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MULTI-LEVEL INVERTER WITH DC LINK SWITCHES FOR RENEWABLE ENERGY SOURCES

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ABSTRACT

In this paper a H Bridge Multi Level Inverter is connected to grid connected photo voltaic system. The major intention for a grid-connected Photo Voltaic (PV) inverter is to supply the harvested power from solar panel to the grid. The H Bridge inverter has high efficiency and high power quality. This paper proposes a H Bridge Multi Level Inverter topology for the solar plants that can account for voltage profile fluctuations among the panels during the day and the performance is studied by comparing total harmonic distortion and switching losses at different switching frequencies. The operating principle and performance of the proposed multi-level inverter is verified through simulation and experimental results.

Keywords: photovoltaic system, multi-level inverter, grid, total harmonic distortion.

INTRODUCTION

Grid connected inverter systems are gaining importance due to the increase in demand on renewable energy sources. It has low initial cost, maintenance cost and it is more efficient, because there is no need for batteries and charge controllers. Generally two-level PWM inverter is used for grid-tied operation [1-3]. In case of a two-level inverter, the switching frequency should be high or the inductance of the output filter need to be big enough to satisfy the required THD. To cope with the problems associated with the two-level inverter, Multi-Level Inverters (MLIs) are introduced for grid connected inverter. The major advantage of cascaded Multi Level Inverter is the switching frequency and device voltage rating can be much lower than those of a traditional two level inverter for the same output voltage level [4]. Since there is a significant reduction in MOSFET switching loss, the inverter system efficiency can also be increased.

GRID TIED INVERTER FED BY PHOTOVOLTAIC SYSTEM

A photovoltaic system converts sunlight into electricity. The basic device of a photovoltaic system is the photo voltaic cell. Several cells are grouped in series and/or parallel to form panels or modules. In practical, photovoltaic device presents hybrid behaviour, which may be of current or voltage source depending on the operating point. The device has a series resistance R_s whose influence is stronger when the device operates in the voltage source region, and a parallel resistance R_{sh} is with stronger influence in the current source region of operation. These resistances are the sum of several structural resistances of the device.

In solar generation system, many PV cells should be connected in parallel and series to obtain the require load current and Voltage. Since Solar panels have a nonlinear voltage-current characteristic, with a distinct maximum power point, which depends on the environmental factors i.e., temperature and irradiation and in order to continuously harvest maximum power from the solar panels. They have to operate at their MPP despite the inevitable changes in the environment; a power electronic controller is employed with some method for Maximum Power Point Tracking (MPPT) algorithm. Basically MPPT controller is DC to DC converter which converts the variable DC Voltage into a fixed DC to exactly match load requirements.

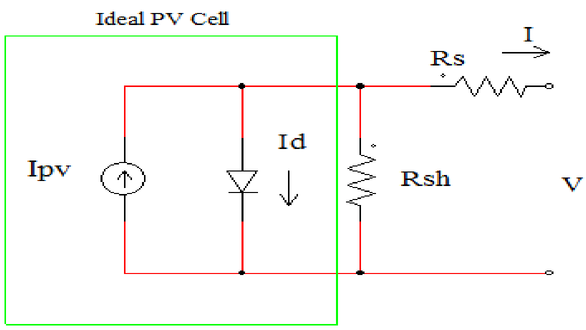

Figure-1. Simple PV model.

The voltage generated at the terminals of a photovoltaic panel can feed directly DC loads through MPPT converter. But for AC loads and grid tie renewable energy resources along with the MPPT. Inverters are employed to convert direct current produced by solar panels, into the alternating current at required voltage level and frequency requirements of the load, typically in stand-alone applications where utility power is not available. In case of grid connected solar or commonly, renewable

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energy resources dedicated grid tie inverter is used to control the power flow and as well as grid integration. A solar grid tie inverter is a special type of synchronous inverter that feeds to an existing electrical grid.

PROPOSED MULTI LEVEL INVERTER

The Multi-Level technique synthesizes the AC output terminal voltage with low harmonic distortion, thus reducing filter requirements. In particular, Multi-Level Inverters are emerging as a visible alternative for high power, medium voltage applications. The major advantages of H bridge multilevel inverter are the less harmonic distortion in the output current and voltage waveforms, less switching frequency provides less switching loss and increased inverter power output as in [5].

The output current and voltage waveform of a H bridge Multi-Level Inverter is consists of the number of steps of voltages, usually produced from the capacitor voltage sources and now a days it can also be produced from solar panel starting from three levels. The output becomes pure sinusoidal, When the number of steps or levels at the output increases. The Multilevel voltage at the output is limited because of packaging constraints, unbalanced voltage problems, requirement of voltage clamping and circuit layout. Three major classifications of Multilevel Inverters are the Flying- Capacitor Multilevel Inverter, H Bridge Cascaded Multilevel Inverter and Diode Clamped Multilevel Inverter.

In all these configurations of Multi Level Inverter, the important issue about is the voltage balance of the DC link capacitor. The voltage of capacitor C_1, C_2 should be equally balanced to V/2 which is very much suitable for solar system. However the midpoint voltage fluctuates when C_1, C_2 charge and discharge continuously. If the capacitor voltage is unbalanced, the output voltage becomes unsymmetrical and it results in a high harmonic content in the load current. Flying-Capacitor type, single phase topology Multilevel Inverter is considered for initial studies.

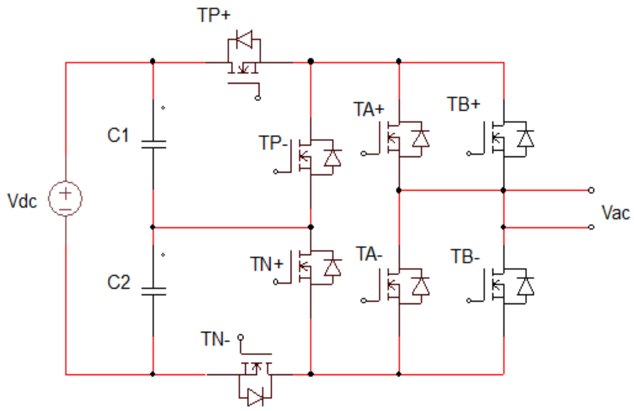

Figure-2. Circuit diagram of multi-level inverter.

The schematic diagram of the proposed multi-level inverter shown in Figure-2 is composed of two DC link capacitors (C1,C2) and four switching devices (TA+, TA-, TB+, TB-) comprising a H-bridge, and four DC link switches (TP+, TP-, TN+, TN) located between DC link and H-bridge. The parameters of the proposed multi-level inverter is shown in Table-1

Table-1. Parameters of the multi-level inverter circuit.

Parameters	Values	Quantity
Capacitor	1000µF	2
MOSFET	IRFP460	8
Input voltage	6V	1

Modes of operation

Mode 1: a signal subtracted from the reference signal by Vc is compared with the carrier signal. If Vref – Vc> Vcarrier, then all switches TP+ and TN- are turned on. If V ref –Vc < Vcarrier, then the switch TP+ or TN- is turned off alternately.

Mode 2: the reference signal is directly compared with a carrier signal. If Vref > Vcarrier, then the switch TP+ or TN- is turned on alternately. If Vref < Vcarrier, then all switches TP+ and TN- are turned off.

Mode 3: -Vref is directly compared with a carrier signal. If - Vref > Vcarrier, then the switch TP+ or TN- is turned on alternately. If - Vref < Vcarrier, then all switches TP+ and TN- are turned off.

Mode 4: a signal subtracted from - Vref by VC is compared with the carrier signal. If - Vref -Vc> Vcarrier, then all switches TP+ and TN- are turned on. If - Vref -Vc<Vcarrier, then the switches TP+ and TN- are turned off alternately.

Switching states

Table-2 shows the Switching States of five level Multi-Level Inverter.

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Table-2. Switching states.

Output voltage	Switching conditions					
	TP+	**TP-**	**TN+**	**TN-**	**TA+,TB-**	**TA-,TB+**
VDC	ON	OFF	OFF	ON	ON	OFF
VDC/2	OFF	ON	OFF	ON	ON	OFF
	ON	OFF	ON	OFF	ON	OFF
0	OFF	ON	ON	OFF	ON	OFF
	OFF	ON	ON	OFF	OFF	ON
-VDC/2	OFF	ON	OFF	ON	OFF	ON
	ON	OFF	ON	OFF	OFF	ON
-VDC	ON	OFF	OFF	ON	OFF	ON

RESULTS AND DISCUSSIONS

The simulation has been carried out using MatLab/ simulink environment. From simulation studies, here an optimized switching frequency has been obtained for a lower level of total harmonic distortion and switching losses. The MATLAB simulink model of the multi-level inverter is shown in Figure-3.

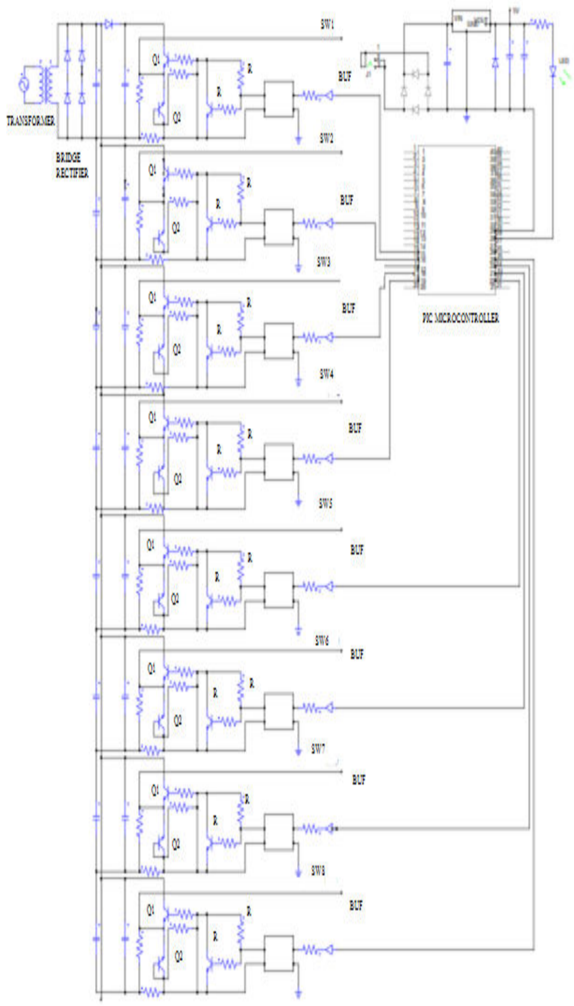

Figure-3. Hardware circuit of multi-level inverter.

The inverter is fed by the voltage from the PV module. The simple circuit of a PV model is shown in Figure-1 which is modeled using the mathematical equations discussed in [4].

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EXPERIMENTAL RESULT

A prototype of five level multi-level inverter was fabricated to validate simulation results. The hardware layout of the system and the test setup of the system are shown in Figure-4.

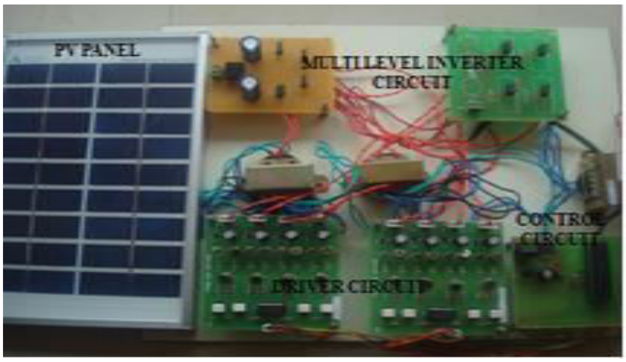

Figure-4. Hardware module of multi-level.

The inverter was constructed using IRFP460MOSFET switches. The inverter is also interfaced with the PV system. The output voltage generated from the solar panel which is measured in DSO is shown in Figure-5 whose output voltage is *6V DC.* The input voltage given to the inverter is shown in figure.

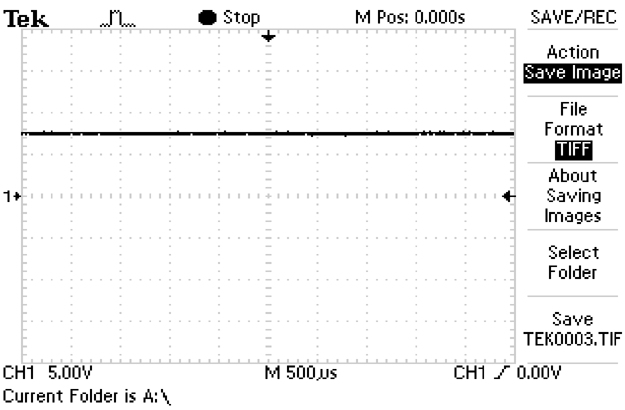

Figure-5. Output voltage waveform of solar panel.

Figure-6 shows the simulation output of switching pulse waveform for the five levels Inverter. The switching pattern for the multi-level inverter is implemented using microcontroller PIC16F877A. Figure-7 shows the switching pulses generated for each MOSFET switch where they are given to the gate terminal of the MOSFET switch in the Multi-Level Inverter circuit where the output forms the five level output.

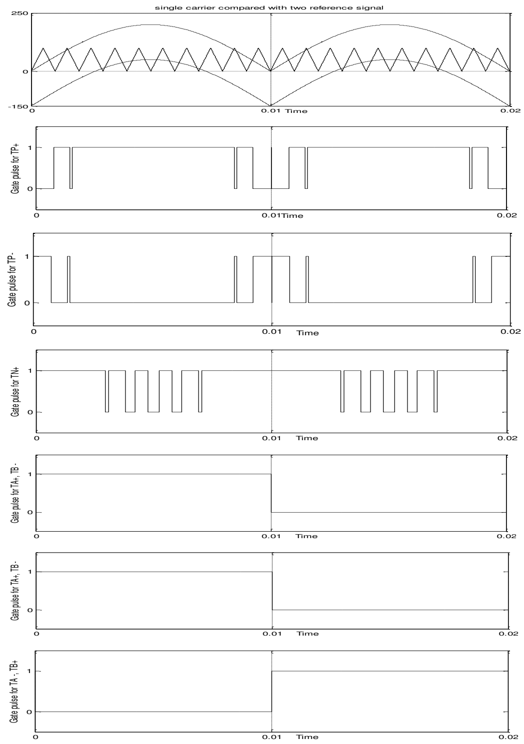

Figure-6. Switching pulse waveform (from simulation).

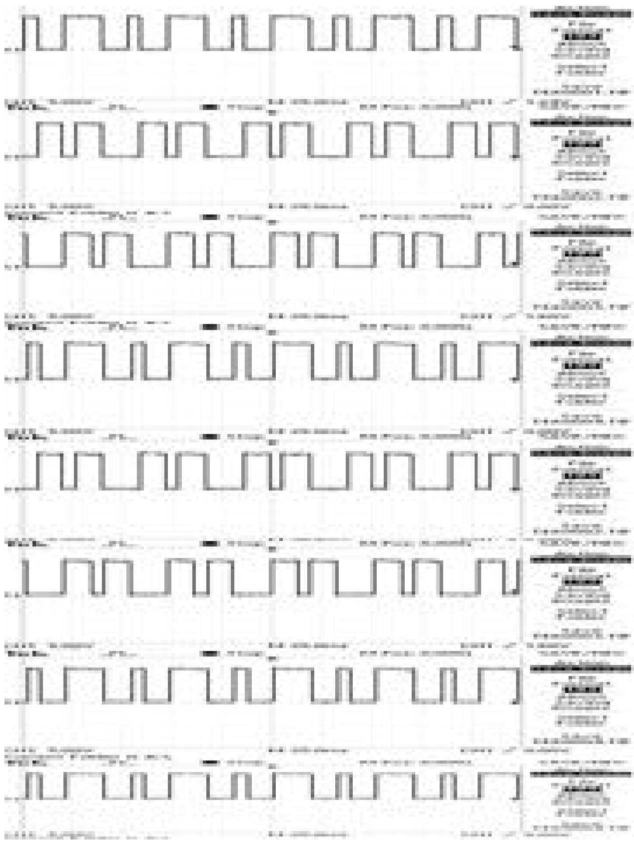

Figure-7. Switching pulse waveform (from hardware).

The obtained five level inverter output voltage from simulation is shown in Figure-8.

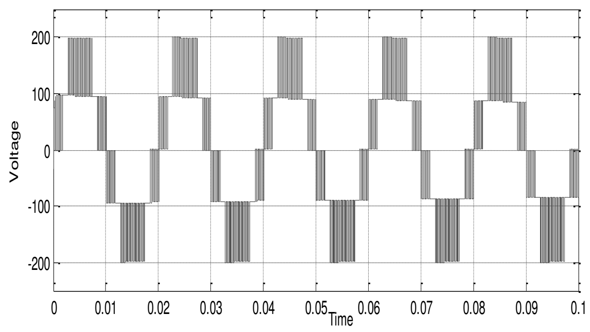

Figure-8. Five level output voltage (from simulation).

The obtained five level inverter output voltage from hardware is shown in Figure-9.

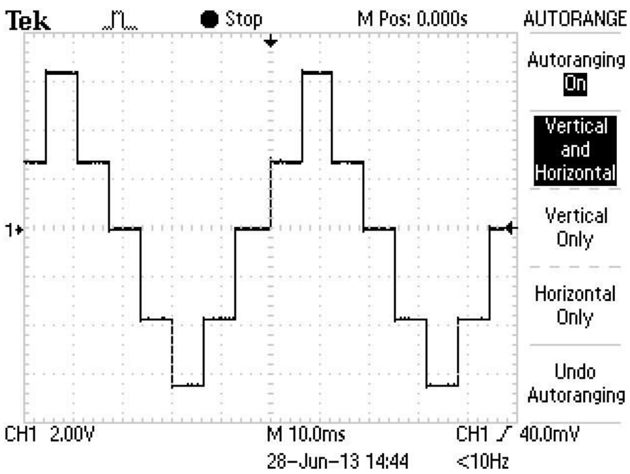

Figure-9. Five level output voltage (from hardware).

CONCLUSIONS

Thus the hardware implementation of Multi Level Inverter drive system is explained using PIC microcontroller. The modules such as control circuit, driver circuit and Multi Level Inverter circuit are designed and modeled. The output waveforms of Multi Level Inverter with solar panel are discussed. The proposed Multi Level Inverter has been implemented for renewable energy applications. The five level output shows the resemblance of sinusoidal AC output waveform which has been converted from DC input of 6V.

REFERENCES

[1] Brendan Peter McGrath. 2002. Multicarrier PWM strategies for Multilevel Inverters. IEEE Transaction Industrial Electronics. 49(4): 858-867.

[2] Calais M. 2001. Analysis of Multicarrier PWM Methods for a Single-Phase Five level Inverter. PESC. 2001 IEEE. 3: 1351-1356.

[3] Carrara G., Gardella S., Marchesoni M., Salutari R. and Sciutto G. 1992. A New Multilevel PWM Method: A Theoretical Analysis. IEEE Transaction Power Electronics. 7(3): 497-50.

[4] Choi N. S., Cho J. H. and G. H. Cho. 1991. A General Circuit Topology of Multilevel Inverter. IEEE Transactions, Power Electronics. 6: 96-103.

[5] Grandi G., Rossi C., Ostojic D. and Casadei D. 2009. A New Multilevel Conversion Structure for Grid-Connected PV Applications. IEEE Transaction Industrial Electronics. 56(11): 4416-4426.

[6] Jose Leon I., Sergio Vazquez, Samir Kouro, Leopoldo Franquelo G., Juan Carrasco M. and Jose Rodriguez. 2009. Unidimensional Modulation Technique for Cascaded Multilevel Converters. IEEE Transaction on Industrial Electronics. 56(8).

[7] Keith Corzine and Yakov Familiant. 2002. A New Cascaded Multilevel HBridge Drive. IEEE Trans on Power Electronics. 17(1).

[8] Lopez O., Teodorescu R and Doval-Gandoy J. 2006. Multilevel Transformerless Topologies for Single-Phase Grid-Connected Converters. IEEE. IECON 2006. pp. 5191-5196.

[9] Nabae, Takahashi I. and Akagi H. 1981. A New Neutral-Point-Clamped PWM Inverter. IEEE Transaction Industrial Application. 1A-17(5): 518-523.

[10] Rodriguez J., Jih-Sheng Lai and Peng F.Z. 2002. Multilevel Inverters: A Survey of Topologies, Controls, and Applications. IEEE Transaction on Industrial Electronics. 49(4): 724-738.

[11] Dr. Seyezhai. R 2012. A Comparative Study of Asymmetric and Symmetric Cascaded Multilevel Inverter employing Variable Frequency Carrier based PWM. International Journal of Emerging Technology and Advanced Engineering. 2(3): 230-237.

[12] Tae-Jin Kim, Dae-Wook Kang, Yo-Han Lee and Dong-Seok Hyun. 2001. The Analysis of Conduction and Switching Losses in Multi-level Inverter System. PESC. 2001 IEEE. 3: 1363-1368.

[13] Villanueva E., Correa P. and Pacas M. 2009. Control of a Single-Phase Cascaded H-Bridge Multilevel Inverter for Grid-Connected Photovoltaic Systems.

IEEE Transaction Industrial Electronics. 56: 4399-4406.

[14] Yu Liu, Alex Huang Q., Wenchao Song, Subhashish Bhattacharya and Guojun Tan. 2009. Small-Signal Model-Based Control Strategy for Balancing Individual DC Capacitor Voltage in Cascade Multilevel Inverter-Based STATCOM. IEEE Transaction on Industrial Electronics. 56(6).

[15] Zambra D. A. B., Rech C. and Pinheiro J R. 2010. Comparison of Neutral- Point Clamped, Symmetrical, and Hybrid Asymmetrical Multilevel Inverters. IEEE Transaction Industrial Electronics. 57(7): 2297-2306.