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Multilevel inverter with cuk converter for grid connected solar PV system

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ABSTRACT

A Multilevel Inverter with cuk converter for Grid Connected Photovoltaic System is composed. In this project medium power (0.15 MW) and large power (>5 MW) scale Photovoltaic (PV) system have attracted great attention, where medium Voltage grid connection is essential for efficient power transmission and distribution. PV voltage can be boosted by the use of cuk converter and then it can be changed into medium frequency supply by the use of controlled DC-AC Converter. Power frequency transformers are operated at 60 or 50 Hz, which is generally used to step up the inverters low output voltage to the Medium-Voltage level. As an alternative way to achieve a small size and less weight direct grid connection, this paper proposes a single phase grid connected PV inverter system.

Index Terms: voltage source inverter, cuk converter, Multi Level Inverter, Power quality, Photovoltaic system (PV), Modular Multilevel Cascade inverter (MMC),.

1. INTRODUCTION

Nowadays solar PV power system plays important role in the power generation area. In the Medium (0.15MW) and large scale (greater than 5MW) PV power plants have attracted great attention, and power plants of more than 10 MW in capacity have thereby become as they actually exist [1], [2]. The number of PV power plants will continue to rise in the near future [3], [4]. But in the grid connected PV system isolation between the grid and PV system and quality of the power plays an important role. For power transmission, the step-up transformers are generally used in the PV inverter system to feed the solar energy into the grid. In this method we are using high frequency special transformers for insulating the grid and PV system. This method is compact compared with the conventional distribution transformers because they are still very large size and heavy weight for remote area PV applications [5], [6].

This type of transformer may increase the size of the system, volume, weight and it can be very expensive and more complex for installation and maintenance. The medium and low voltage inverter may be a possible solution to connect the solar PV power plant to the grid directly and to ensure electrical. isolation between the inverter and grid, which is important for the connection of solar PV power plants with medium-voltage grids. Therefore, low and medium voltage inverters with step-up-transformer for direct grid connection of PV systems have attracted a high degree of attention.

Normally improving the power quality with the help of multilevel inverters and different types multilevel inverters are compared for medium-voltage grid connection of PV power plants [7], [8]. The Modular Multilevel Cascaded (MMC) inverter topology having some special features compared with other multilevel inverter. Hence MMC was considered for low and medium-voltage grid connection application . The number of components in the MMC inverters scale linearly with the number of levels of the output, and the modules are individually identical and completely modular in constriction, thereby enabling higher number of levels are attainable. Single phase low or medium voltage inverter is proposed for direct grid connected of PV

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system. The common dc link is replaced with a medium frequency common magnetic link to generate the isolated and balanced dc supply for MMC inverter from a single or multiple PV arrays. In the MMC inverter does not require any additional auxiliary diodes or capacitors but it must be requires balanced DC source from the multiple isolated DC sources. In 2011, a high-frequency link was proposed to generate multiple-imbalanced sources for asymmetrical multilevel inverters [9].

In the proposed system, only the auxiliary H-bridges are connected through high frequency common magnetic link. In MMC the main H-bridges are directly connected to the source, which means that there is no electrical isolation between the source and MMC. Therefore, the use of this type of inverter is only for isolated winding motor applications. Power frequency transformers are compared with the medium-frequency link has much smaller in size, lighter magnetic cores and windings, so that cost is lower. In the medium-frequency link is based on amorphous alloy shows an excellent electro-magnetic characteristics, hence the specific core losses are very less and possibility to generate multiple-balanced sources [10]. The combination of a quasi-Z source inverter with MMC converter, a medium voltage PV inverter was proposed. This PV inverter does not have any isolation between PV array and medium-voltage grid. Multiple-isolate DC/DC converter-based PV inverter topologies were proposed [11], [12]. In the proposed configuration, the input voltage balancing is a challenging issue, since each H-bridge cell is connected to a individual PV array through a dc/dc converter. A common dc link may be a one of the possible solutions. In this paper, a single phase medium-voltage multilevel inverter for grid connected photovoltaic system is proposed and its basic block diagram is shown in figure.1.

The proposed PV inverter has the following merits.

1) line-filter-less medium voltage grid connection,
2) minimization of the grid and PV isolation problem through the magnetic link,
3) an inherent dc-link voltage balance due to the common magnetic link, and
4) an overall compact and lightweight system.

2. PROPOSED PHOTOVOLTAIC SYSTEM

In this system, as an alternative approach to minimize the voltage imbalance problem with a wide range of Maximum Power Point Tracking (MPPT) operation, common magnetic link is considered. The step-up converter is considered for the MPPT operation. The array of DC power is converted to a medium frequency AC power through a medium-frequency inverter. The inverter also ensures constant output voltage. In the primary winding of the medium frequency multi winding transformer is connected to the output of the

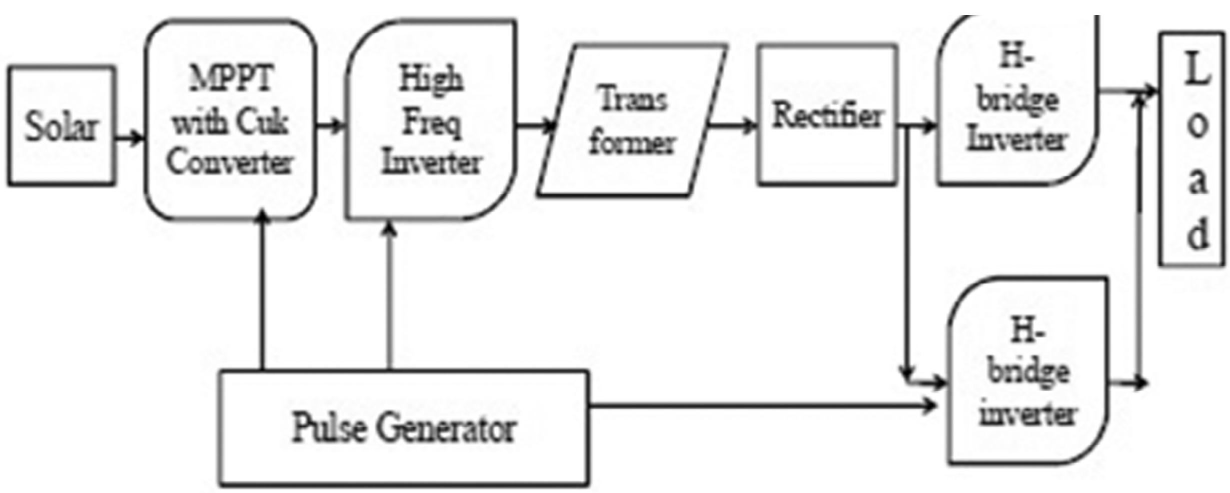

Figure 1: Block diagram of the proposed system

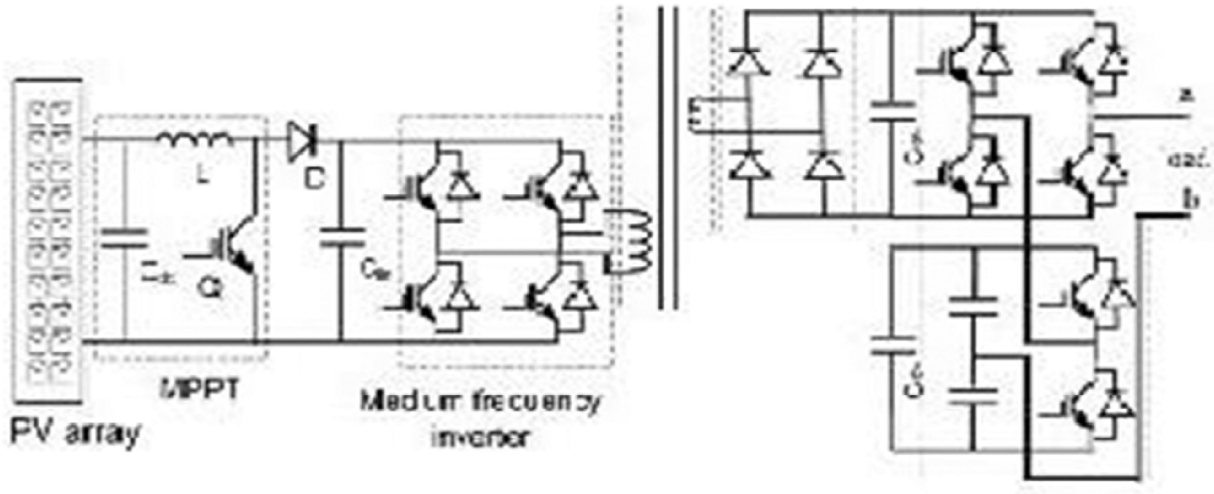

Figure 2: Power conversion circuit with single phase 5-level MMC inverter

inverter. The secondary side of the transformer each winding works as an isolated source and is connected to an MMC H bridge cell through a rectifier. The number of primary winding is depends on the number of PV arrays and the number of secondary winding is depends on the number of levels of the multilevel inverter. The power circuit of a single-phase five-level PV inverter system is shown in Fig. 2, which is used to validate the proposed inverter in the laboratory. In large PV system, more number of PV arrays are operated in parallel. Each PV array output is connected to the primary of the multi input and multi output magnetic link through a booster and medium-frequency inverter.

3. MULTILEVEL INVERTER

PV systems are expected to play an important role in recent power generation system. Such systems transform light energy into electrical energy. The input current of the cuk converter is continuous, and they can draw a ripple free current from a PV array that is important for efficient MPPT. For rectification in this method we are using an H-bridge electronic circuit that enables a applied voltage across the load in either positive or negative direction. These circuits are mostly used in robotics and other applications to allow DC motors to run forwards and backwards direction. Nowadays most of the dc to ac power inverters, ac to ac converter, dc-to-dc push pull converter, and many other kinds of power electronics motor controllers are used H-bridges. The term H-Bridge is derived from the shape of the circuit and they contains four power electronic switches. Normally the H bridge is used to convert dc supply in to the ac supply so its called as H bridge inverter. In figure 3 shows schematic diagram of H bridge inverter. In this inverter the power switches named S1, S2, S3 and S4. Normally the switches S1 and S4 ON and S2 and S3 OFF a positive voltage will be flowing through the load and the switches S1 and S4 OFF and S2 and S3 ON, in this time the output voltage is flowing in the load is opposite direction. Using the above circuit, the switches S1 and S2 should never be ON the same time, because this would cause a short circuit on the input source. The same applies to the switches S3 and S4. This condition is called as shoot-through.

In this proposed system we are using three H bridges, one of the H bridge is used for convert the Dc supply into medium frequency AC supply. Another two H bridges are used for MMC converter. In this method the number of H bridge is depends on the level of the multilevel output. In this method the main aim is to connect the solar PV output in the medium voltage AC grid. So that the medium voltage inverter is the possible best solution to directly connect the solar PV system in to the medium Voltage AC grid. Therefore the use of this medium voltage inverter need isolation between the grid and PV source because this type of inverter is mostly used only for isolated motor winding applications. Normally the step up transformer is used for the isolation between the low voltage side and high voltage side, but this type of transformers are very bulky in size and heavy weight. Therefore they can increase the overall weight and volume of the system, and they can be very expensive and more complex for maintenance and installation. In this system a medium frequency transformer operated at a few Kilo Hz to Mega Hz was used for generate multiple isolated and balanced DC sources for MMC inverters. In the proposed system the balanced voltage is a challenging issues because each H bridge is connected to a PV arrays through the converter and limits the range of Maximum Power Point Tracking (MPPT) operation. In the multilevel inverter output the width of the each level is can be depends on the switching time of the H bridge cells. The switching speed is can be controlled with the help of Pulse Width Modulation (PWM) technique or Pulse Duration modulation (PDM) technique. This techniques are suitable for all the controlled converters and inverters by the use of advance controllers. In this system the controller decides the duty cycle of the inverter switches and also varies the ON time and OFF time of the power switches.

4. CUK CONVERTER

In the Proposed system the PV arrays are generate the very Low DC output voltage. For grid connected application the voltage level should be medium or high voltage range. In conventional method mostly the step up transformer are used to step up the voltage in low range to medium or high range, but this type of transformers are very bulky and it creates the losses. Therefor in this system we are replaced the step up transformer with the use of power electronics Boost dc-dc converter. Few years before, Dr. Cuk designed the integrated magnetic concept is called DC transformer, where the total DC fluxes produced by currents in the input inductor (L1) and the dc flux produced by the current in the inductor (L2) is equal to the

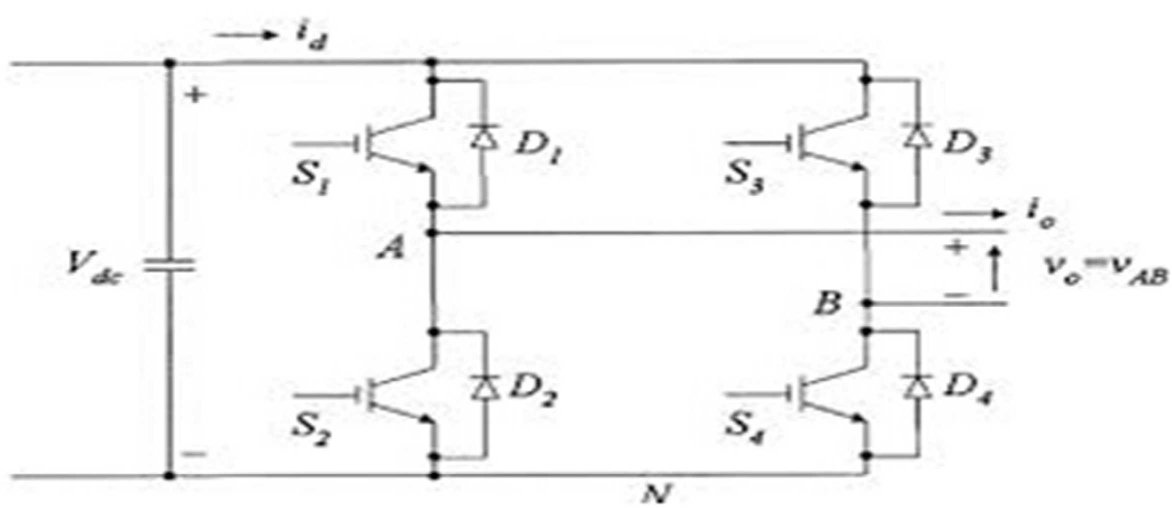

Figure. 3: Schematic diagram of H-bridge Inverter

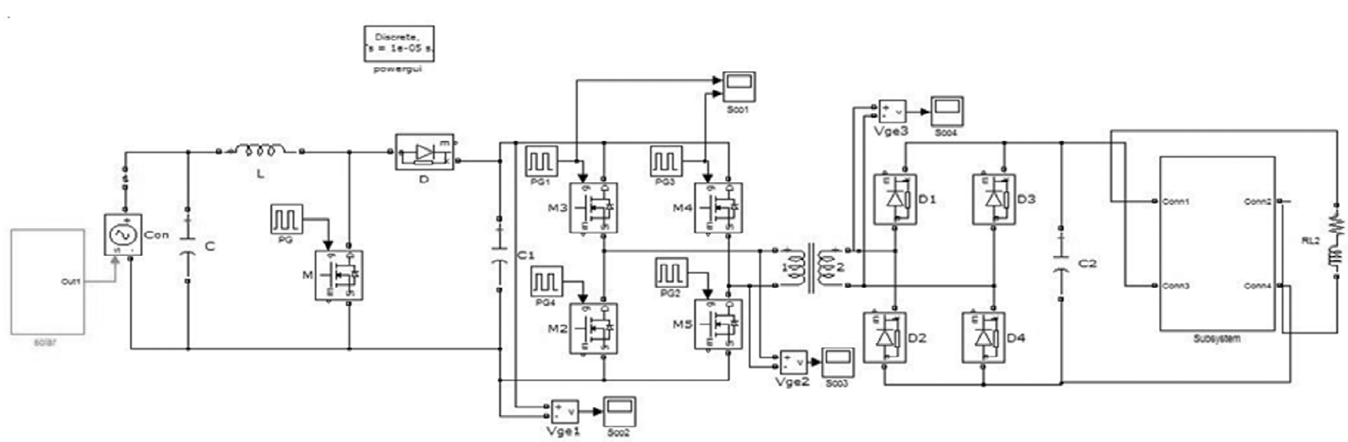

Figure 4: Simulation circuit for 5 level MLI with cuk converter

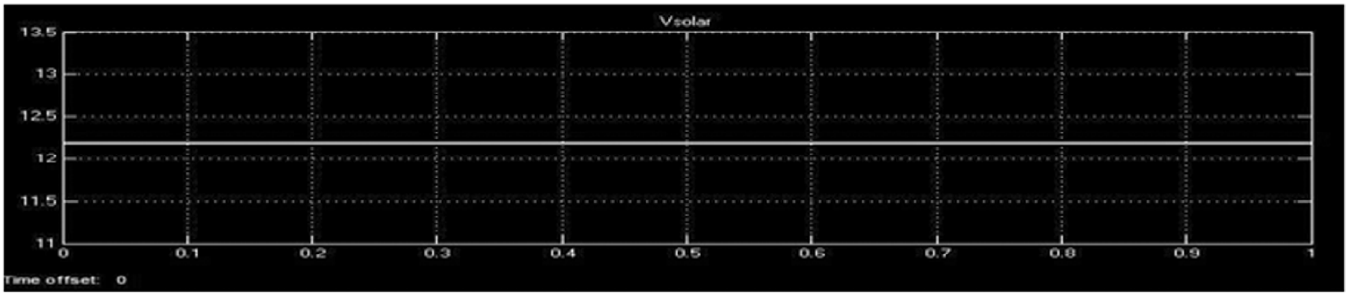

Figure 5: PV output voltage

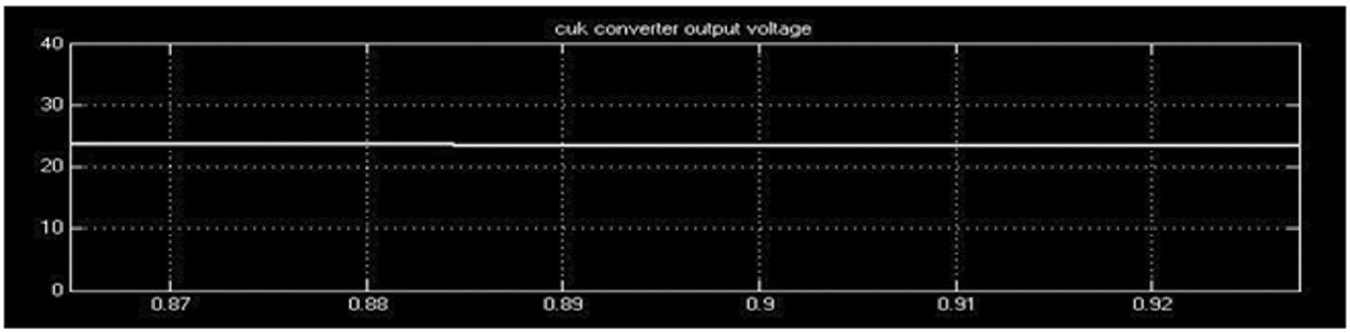

Figure 6: Output Voltage from Cuk Converter

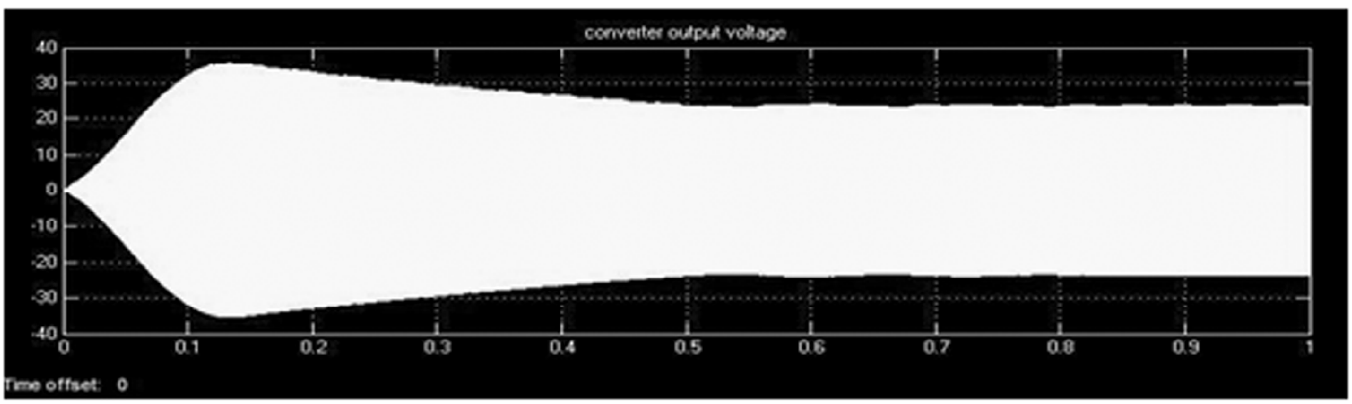

Figure 7: Output Voltage Waveform from DC-AC Converter

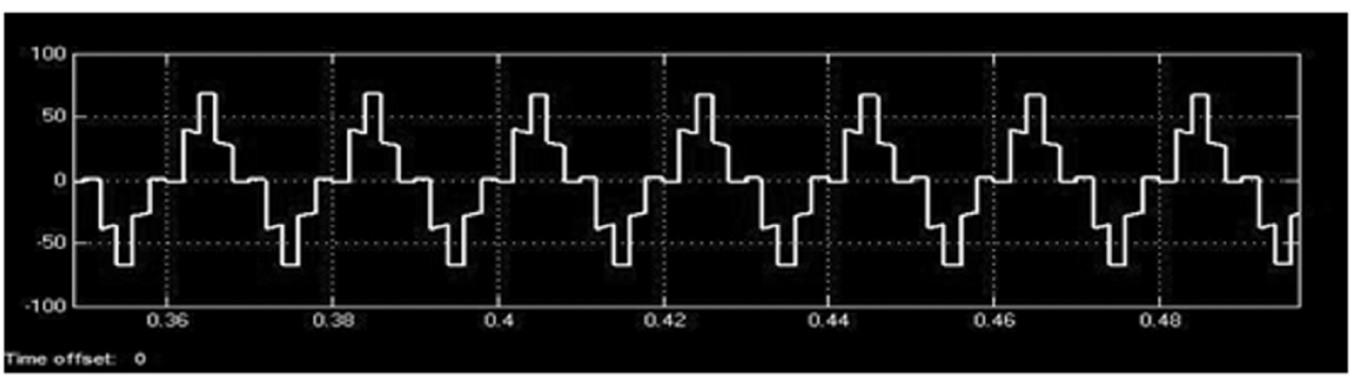

Figure 8: Output Voltage from 5 Level H-bridge Inverter

transformer. Hence this dc fluxes are opposing each other and thus result in a mutual cancellation of the dc fluxes. Boost converter has morel advantages over the buck converter. One of them boost converter provides the capacitive isolation which protects the switch against the failure. The main advantage of the boost operation the input current is continuous, and they can draw a ripple free current from a PV array that is important for efficient MPPT. So that in our proposed system the cuk converter is can be used for step up the dc supply from the PV arrays. The output of the cuk converter is can be connected to the medium frequency controlled dc to ac converter, therefor the medium frequency supply is connected to the one of the input of multi input multi output medium frequency isolated transformer. In this method more number of PV array with cuk converter is connected to the multi input multi output medium frequency isolation transformer. The more number of PV array inputs are connected in common magnetic link, so they need balanced dc supply.

5. SIMULATION RESULTS AND DISCUSSION

In this proposed system a single phase five-level MMC inverter is simulated by the use of MATLAB. The MMC inverter requires six isolated switches and they need balanced dc sources. The output of medium frequency isolated transformer is connected to a diode-based rectifier with a low-pass filter circuit. The electromagnetic performances of all the outputs of medium frequency multi input multi output isolated transformer are found almost the same, because the inputs balanced multiple sources for the MMC inverters. A five level medium voltage H Bridge inverter with cuk converter is shown in figure 4. In this system 12V PV panel is considered and this voltage can stepped up to 24 Volt by the use of Cuk converter. In figure4 shows the output voltage of the solar PV System and figure 5 shows the output of the cuk converter. This 24 V Dc supply can be converted in to medium frequency AC supply using power controlled converter and then connected to magnetic link for isolating the PV Panel and grid. Output of the DC to AC converter is shown in figure 6. The medium frequency output voltage is given to the controlled ac to dc converter with filter. Now the balanced dc voltage is applied to the five level MMC converter. The each level of the output voltage is having 30V difference and finally we are getting 60V ac in the output The five level output voltage of the H bridge multilevel inverter is shown in figure7. In this result we are getting a minimum value of Total Harmonic Distortion (THD) has 6.8 % by using FFT analysis in MATLAB. In the system minimum THD means reduction in the peak currents, heating, and emission .If the signal passes through a non linear devices, non ideal the contents are added at the harmonics of the original frequency.

6. CONCLUSION

A new medium-voltage PV inverter system is proposed for grid connected Medium power or Large power PV system. In this system a medium frequency common magnetic link is used to interconnect PV arrays to form a single source. Therefore an isolated and balanced DC supplies for the multilevel inverter have been generated through the common magnetic link, they can minimizes the voltage imbalance problem automatically. The electrical isolation and safety problems between the grid and PV array has been solved due to the use of Medium Frequency link. Although in this method we are using additional windings and rectifiers may increase the loss of the inverter, and then the overall performance is still similar to the traditional system. In this system we are eliminating the step up transformer from the existing system the size and weight of the system is reduced and also saving the large amount for the installation, maintenance and running cost. In future we are planned to do the hardware model for this system and validating the results with the traditional system, and also we tried to change the new boost converter for increasing the voltage level of the grid.

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