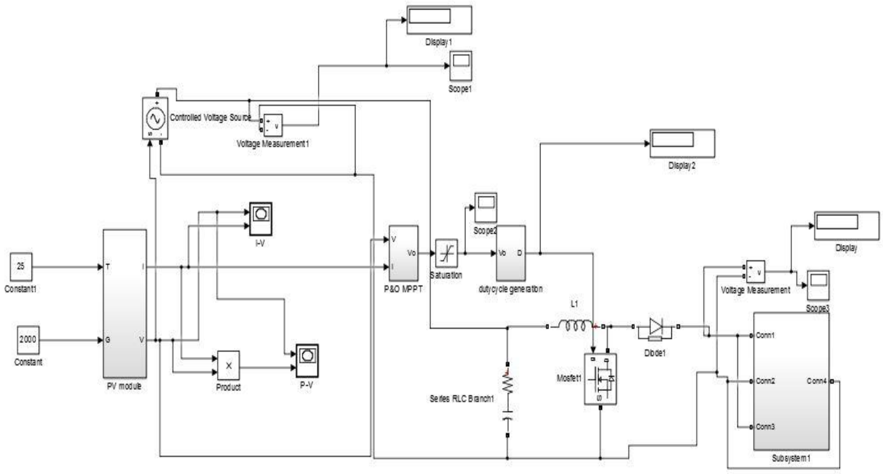

Fig.10. Proposed circuit implemented in Simulink

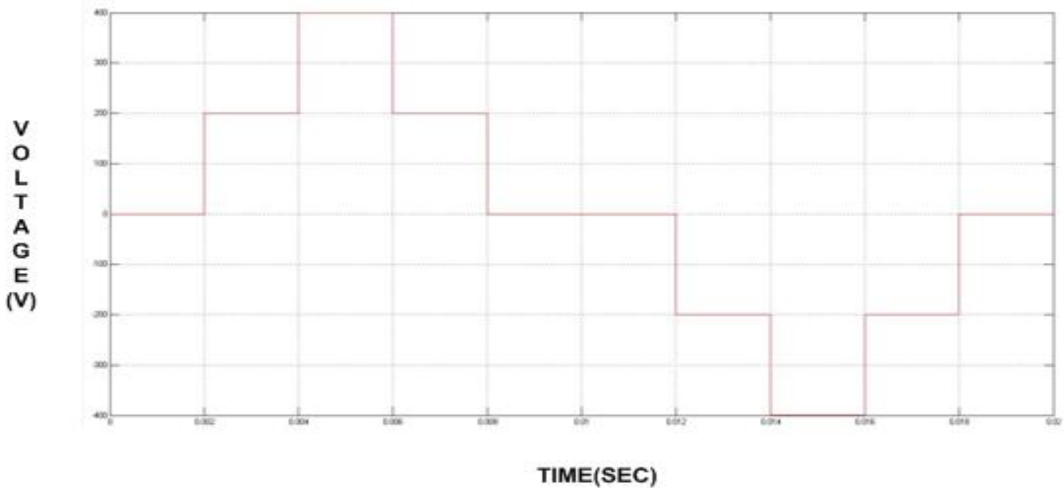

Fig.11. Output of MLI

The proposed five phase five level cascade H bridge multilevel inverter is implemented in hardware fed from PV training system. The output of PV training system is shown in Fig 12.

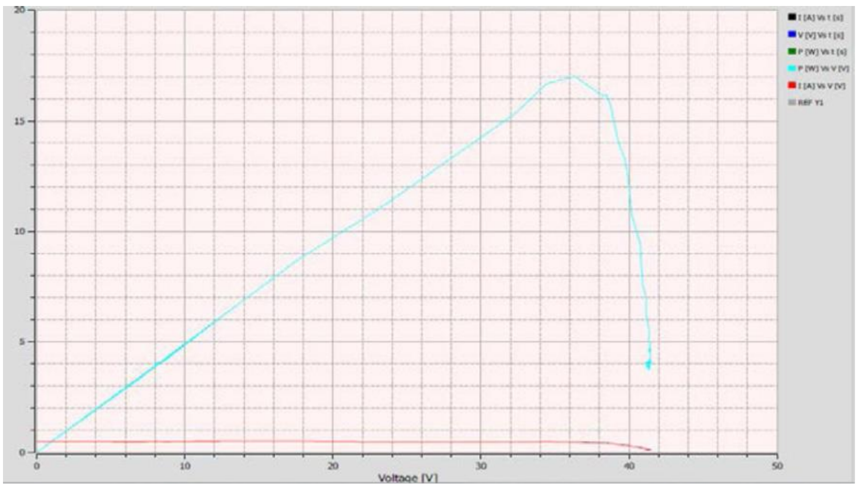

Fig.12.Output of PV training system

Fig 13 shows the hardware implementation of 5 phase 5 level cascade H-Bridge MLI fed by photovoltaic emulator. Fig 14 shows the 5 level output. Fig 15 and Fig 16 shows the pulses for first H bridge inverter and second H bridge inverter. Fig 17 shows the THD of the output voltage.

Fig.13. Hardware implementation of the proposed circuit

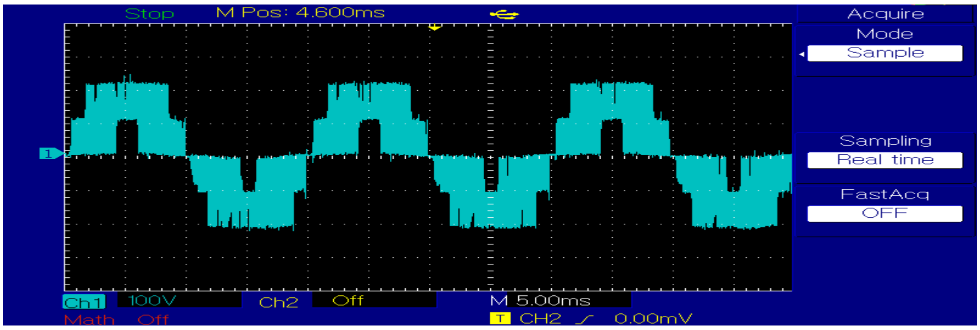

Fig.14. Output of MLI

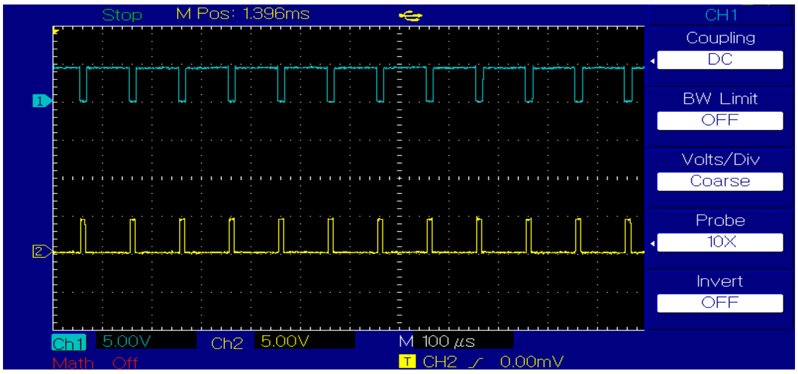

Fig.15. Pulses for first H-Bridge inverter

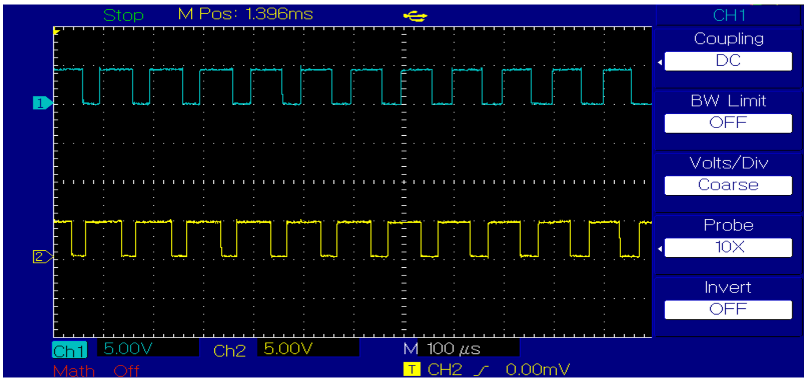

Fig.16.Pulses for second H-Bridge inverter

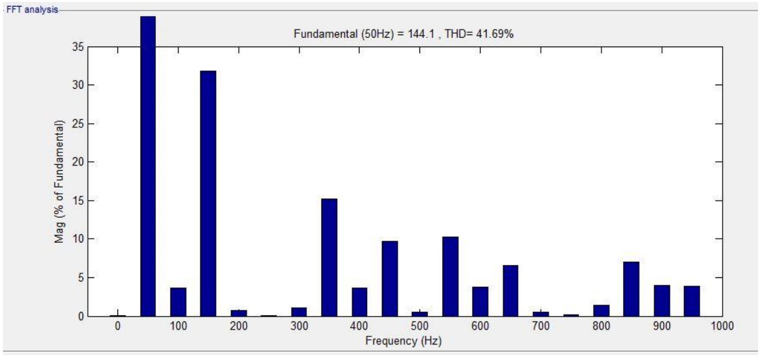

Fig.17. Total Harmonic Distortion(THD)

4. CONCLUSION

A cascaded H-Bridge MLI integrated with grid-connected photovoltaic systems was reported in this study. Results of the hardware and MATLAB/SIMULINK simulations are shown. Efficiency, improved MPP tracking, less THD, and fewer component requirements are demonstrated here. THD can be further reduced by increasing the levels.

5. REFERENCES

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