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Closed Loop Control of Grid Connected PV Generation System Fed with Cascaded H-Bridge Multilevel Inverter

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Abstract

The harvesting of renewable solar energy is on demand due to the rising need of electricity in the current global scenario. PV generation system which is connected with Cascaded H-Bridge Multilevel Inverters. Many companies are striving to improve the performance of this system since electrical has become a very precious thing hence this paper proposes an idea as a solution to that by improving the system performance by reducing its THD and harmonics.
Keyword- Photovoltaic (PV) Generation System, Cascaded H- Bridge Multilevel Inverter, PI Controller

I. INTRODUCTION

Energy demand is increasing day by day due to increase in population, urbanization, and industrialization, renewable energy resources are alternatives to our traditional energy sources which are limited and will expire. Clean energy resources such as solar, wind and hydro became more and more popular mainly because they produce no emissions and inexhaustible.

The photovoltaic (PV) energy effect can be considered an essential sustainable resource, because of solar radiant energy abundance and the sustainability thus grid connected photovoltaic system is widely used, although solar energy is available abundantly and free of cost, the cost of the photovoltaic cells is very high. Hence the initial investment on solar energy will be very high. The basic element of a PV system is the solar cell which converts the solar irradiance into direct current. Grid interconnection of PV system requires an efficient converter to converter the low DC voltage into AC.

It is clear from the above literature works that many researchers are addressing their efforts in proposing new inverter topologies or in modifying the existing ones, aiming at improving the quality of the energy available at the inverter terminals. Among the available multilevel inverter topologies, cascaded H-bridge multilevel inverter is proven to be the best for its high power-handling capacity and reliability due to its modular topology and constitutes a promising alternative that can be extended to allow a transformer-less connection to the grid.

The cascaded H-bridge multilevel inverter requires separate DC source, and it is a drawback when a single DC source is available, but it becomes a very attractive feature in the case of PV system, because solar cells can be assembled in a number of separate generators. The CHB-MLI supports different PWM techniques like SPWM, selective harmonic elimination pulse width modulation (SHEPWM), and optimized harmonic stepped waveform (OHSW).

The harmonic components of the output voltage are determined by the carrier frequency and switching functions. Therefore, their harmonic reduction is limited to a certain degree.

To overcome this limitation, this paper presents a seven-level inverter whose output voltage can be represented in seven levels. As the number of output levels increases, the harmonic content can be reduced. This inverter topology uses two reference signals, instead of one reference signal, to generate PWM signals for the switches.

In this paper, a single-phase cascaded H-bridge seven-level inverter for grid connected PV system using proportional–integral (PI) controller is proposed. The results confirm the effectiveness of the proposed PI controller. The experimental results are presented to confirm the simulation results.

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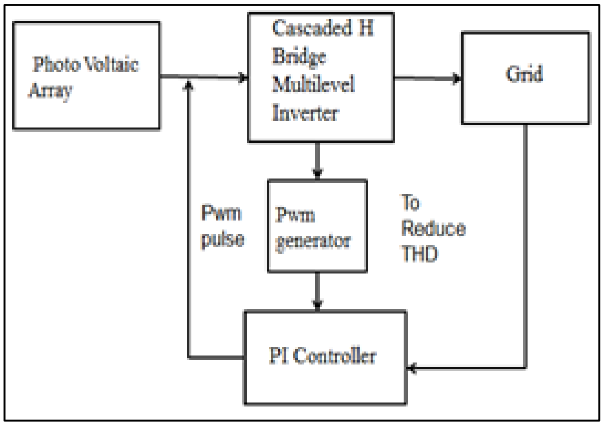

Fig. 1: Closed Loop Grid Connected of PV generation system Fed with Cascaded H-Bridge Multilevel Inverter

II. PHOTOVOLTAIC MODULE

The solar panel is the power source of all photovoltaic installation. It is the result of a set of photovoltaic cells in series and parallel. PV cell directly converters the solar irradiance into electricity in the form of dc when sunlight interacts with semiconductor materials in the PV cells. Figure (2) shows the equivalent circuit of a PV, from which non linear I-V characteristic can be deduced. Hence, the cells are connected in series and in parallel combinations in order to form an array with desired voltage and power levels, solar cells are combined to form 'modules' to obtain the voltage and current (and therefore power) desired.

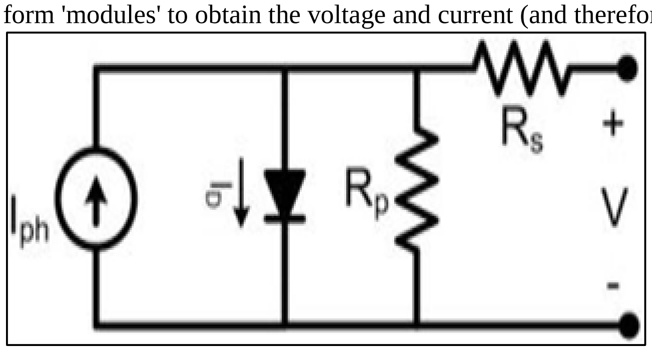

Fig. 2: Equivalent circuit of photovoltaic cell

III. DC-DC BOOST CONVERTER

The positioning of the boost converter will improve the whole photovoltaic installation, allowing different controls from the system. Depending on the applied regulation, the panels will contribute to the maximum energy given to the system or the optimal energy for their operation. The boost converter is a medium of power energy absorption and injection from solar panel to grid-tied CHMLI. The process of energy absorption and injection is performed by a combination of four components which are an inductor. Electronic switch, diode and output capacitor. The connection of a boost converter is shown in figure (3).

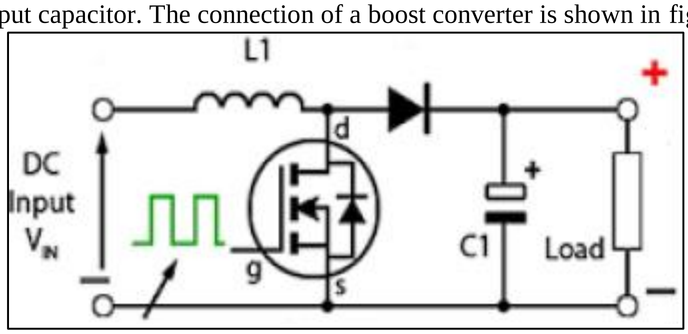

Fig. 3: Basic Boost Converter Circuit

When switch is closed for time t1, the inductor current rises and energy is stored in inductor L. If the switch is open for time t2, the energy stored in the inductor is translated through diode D and inductor current falls, the switching duty cycle □ is defined as the ratio of the on duration to the switching time period so the output voltage is greater than the input voltage and is expressed as in equation

$$Vout/Vin = 1/(1-\alpha)$$

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IV. CASCADED H-BRIDGE MULTILEVEL INVERTER

Cascaded H-bridge Multilevel Inverter was introduced for motor drive application at initial stage. But in high voltage application due to the limited power rating of electronics switches, the conventional converters became very lossy and inefficient. So Cascaded H-bridge Multilevel Inverter become significant for renewable energy system integration to electrical power grid for medium and high power application. The Cascaded H-Bridge Multilevel Inverter provides lower cost, less electromagnetic interference, higher performance i.e. lower THD (Total Harmonic Distortion), and higher efficiency for grid voltage or current conditioning application in both shunt and series compensation. Each H-bridge of symmetrical cascaded H-bridge Multilevel Inverter requires a separate DC source of equal value so integration of different renewable energy sources is less complex in comparison with other multilevel inverter topology. The generated voltage through three phase symmetrical structure of cascaded H-bridge Multilevel Inverter. The quality of the output waveform depends upon the synthesized levelled output. So performance of Cascaded H-bridge Multilevel Inverter can be improved by increasing number of H-bridge. The relation of number of H-bridge (n) and levelled output per phase (m) is m=2n+1. Due to limitation of switches and losses in the system, the number of level can be increased according to the system requirement and application.

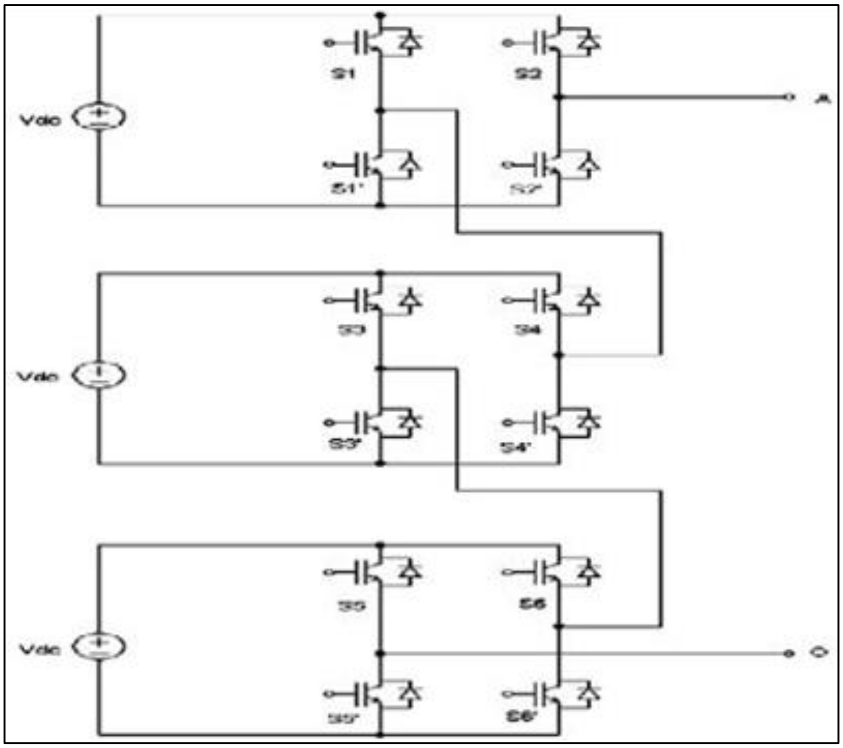

Fig. 4: Cascaded H-bridge inverter topology of grid-connected photovoltaic system

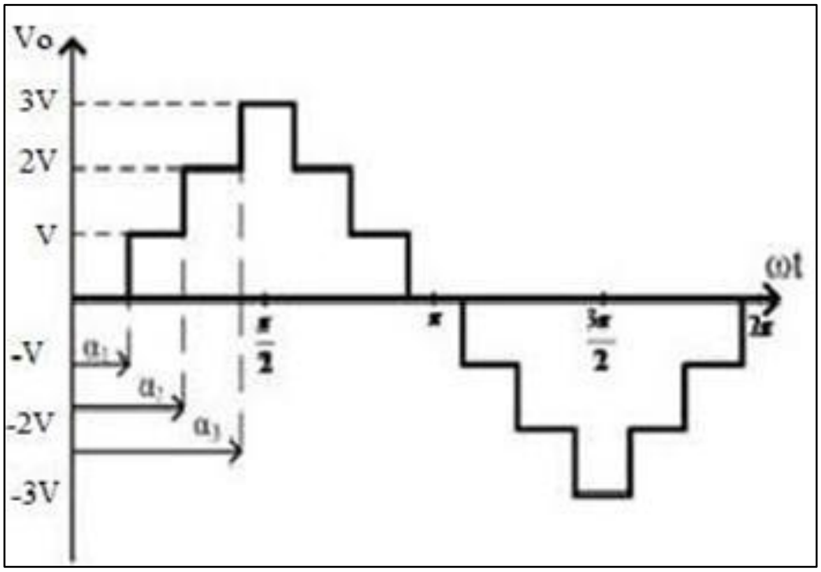

Fig. 5: Waveform

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V. PULSE WIDTH MODULATION (PWM)

PWM technique is extensively used for eliminating harmful low-order harmonics in inverters. In PWM control, the inverter switches are turned ON and OFF several times during a half cycle and output voltage is controlled by varying the pulse width. Several modulation strategies have been developed for multilevel inverters.

In PWM, instead of maintaining the width of all pulses the same as in the case of multiple PWM, the width of each is varied in proportion to the amplitude of a sine wave evaluated at the same pulse. The distortion is reduced significantly compared to multiple PWM. The gating pulses are shown in Figure (6)

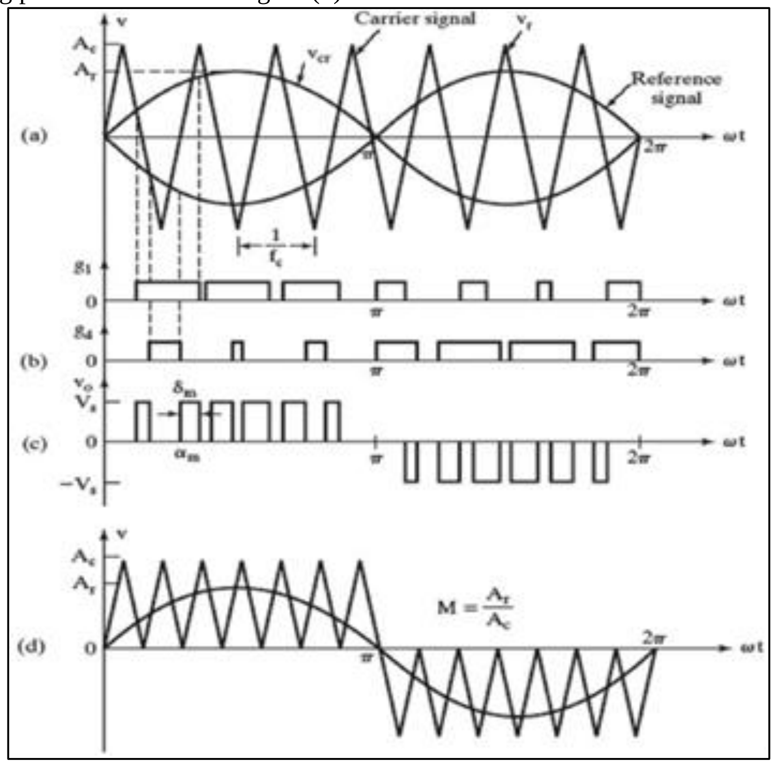

Fig. 6: Pulse width modulation

Parameters	*Values*
No. of H-bridge levels	*7*
No. of switches	*12*
DC source voltage for individual H-bridge	*24V*
Fundamental frequency	*50 Hz*
Load resistor	*30 U*
Load inductor	*10 mH*

Table 1: Parameters of the Cascaded H-Bridge Inverter

VI. POWER BALANCE BETWEEN THE H-BRIDGE INVERTERS

The power balance between the three Cascaded H-Bridge Multilevel Inverters depends on the DC-link voltages and the individual have been replaced by voltage modulation signals. To evaluate the sources with values v1 and v2 that are steady-state power balance in the equal to the root mean square (rms) cells of a cascaded inverter, the cells values of the fundamental harmonic of the voltages. Moreover, to have a stable operation, it is necessary to ensure that, for a total amount of active power supplied to the three-cell Cascaded H-bridge inverter, cell loads are between the maximum and minimum allowed.

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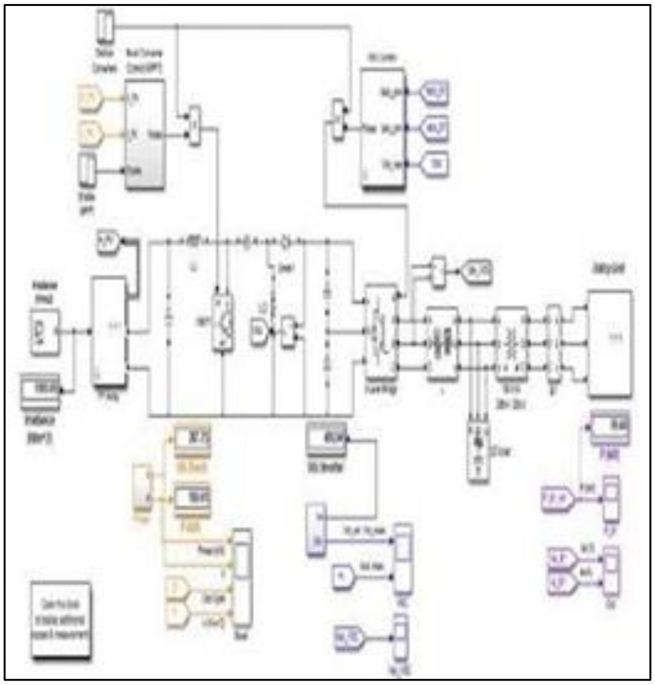

Fig. 7: Simulink model of the grid - connected photovoltaic system

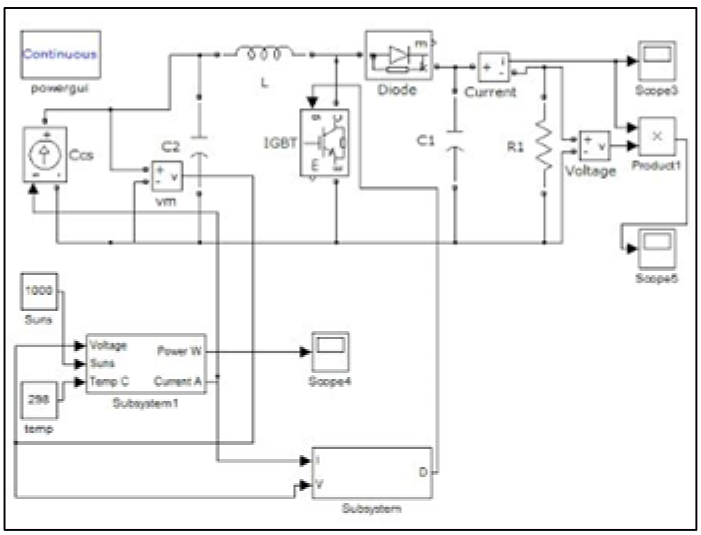

Fig. 8: Simulink model of PV system with MPPT

VII. SIMULATION RESULTS

A simulation is carried out in MATLAB/ Simulink software for a seven-level Cascaded H-bridge Multilevel Inverter with isolated DC sources. The elements and the parameters considered for simulation are presented in Table 1 for the cascaded H-Bridge seven-level inverter topology.

The simulation model of grid-connected PV system is shown in Figure and the PV system with maximum power point tracking (MPPT) is shown in Figure. The Simulink model consists of three Cascaded H-Bridges Multilevel Inverter whose nominal DC voltage is considered to be 24V, a DC boost converter working as MPPT, and a PWM inverter that connects the system to the grid, and the seven- level stepped output voltage is obtained and the harmonics are reduced. Also, it consists of PWM generator block which has parameters such as amplitude, pulse width period, and phase delay which are used to determine the shape of the output.

Therefore, the efficiency of the inverter is increased. The inverter must perform reliably and efficiently to supply a wide range of AC loads with the voltage and required power quality necessary for reliable and efficient load and system performance. The advantages of the system are high-power, high-voltage capacity; low harmonics; and low switching loss. The output voltage and output current have seven levels. It can be achieved using the PWM technique. The output seven-level inverter fundamental frequency is 50 Hz. The loads are connected across the cascaded H-Bridge seven-level inverter. The response of the MLI with

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SPWM is satisfactory, and the load voltage and load current waveforms are shown in Figure. The THD waveforms for voltage and current are shown in Figures, respectively. It is observed from the results that the THD for voltage is 19% and current is 16%. When the temperature of a cell decreases, the voltage of the corresponding cell increases, and when the cell temperature increases, the corresponding cell voltage decreases in order to extract the maximum power from the connected PVA.

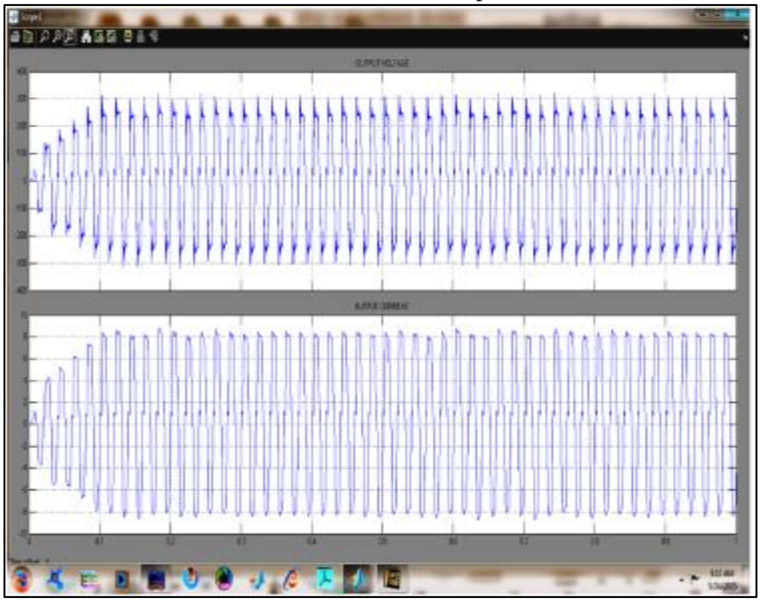

Fig. 9: Load voltage and load current waveforms

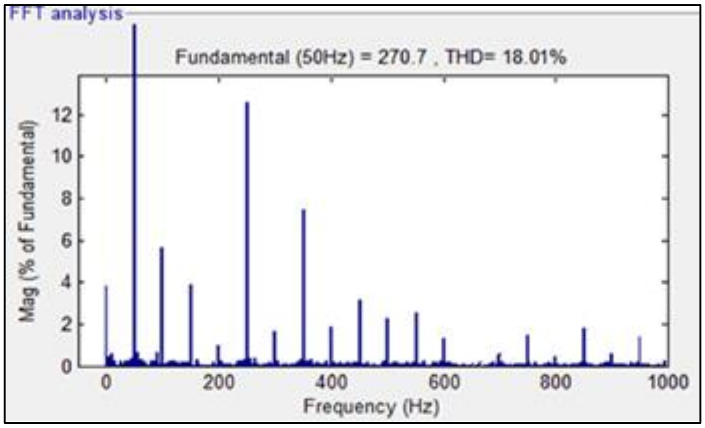

Fig. 10: Voltage THD (Total Harmonics Distortion)

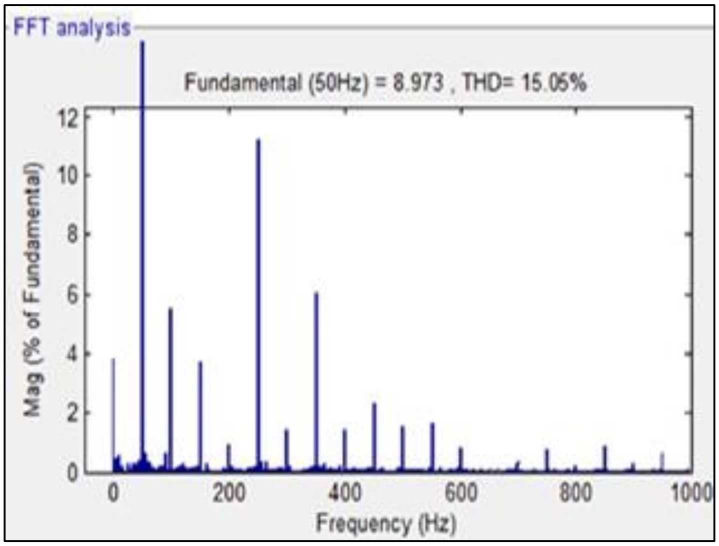

Fig. 11: Current THD

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VIII. CONCLUSION

A complete simulation and prototype model of a Cascaded H-Bridge seven-level Inverter has been proposed in this paper. The cascaded H-bridge seven-level inverter with PI controller employing PWM technique is found to be better when compared with the conventional three-level inverter. The proposed controller adjusts the inverter PF and manipulates the distribution of the reactive power between the cells to maintain the stability of the inverter. The experimental results are presented to confirm the simulation results under PV conditions and proved that with this inverter strategy, harmonics are reduced to a lower value. It can be extended further by increasing the number of levels in multilevel inverter so that the THD approaches to small value as expected to achieve better harmonic performance of the inverter.

REFERENCES

[1] Franquelo LG, Rodriguez J, Leon JI, Kouko S, Portillo R, et al. The age of multilevel converters arrives. IEEE Industrial Electronics Magazine 2008;
[2] Lai J-S, Peng FZ. Multilevel converters—A new breed of power converters. IEEE Transactions on Industry Applications 1996;
[3] Rodriguez JR, Lai J-S, Peng FZ. Multilevel inverters: A survey of topologies, control, and applications. IEEE Transactions on Industrial Electronics 2002;
[4] Tolbert LM, Peng FZ, Habetler TG. Multilevel converters for large electric drives. IEEE Transactions on Industry Applications 1999;
[5] Rodriguez JR, Dixon JW, Espinoza JR, Pontt J, Lezana P. PWM regenerative rectifiers: State of the art. IEEE Transactions on Industrial Electronics 2005;
[6] Cecati C, Dell'Aquila A, Liserre M, Monopoli VG. Design of H-bridge multilevel active rectifier for traction systems. IEEE Transactions on Industry Applications 2003;
[7] Cecati C, Dell'Aquila A, Liserre M, Monopoli VG. A passivity-based multilevel active rectifier with adaptive compensation for traction applications. IEEE Transactions on Industry Applications 2003; 8. Kjaer SB, Pedersen JK, Blaabjerg F. A review of single-phase grid-connected inverters for photovoltaic modules. IEEE Transactions on Industry Applications 2005; 41(5): 1292–306.
[8] Calais M, Agelidis VG. Multilevel converters for single-phase grid connected photovoltaic systems—An overview. In Proceedings of the ISIE, Pretoria, South Africa, 7–10 July 1998, vol. 1, pp.224–9. New York: IEEE.
[9] Calais M, Agelidis VG, Borle LJ, Dymond MS. A transformerless five level cascaded inverter based single phase photovoltaic system. In Proceedings of the IEEE 31st annual power electronics specialists conference, Galway, 23 June 2000, vol. 3, pp.1173
[10] New York: IEEE.
[11] Gonzalez R, Gubia E, Lopez J, Marroyo L. Transformerless single-phase multilevel-based photovoltaic inverter. IEEE Transactions on Industrial Electronics 2008; 55(7): 2694–702.
[12] Ertl H, Kolar JW, Zach FC. A novel multicell DC–AC converter for applications in renewable energy systems. IEEE Transactions on Industrial Electronics 2002; 49(5): 1048–57.
[13] Alonso O, Sanchis P, Gubia E, Marroyo L. Cascaded H-bridge multilevel converter for grid connected photovoltaic generators with independent maximum power point tracking of each solar array. In Proceedings of the 34th IEEE power electronics specialists conference, Acapulco, Mexico, 15–19 June 2003, vol. 2, pp.731–5. New York: IEEE.
[14] Walker G, Sernia P. Cascaded DC-DC converter connection of photovoltaic modules. IEEE Transactions on Power Electronics 2004; 19(4): 1130–9.
[15] Rahiman A, Kumar U, Ranganathan V. A novel fifteen level inverter for photovoltaic power supply system. In Proceedings of the 39th IAS annual meeting conference record of the 2004 IEEE industry applications conference, Seattle, WA, 3–7 October 2004, pp.1165–71. New York: IEEE.
[16] Kang FS, Park SJ, Cho SE, Kim CU, Ise T. Multilevel PWM inverters suitable for the use of stand-alone photovoltaic power grid-connected inverters for photovoltaic modules. IEEE Transactions on Energy Conversion 2005; 20(4): 906–15.
[17] Alepuz S, Busquets-Monge S, Bordonau J, Gago J, Gonzalez D, et al. Interfacing renewable energy sources to the utility grid using a three-level inverter. IEEE Transactions on Industrial Electronics 2006; 53(5): 1504–11.
[18] Ozdemir E, Ozdemir S, Tolbert LM. Fundamentalfrequencymodulated six-level diode-clamped multilevel inverter for three-phase stand-alone photovoltaic system. IEEE Transactions on Industrial Electronics 2009; 56(11): 4407–15.
[19] Leon JI, Vazquez S, Watson AJ, Franquelo LG, Wheeler PW, et al. Feed-forward space vector modulation for single-phase multilevel cascaded converters with any DC voltage ratio. IEEE Transactions on Industrial Electronics 2009; 56(2): 315–25.
[20] Filho FJT, Mateus THA, Maia HZ, Ozpineci B, Pinto JOP, et al. Real-time selective harmonic minimization in cascaded multilevel inverters with varying DC sources. In Proceedings of the IEEE power electronics specialists conference, Rhodes, 15–19 June 2008, pp.4302–6. New York: IEEE.
[21] Fortunato M, Giustiniani A, Petrone G, Spagnuolo G, Vitelli M. Maximum power point tracking in a one-cycle-controlled single-stage photovoltaic inverter. IEEE Transactions on Industrial Electronics 2008; 55(7): 2684–93.

[22] Shanthi B, Natarajan SP. FPGA based fuzzy logic control for single phase multilevel inverter International Journal of Computer Applications 2010; 9(3): 10–8.
[23] Yang S, Lei Q, Peng FZ, Qian Z. A robust control scheme for grid-connected voltage-source inverters. IEEE Transactions on Industrial Electronics 2011; 58(1): 202–12.
[24] Josh FT, Jerome J, Arulwilson J. Fuzzy logic based nine level Inverter for photovoltaic systems. European Journal of Scientific Research 2012; 78(3): 522–33.
[25] Mei J, Xiao B, Shen K, Tolbert LM, Zheng JY. Modular multilevel inverter with new modulation method and its application to photovoltaic gridconnected generator. IEEE Transactions on Power Electronics 2013; 28(11): 5063–73.