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Eleven Level Cascaded H-Bridge Multilevel Inverter Using Fuzzy Logic Controller

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***Abstract* - This paper presents Eleven level multilevel inverter with Photovoltaic system controlled by Fuzzy logic. This multilevel topology generates eleven level output voltage using only nine power switches. This reduces the circuit complexity and also cost. As the inverter voltage levels increases, it reduces harmonic pollution and gives nearly sinusoidal output voltage. Sinusoidal Pulse Width Modulation technique also used to control the output voltage. Mamdani type fuzzy logic controller is used to control the system. Simulation model is developed by using MATLAB / Simulink.**

Keywords: Cascaded multilevel inverter, Photovoltaic source, Fuzzy logic controller, SPWM

I . INTRODUCTION

The multilevel inverter concept was first introduced in 1975. First inverter invented was the three level inverter. Following this the topologies of the several multilevel inverters were developed. Currently, the use of power equipment has been manifold. So the presented harmonics of the power utility system is becoming severe. The injection of dc into the grid is problem for electric utility system that leads to the transformer's saturation at distribution. [1] Multilevel topologies that mean it should be able to supply current demand for stand-alone PV system. [2], [6]. The multilevel inverter has disadvantage over the two level inverter that is it has circuit complexity because of using many power devices. So there is need to minimize the quantity of power switches. [4], [5], [18]. The voltage imbalance problems in the capacitors may lead the harmonics at output voltage. For the voltage imbalance problem it has two solutions, one is to keep voltage balanced circuit at dc part of inverter. And second is use modified switching technology according to control scheme.[9], [10]. Now a day's quality of power is the basic problem in the energy distribution system. While using power electronic equipments leads to harmonic pollution that makes more serious problem. To limit the harmonic pollution in power system different modulation techniques are developed.

Renewable energy sources are increasingly in demand because of shortage of fossil fuels and the problems like global warming, increasing air pollution compels to look towards renewable sources as a future energy solution. Generating energy from Solar and wind is becoming more popular and are in demand in the power electronics. Photovoltaic source (PV) is maintenance and pollution free this is the advantage of this source so that it is used in many applications. For high and medium power applications and there is development in the power semiconductor devices with high frequency that improves the performance of the power converter. Multilevel topologies are classified into two sections first with the common DC source. And second is the separate DC source.

This paper presents cascaded H- bridge topology with PV panel and this system is controlled by fuzzy logic. In this buck-boost converter is used to maintain constant voltage. This multilevel inverter generates eleven level at the output with reduced harmonics. Sinusoidal pulse width modulation technique is also used to get the required gate signal.

II. Cascaded H- Bridge Inverter

This inverter is very well-liked and important topology. It is drawn on single phase inverter's series connection with the divided dc sources. With each leg, this inverter needs its own dc source. All H- bridge cells have same DC sources. For various renewable energy resources like the wind energy, photovoltaic cell, and fuel cell separate DC source is suitable. DC sources can be added or subtracted as per voltage level requirement. It requires few components as compared to other topologies. The Cascade multilevel inverter has two types that are asymmetrical and symmetrical. Symmetrical type requires more switches. And asymmetrical type requires less switches, or it gives exact output voltage waveform. The Cascaded H-bridge does not have voltage- balancing problem and capacitor pre-charging problem. This does not require any diodes or capacitors for clamping. So there is reduction of the energy wastage and maximum use of the power. We get nearly sinusoidal waveform without filter.

In this multilevel inverter quantity of the voltage levels can be derived from, $m=2n+1$. where, m is quantity of maximum level of phase voltage and n is the quantity of dc voltage source

III. Proposed topology

Block Diagram of proposed system

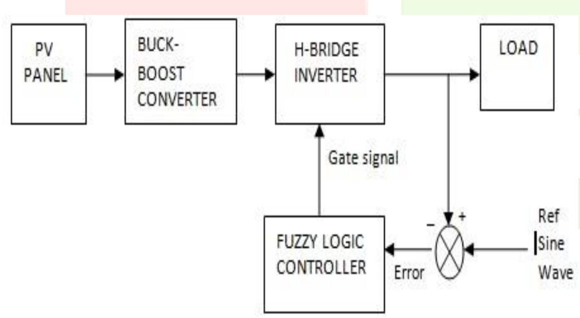

Fig. 1 Block diagram of proposed multilevel inverter

This proposed system consist PV panel, Buck- boost converter, H-bridge inverter, and Fuzzy logic controller. The input to the proposed 11 level multilevel inverter is come from solar panel . In PV panel solar cells are depends on solar irradiation. Solar irradiation keeps on fluctuating due to environmental changes. As the solar energy is not constant, It varies with time. This solar energy absorbed by the solar panel. Buck- boost converter is used to maintain the constant output voltage which is obtained from the solar panel. And this constant output voltage is given to the cascaded H-bridge multilevel inverter.

A) PV panel

Photovoltaic source consist photovoltaic cell which absorbs the sun's energy and convert it into DC electricity. Photovoltaic cells deliver this dc supply to buck boost converter. In PV- panel solar cells are depends on solar irradiation. Solar irradiation keeps on fluctuating due to environmental changes. As the solar energy is not constant, it varies with time. Output of solar panel is given to the buck-boost converter.

B) Buck-boost converter

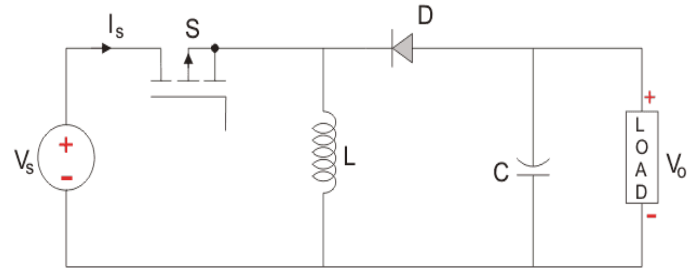

Fig. 2 Structure of buck-boost converter

The Buck –boost converter is one of the type of DC into DC converter which having an output voltage magnitude which is either more than or lower than the input voltage magnitude. Output of buck-boost converter is provided to the H-bridge inverter which is constant dc input voltage. The amount of output voltage is produced then it is controlled by a microcontroller program which regulates pulse widths produced by SPWM signals.

Above fig. 2 shows typical buck-boost converter. This converter has two switches one is solid state device called MOSFET and second is diode (D). The input voltage source (Vs) is joined to solid state switch (S). And the diode D is connected on reverse direction so the current is flow from source to capacitor and the load. By using sinusoidal pulse width modulation technique controlled switch can be turned on and off. The circuit operation depends on the conducting state of switch (MOSFET). Buck boost converter has two states of operation, one is ON state and the other is OFF state.

ON state: The Switch is on and Diode is off

When the switch is turned on, current flows through switch, and the inductor and again turns back to the dc input voltage source. During the period of switch is turned on inductor stores the energy.

OFF state: The Switch is turned off and Diode is on

When the switch is turned off, that time inductor polarity reverses, then current flows through the given load and through the diode and turns back to the inductor. So the direction of the current flowing through the inductor remains same.

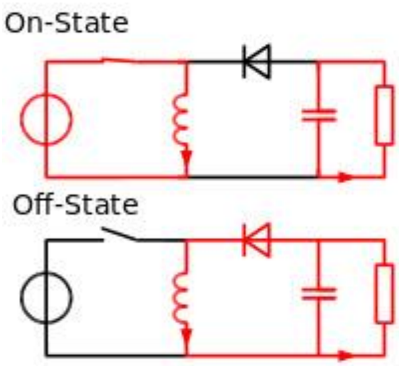

Fig. 3 shows the ON state and OFF state of buck-boost converter

C) H- Bridge inverter

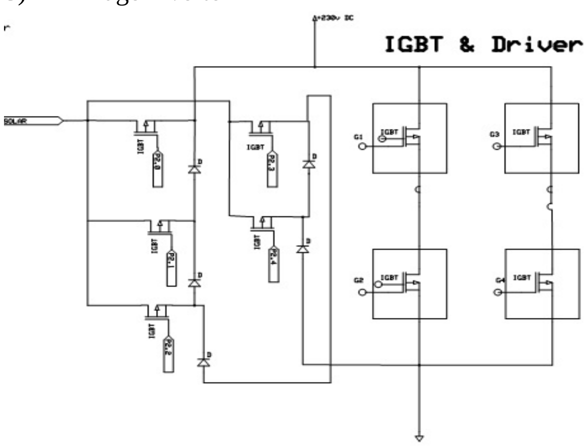

Fig. 4 Circuit diagram of proposed inverter

TABLE I

Switching combination of eleven level MLI

Voltage level	Switches
1/5 Vdc	S1,S6,S9
2/5 Vdc	S1,S2,S6,S9
3/5 Vdc	S1,S2,S3,S6,S9
4/5 Vdc	S1,S2,S3,S4,S6,S9
Vdc	S1,S2,S3,S4,S5,S6,S9
0	S7,S9
-1/5 Vdc	S1,S7,S8
-2/5 Vdc	S1,S2,S7,S8
-3/5 Vdc	S1,S2,S3,S7,S8
-4/5 Vdc	S1,S2,S3,S4,S7,S8
-Vdc	S1,S2,S3,S4,S5,S7,S8

Table 01 Switching combination of eleven level MLI

D) SPWM Technique

The Sinusoidal pulse width modulation method is very popular control method which is used in multilevel inverters to control the total harmonic components in the output voltage. This technique is used for pulse generation; after comparing the sinusoidal reference signal to the triangular carrier signal gate pulses are generated. In this technique pulse magnitude is same but only the pulse width is different. The maximum value of sinusoidal reference signal is lesser than or equal to the maximum value of carrier signal. This confirms that value of modulating signal not overpass the higher value of the carrier signal.

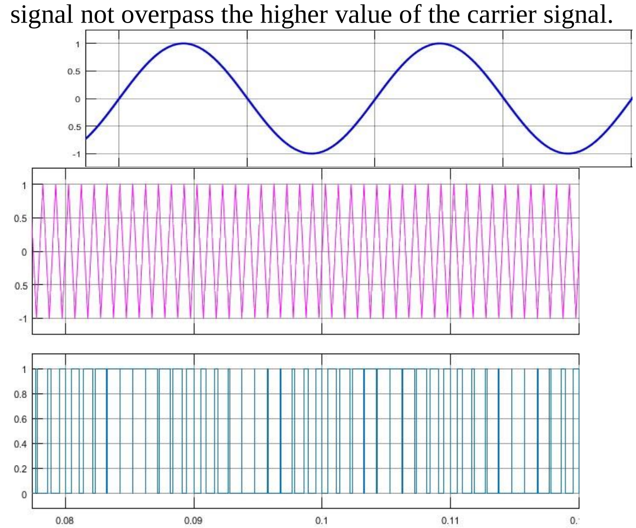

Fig. 5 Reference sine wave, triangular carrier, and gate pulses of switches.

The output voltage is kept in check by controlling modulation index (MI). The modulation index is the ratio of higher value of modulating wave (Vˆm) and the carrier wave (Vˆc). i.e. MI = Vˆm / Vˆc. Basically, the value of modulation index is kept lower than one to avoid over-modulation. (i.e. $0 < m < 1$).

E) Fuzzy logic controller

In this controller a control operation is based on fuzzy logic. Fuzzy inference mechanism is the mechanism to calculate the provided input into an required output by using the fuzzy logic. In the closed loop systems, Mamdani type FLC is generally used as it helps in reducing the steady state error to level of zero. Fuzzy logic controller has a tendency to work in a closed loop system without using any mathematical application.

In fuzzy logic controller two main parameters are required for designing a system. That is first step of the controller is to define input variables as well as output variables. And second step follows to select membership function. The voltage error is used in the input variable and the reference sine wave amplitude is used in the output variable. The fuzzy logic controller controls the PWM sine wave amplitude w.r.t. the error voltage as per rules. This advantage of fuzzy logic for a problem can be analyzed easily. Fuzzy logic controller gives excellent results as compared with the PI controller; however its drawback is it having large number of fuzzy sets and rules.

IV. SIMULATION RESULTS

MATLAB/ Simulink (R2016a) software is used for software implementation of 11 level cascaded MLI with solar panel using FLC. PV panel has Operating temperature (T) = 25ºc Solar irradiance (S) = 1Kw/m²

Time (t) = 1s Rating = 20w. In this model DC supply voltage 230 V is used.

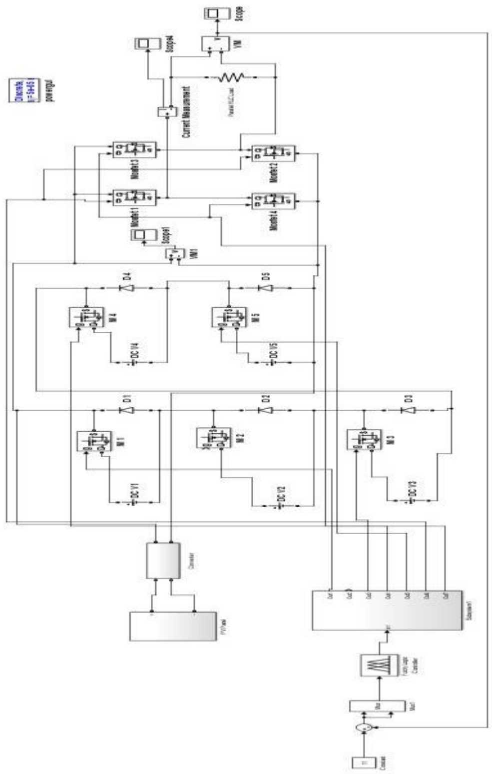

Fig. 6 Simulation model

This inverter is developed to produce eleven level sinusoidal waveforms. The system is connected with resistive load. FLC has mamdani type controller. It requires two inputs, one output and seven rules. Converter gives frequency of 50 Hz. Sinusoidal pulse width modulation (SPWM) scheme is used to obtain required gate signals. With comparing a reference signal to a triangular carrier waveforms, the gate signals are generated. This is very simple phase shifting scheme that reduces the harmonics in load voltage. Total harmonic distortion (THD) at load voltage is 12.16%. Nominal voltage is 1000Vrms. Fig. 7 & fig. 8 shows waveforms of output current and output voltage. And fig. 9 shows THD of output voltage.

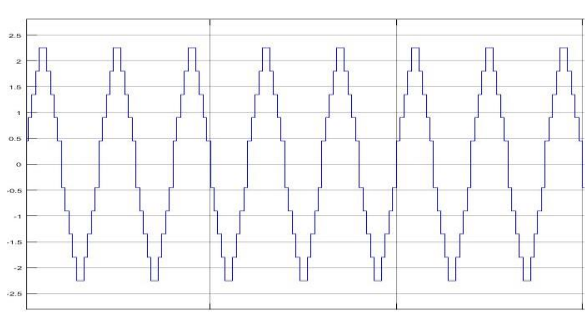

Fig. 7 Output current waveform of MLI

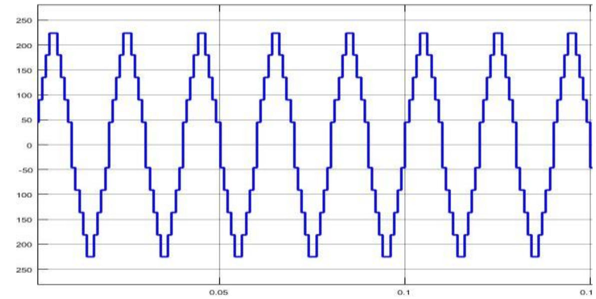

Fig. 8 Output voltage waveform of MLI

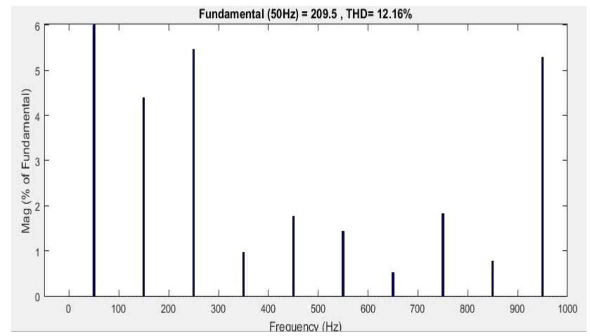

Fig. 9 THD of output voltage calculated by FFT.

V. CONCLUSION

The proposed eleven level cascaded multilevel inverter with solar panel using the fuzzy logic controller is modeled in the MATLAB / Simulink (R2016a) software. The Mamdani type fuzzy logic controller is applied to control the system. This fuzzy logic controller gives better result and accuracy. Sinusoidal pulse width modulation strategy is applied for pulse generation. In this project less switches are used for switching which becomes less complex and not only reduces switching losses but also reduces its cost and installation area.

From simulation results we conclude that the system is capable to generate eleven level voltages at the output with reduced harmonics.

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