A New Sensorless Multilevel Inverter with reduced part count with flying capacitor voltage balancing technique

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Abstract-In this paper, a single phase thirteen level inverter which suitable for renewable energy systems is proposed. To clamp the neutral point voltage and to attenuate the fluctuation of common mode voltage neutral-clamped inverter is used. As compared to conventional multilevel inverter in sensorless multilevel inverter voltage balance is easily. Flying capacitor (FC) H-bridge is cascaded with neutral point- clamped inverter. The low frequency switches are connected across the dc-link which enables to generate a 13L waveform. The PWM controller which is embedded with a sensorless voltage control is responsible for regulating the FC voltage. As the levels increases the harmonics are reduced. The THD is compared and analysed. Simulation work for the proposed topology is carried out in MATLAB/Simulink.

Keywords – Flying capacitor, sensorless multilevel inverter, thirteen level inverter, THD (Total harmonic distortion)

I. INTRODUCTION

Now a day's, renewable energy based system are emerging for electric power generation in the field of power electronic converter structures which enables the integration of renewable energy sources, as they are eco-friendly. Demand for electrical energy is increasing day-by-day therefore, alternate sources is required. When compared to the other technologies in renewable energy sources, PV technology have more advantages and it is environment-friendly [5]. Multilevel inverter has more energy from medium voltage source, but devices such as super condensers, batteries, solar panels have either low or high voltage sources. There are many switches in the multilevel inverter. In the multilevel inverter, the firing angle of the switches is most essential. There are several voltage levels and currents in the multilevel inverter. The output has zero total harmonic distortion as the concentrations increase and reach greater volume value. Achievable voltage levels can be restricted by voltage issues, clamping voltage demands, circuit layout, packaging limitations, hard control and cost of repair. The 3L common topology of the multilevel inverter cannot deliver power to the grid from distributed generator sources. Therefore, conventional boost converter is used to step up the voltage as, the DG sources. PHOTOVOLTAIC (PV) energy provided to the utility grid is gaining more and more visibility, with growing global power demand. Due to the relatively high cost, not many PV systems have been put into the grid so far compared to more traditional sources of energy such as oil, gas, coal, nuclear, hydro and wind. The switching of the converter is controlled by the MPPT (Maximum Power Point Tracking) which tracks the maximum power from environmental condition [1]. Some of the significant features of multilevel inverter, like conduction losses, ability to handle high voltages with reduced stress across individual devices. The output voltage obtained will be with lesser harmonic content since, the level is increased from 9 level to 13 level. Even switching power semiconductor devices are reduced [9]. It is decided that, flying capacitor is charged during positive and discharged during negative half cycles of the voltage to regulate the capacitor voltage. Hence, voltage balancing is not necessary for sensorless multilevel inverter [8]. Hence, multilevel inverter has become more popular in industrial applications and also in household applications like UPS etc.

II. BLOCK DIGRAM OF PROPOSED INVERTER

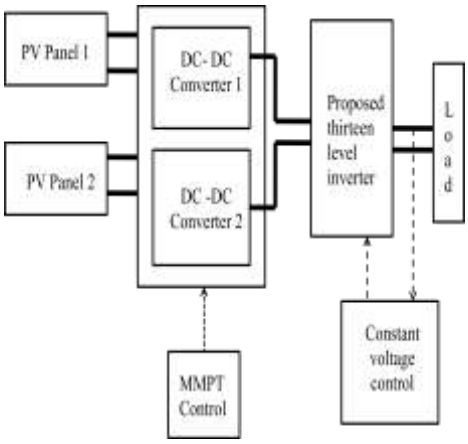

Fig 1: Block Diagram

➢ The block diagram consists of:

- Two PV panels
- DC-DC converters
- MPPT Control
- Inverter
- Constant Voltage Control

PV Panels:

A number of modules constitute a typical photovoltaic panel that can be connected to the inverter input in a string configuration to achieve the desired current and voltage. A number of photovoltaic panels connected in a string configuration are typically referred to as a photovoltaic array.

DC-DC converters:

Switched-mode DC-to-DC converters convert one DC voltage level to another that may be higher or lower by temporarily storing the input energy and then releasing that energy at a different voltage to the output. Most DC-DC converters are intended to move from input to output unidirectionally, but the topologies of the switching regulator can be intended to move bidirectionally by replacing all diodes with active rectification separately regulated. Boost DC-DC converter is used.

MPPT (Maximum Power Point Tracking) Control:

In many different configurations, PV solar systems exist in relation to inverter systems, external grids, battery banks or other electrical loads. Regardless of the ultimate location of the solar power, however, MPPT's main issue is that the effectiveness of transferring energy from the solar cell depends on both the quantity of sunlight falling on the solar panels and the electrical features of the load. The load characteristic that gives the highest power transfer efficiency changes as the amount of sunlight varies, so that the system efficiency is optimized when the load characteristic changes to keep the power transfer at the highest efficiency. This characteristic of the load is called the maximum power point (MPP), and MPPT is the process of finding this point and maintaining the characteristic of the load.The voltages across the dc-link condensers and FC are equivalent to $V_{dc}/4$ and $V_{dc}/8$ respectively, with V_{dc} being the complete input voltage. The concept of cascading TNPC with FC produces less power devices, energy diodes, and capacitors in the following benefit, and more importantly it is modular compared to other inverters that generate the same amount of concentrations. The resulting topology can be adapted to a greater voltage level by adding more FC H-bridges according to the level requirement. In order to stabilize and control the FC voltage, the decision is made to charge FC during the favourable half-cycles of the basic voltage and release during the adverse half-cycles. The FC's charging and discharge time period is kept similar to one complete cycle of the fundamental output voltage, which leads to energy equalization in and out of the FC in each output voltage cycle and consequently the voltage across the FC is maintained at the desired level under all conditions.

III. MPPT Incremental Conductance

Maximum Power Point Tracking, often referred to as MPPT, is an electronic system that operates the Photovoltaic (PV) modules in a way that allows the modules to generate all the power they can. MPPT is not a mechanical monitoring system that "moves" the modules physically to make them point to the sun more directly. MPPT is a fully electronic system that changes the modules electrical working point so that the modules can produce the highest energy available. Additional energy from the modules is then produced accessible as an enhanced charge current for the battery.

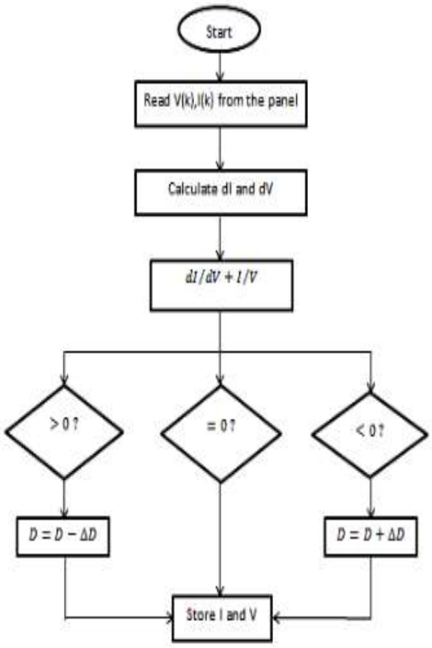

Fig 2: Flow Chart of Incremental conductance

Incremental Conductance Algorithm

The Inc. Cond. The method is based on the P-V curve path where ;

$$\frac{dP}{dV} = 0 \quad \text{at MPP}$$

$$\frac{dP}{dV} > 0 \quad \text{left to MPP}$$

$$\frac{dP}{dV} < 0 \quad \text{right to MPP}$$

Since

$$\frac{dP}{dV} = \frac{d(IV)}{dV} = I + V\frac{dI}{dV} \cong I + V\frac{\Delta I}{\Delta V}$$

Then

$$\frac{\Delta I}{\Delta V} = \frac{-I}{V} \quad \text{at MPP}$$

$$\frac{\Delta I}{\Delta V} > \frac{-I}{V} \quad \text{left to MPP}$$

$$\frac{\Delta I}{\Delta V} < \frac{-I}{V} \quad \text{right to MPP}$$

The MPP can be monitored by replacing instant conductance (I / V) with incremental conductance (I / V) and thus the voltage disturbance variable will be determined until the MPP is reached. This technique takes advantage of the premise that the change proportion in yield conductance is equal to the instantaneous conductance of the adverse yield. However, if the irradiance increases (decreases) i.e. the array current increases (decreases), the MPP moves right (left) with regard to the voltage of the array. The MPPT must increase (decrease) the operating voltage of the array to compensate for this motion.

IV. PROPOSED THIRTEEN LEVEL INVERTER TOPOLOGY

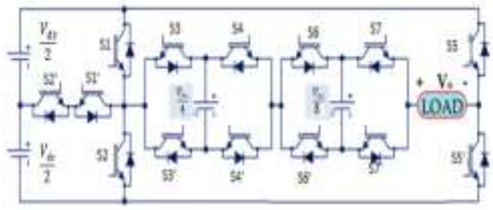

Fig 3: Thirteen level inverter topology

The proposed 13 level inverter topology is shown in Fig 4. The fundamental unit consists of twelve unidirectional switches and one bidirectional switch (S_1 and S_2 complementary switches) with four dc voltages. In the proposed inverter topology, the fundamental unit on the left side is linked with a magnitude of $V_{dc}/2$. This topology is similar to the nine level fundamental unit of the proposed multilevel inverter. Which is implemented using four switches S_6, S_7 and its complementary switches. This topology consists of three H-bridges. First H-bridge is formed by the switches S_1, S_2, S_5 and their complementary switches. Second H-bridge is formed S_3, S_4, and their complementary switches. Third H-bridge is formed by S_6, S_7 and their complementary switches. Flying capacitor is charged and discharged during positive half cycle and negative half cycle respectively in order to stabilize and regulate the flying capacitor voltage. The capacitor voltage is maintained at the required level, the waveform of the output voltage would have symmetrical rates with less harmonic distortion. Reduced Device Count Multilevel Inverter (RDC-MLI) Topologies: topologies proposed presented to reduce the number of controlled switching power semiconductor devices for a given number of phase voltage levels are referred to as RDC-MLI topologies.

FOR POSITIVE HALF CYCLES:

Maximum output is obtained when switches S_1, S_3, S_4, S_6, S_7 are ON, output voltage is V_O= Vdc

Table 1: Positive half cycle of thirteen level inverter

SWITCHES ON	OUTPUT VOLTAGE
S_2, S_3, S_4, S_6, S_7	$V_o = 0$
S_3, S_6	$V_o = \frac{Vdc}{8}$
S_3, S_6, S_7	$V_o = \frac{Vdc}{4}$
S_3, S_4, S_6	$V_o = 3\frac{Vdc}{8}$
S_3, S_4, S_6, S_7	$V_o = \frac{Vdc}{2}$
S_1, S_3, S_6, S_7	$V_o = 3\frac{Vdc}{4}$

FOR NEGATIVE HALF CYCLES:

Table 2: Negative half cycle of thirteen level inverter

$S_1, S_3, S_4, S_5, S_6, S_7$	$V_o = 0$
S_2, S_3, S_5, S_6	$V_o = \frac{-Vdc}{8}$
S_3, S_5	$V_o = \frac{-Vdc}{4}$
S_3, S_5, S_6	$V_o = \frac{-3Vdc}{8}$
S_3, S_4, S_5, S_6, S_7	$V_o = \frac{-Vdc}{2}$
S_3, S_5, S_6, S_7	$V_o = \frac{-3Vdc}{4}$
$S_2, S_3, S_4, S_5, S_6, S_7$	$V_o = -Vdc$

Table 3: The switching table for the 13 level proposed inverter is shown below:

S_1	S_2	S_3	S_4	S_5	S_6	S_7	V_o
1	0	1	1	0	1	1	Vdc
1	0	1	0	0	1	1	3Vdc/4
0	0	1	1	0	1	1	Vdc/2
0	0	1	1	0	1	0	3Vdc/8
0	0	1	0	0	1	1	Vdc/4
0	0	1	0	0	1	0	Vdc/8
0	1	1	1	0	1	1	0
1	0	1	1	1	1	1	0
0	0	1	0	1	1	0	-Vdc/8
0	0	1	0	1	0	0	-Vdc/4
0	0	1	0	1	1	0	-3Vdc/8
0	0	1	1	1	1	1	-Vdc/2
0	0	1	0	1	1	0	-3Vdc/4
0	1	1	1	1	1	1	-Vdc

V. MATLAB SIMULATION

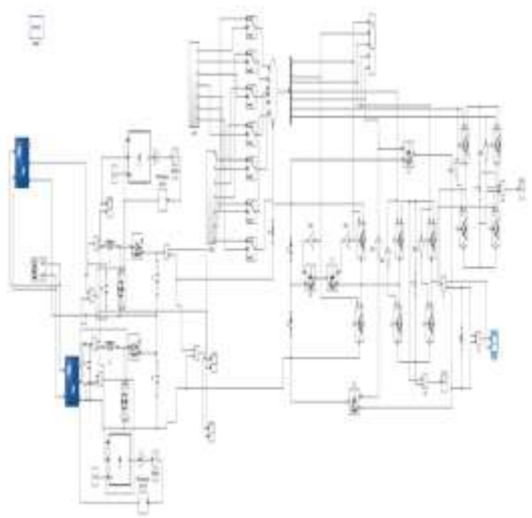

Fig 4: MATLAB model for thirteen level inverter with resistive load

➢ **Description of Simulink Model:**

- By using simulink models Group signal 1 and signal 2 are connected to PV panels, each PV panels is designed for 1.5kW and voltage is designed as 110V.
- MPPT (Incremental conductance algorithm is provided to obtain maximum power from PV panel. Depending on the coding of voltage, current and Adc (Change in duty ratio) value selected.
- PV panels and MPPT are connected to two DC-DC boost converters. From boost converters voltage, voltage is boosted to 400V.
- To obtain gate pulses PWM generators (DC-DC) are used. PWM generators are connected to the gate terminals of a two MOSFET's.
- DC converters are connected to two H-bridges which are formed by the ten switches and for complementary switches, NOT logic gates are used. For thirteen level implemented inverter three H-bridges are provided by simulink model.
- Each levels are compared by using suitable logic operation i.e., NOT logic operation to obtain required levels at the output.
- Each level and polarity models are chosen depending up on the switching states.
- Sine wave block is provided, which is compared with zero. If sine wave is greater than zero then it is chosen as positive cycle otherwise, it is chosen as negative cycle.

- The output is connected to a load (Resistive load) or grid where the efficiency is high due to control of output voltage which is done by PWM technique.

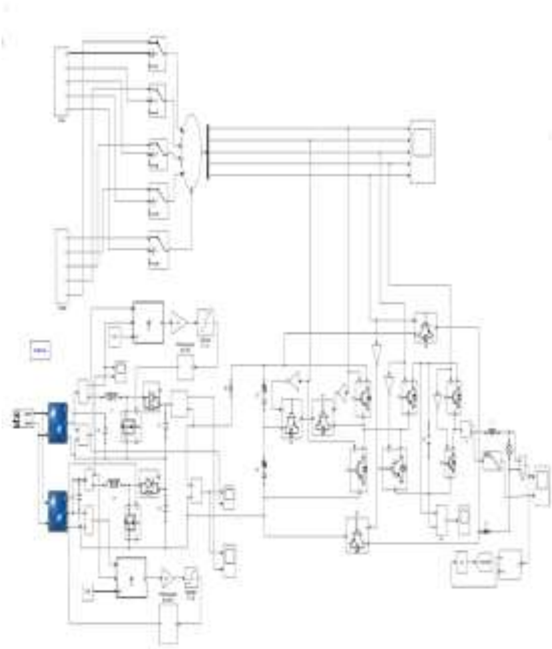

Fig 5: Simulation of nine level Multilevel inverter circuit using MATLAB

Design:

PV panel voltage = 110v

Converters voltage = 400v

$P_{pv1}= P_{pv2}$ = 1.5kW

Frequency (f_s) = 2.5 kHz

Duty ratio = 0.45

Change in inductor current = 2.73A

L = 7.25mH

C = 0.675µf

VI. SIMULATION RESULTS

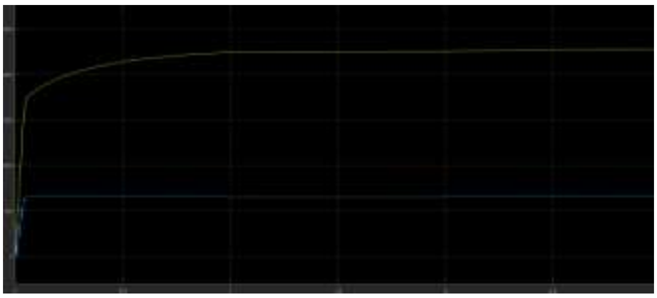

Fig 6: Waveform of converter voltage and PV panel voltage

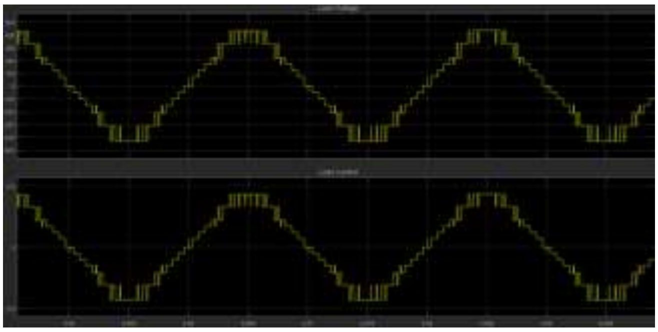

Fig 7: Thirteen level inverter waveform

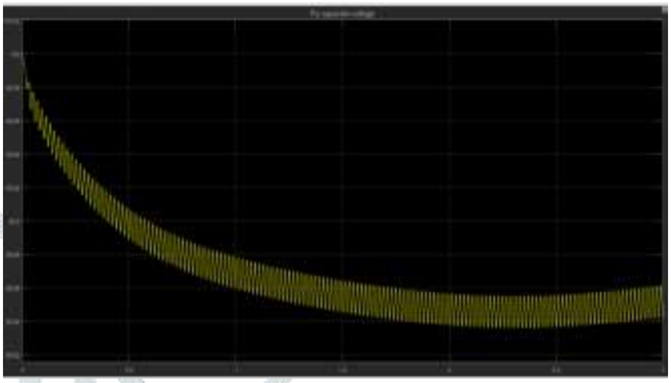

Fig 8: Flying capacitor voltage

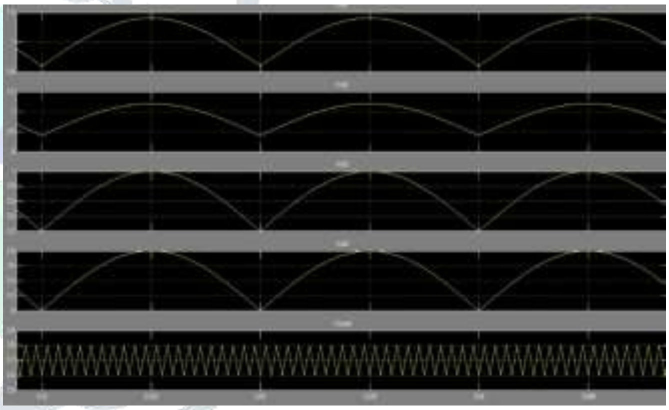

Fig 9: Reference voltages and carrier signals

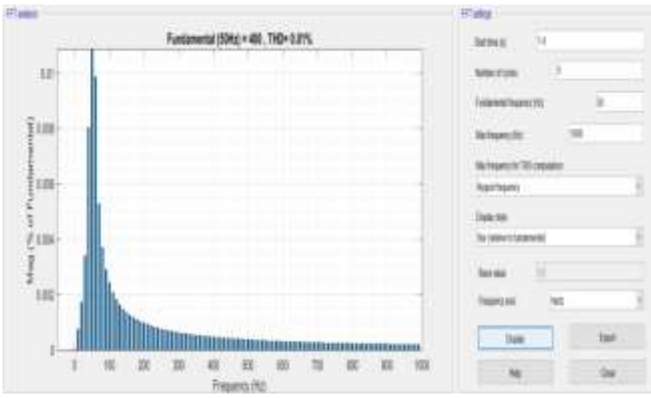

Fig 10: Total harmonic distortion

CONCLUSION

Multilevel inverters are being developed and widely used to generate high-quality output voltages for numerous fields of medium voltage application. Applications calling for higher voltage levels will increase the number of components required. Multilevel inverters are being developed and widely used to generate high-quality output voltages for numerous fields of medium voltage application. Applications calling for higher voltage levels will increase the number of components required. Therefore, in the proposed thirteen level inverter THD from is reduced from 6% to 0.01% .Furthermore, a sensorless PWM technique is suggested based on the principle of energy balance to regulate FC's voltage. An exhaustive review of the recently proposed multilevel inverter topologies with RPC applicable to renewable sources grid integration is conducted and the subsequent comparison certifies the merits of the proposed topology over conventional inverters.

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