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IMPLEMENTATION OF NEUTRAL POINT CLAMPED MULTILEVEL INVERTER WITH REDUCED PART COUNT

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Abstract **-Multilevel inverter is a power electronic device mainly suitable for renewable energy systems and industrial applications. It is used to handle high voltage with reduced stress across individual devices, low switching and conduction losses.In this paper, a single-phase nine-level inverter using neutral point-clamped inverter is connected in cascade to a floating capacitor (FC) H-bridge. In comparison to conventional and recent topologies, generation of the 9L waveform using a lower number of switches in neutral point clamped inverter possess less disturbance, reduced harmonic ripples and minimize the semiconductor losses.The proposed neutral point-clamped inverter with reduced part count topologies are designed and investigated using MATLAB/Simulink. This simulation and experimental result exhibits that the proposed inverter reduces the switching losses**

***INDEX TERMS*- Floating Capacitor (FC), Nine Level (9L).**

I. INTRODUCTION

Multilevel inverters (MLIs) have widely gained its popularity for medium voltage and high power applications due its distinct advantages when compared to its two-level inverters. It has lower voltage stress on switches, better quality output voltage across the devices and current waveforms and lower common-mode voltages. For medium voltage inverters, cascaded H-bridge (CHB), Neutral point clamped (NPC), and Flying Capacitor (FC) are the primary topologies of the proposed inverter [1]. Among them, NPC and FC provide a common dc-link which is a strict requirement for many application devices. Of the conventional multilevel inverter topologies, T- type neutral point clamped (NPC) inverters have a remarkable place in industrial motor drive applications. Yet, for medium voltage applications, higher level multilevel inverters are required to reduce the voltage stress across the switches, improved output waveforms with lower harmonic distortion, lower electromagnetic interference, reduced stress across the semiconductor devices, and fault-tolerant operation. They are also equally attractive for low voltage/power applications due to reduction in filter requirement, switching losses and better power quality.

In addition, they exhibit a favourable condition for grid-connected renewable system, especially for solar Photo Voltaic (PV). The solid connection between the PV module and the grid via neutral point of NPC or ANPC topologies help to keep the Common Mode Voltage (CMV) constant which reduces the leakage current in the system [2]. This condition is equally appealing for motor drives and marine power supply.

There are mainly three types of classic multilevel inverter topologies are Neutral Point Clamped (NPC), Flying Capacitor (FC) and hybrid structure consisting of H-bridge and NPC. Single-phase leg of these types of topologies generating nine-level output. Besides the advantages discussed above, the main drawback of the multilevel inverter is their complexity regarding the structure and control technique [3]. In addition, they require a higher dc-link voltage (two times the peak ac output voltage), which needs an additional front-end boost dc-dc converter or string of series connected PV modules to lift the dc-link voltage for active power control to the grid. The multistage power conversion reduces the efficiency and reliability of the device, while increasing the size and cost of the system. The additional boost stage can be eliminated by connecting PV modules in series (string) to produce high dc link voltage across the circuit.

From the industrial point of view, they use of a high number of part counts in conventional multilevel inverters which increases both the intricacy of the circuitry as well as the complexity of the control scheme involved. This leads to higher cost implications and reduced reliability. Therefore, this proposed method presents a novel hybrid 9L inverter on the basis of reduced part count, less disturbance, minimizes the semiconductor losses.

A comparison is carried out and presents a illustrate the distinctive characteristics and the benefits about the proposed nine level inverter

Firstly, a single phase grid connected system comprises the NPC topology is simulated and the evaluation is made through the simulation results. Simulated waveform is elucidates for both the steady state and transient conditions for the proposed hybrid inverter.

II. SOLAR CELL PV MODULE

Renewable sources of energy acquire growing importance due to the enormous consumption and exhaustion of fossil fuel. Also, solar energy is the most readily available source of energy and it is free for the usage. Moreover, solar energy is the best among all the renewable energy sources since, it is non-polluting and easily available. Energy supplied by the sun in one hour is equal to the amount of energy required by the human in one year. Photo voltaic arrays are used in many applications such as water pumping, street lighting in rural town, battery charging and grid connected PV systems and other renewable sources. As known from a Power-Voltage curve of a solar panel, there is an optimum operating point such that the PV delivers the maximum possible power to the load. The optimum operating point changes with solar irradiation and cell temperature.

A. PHOTOVOLTAIC CELL

Photovoltaic cell generates electricity from the sun. PV panel works under the phenomenon of photoelectric effect. It directly converts sunlight into electricity. The diagram of PV based system is shown in Figure1

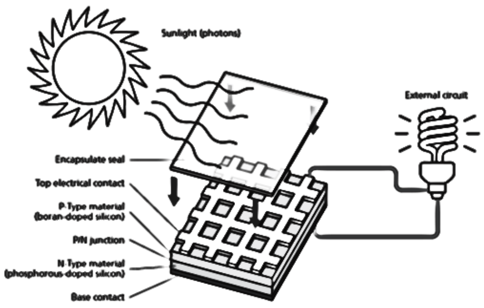

Figure 1 PV based system

B. PV EQUIVALENT CIRCUIT

Solar cells are connected in series and parallel to set up the solar array. Solar cell will produce dc voltage when it is exposed to sunlight. Figure 2 shows the equivalent circuit model for a solar cell. Solar cell can be regarded as a non-linear current source. Itsgenerated current depends on the characteristic of material, age of solar cell, irradiation and cell temperature.

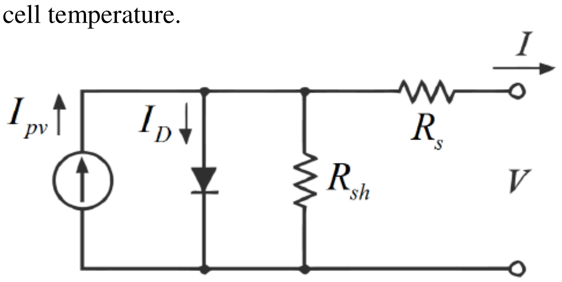

Figure 2 Equivalent Circuit of Solar Panel

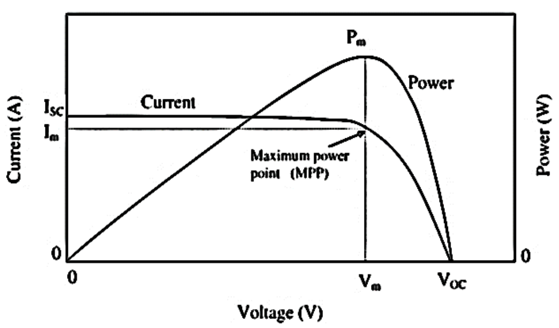

Figure3 P-V Characteristics of Solar Panel for Various Irradiance

C. MAXIMUM POWER POINT TRACKING(MPPT)

In the incremental conductance method, the controller measures incremental changes in PV array current and voltage to predict the effect of a voltage change. This method requires more computation in the controller, but can track changing conditions more rapidly when compared tothe perturb and observe method (P&O). Like the P&O algorithm, it can produce oscillations in power output.

This method utilizes the incremental conductance (dI/dV) of the photovoltaic array to compute the sign of the change in power with respect to voltage (dP/dV). The incremental conductance method computes the maximum power point by comparison of the incremental conductance (I_Δ / V_Δ) to the array conductance (I / V). When these two are the same ($I / V = I_\Delta / V_\Delta$), the output voltage is the MPP voltage. The controller maintains this voltage until the irradiation changes and the process is repeated.

In incremental conductance method the array terminal voltage is always adjusted according to the MPP voltage. It is based on the incremental and instantaneous conductance of the PV module.

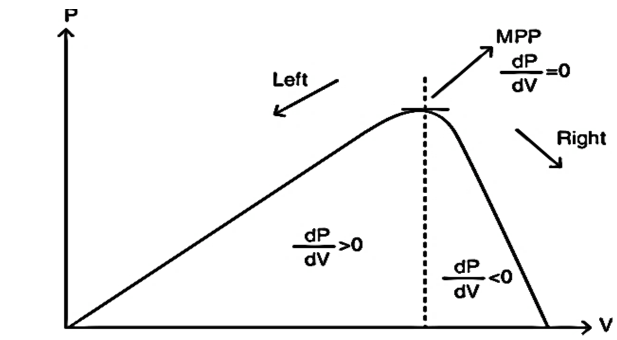

Figure 4 Incremental conductance method on a P-V Curve of solar module

$dIdV = -IV$ At MPP

$dIdV > -IV$ Left of MPP

$dIdV < -IV$ Right of MPP

Where I and V are P-V array output current and voltage respectively. The left hand side of equations represents incremental conductance of P-V module and the right hand side represents the instantaneous conductance. When the ratio of change in output conductance is equal to the negative output conductance, the solar array will operate at the maximum power point.

III. PROPOSED NINE LEVEL INVERTER OPERATING PRINCIOLE AND CONTROL

The NPC topology has been adopted for high power applications as it can achieve better harmonic reduction than traditional two-level voltage source inverters and the associated control strategies help to minimize semiconductor losses.

When an NPC module is used as in inverter operation, the DC-link voltage can be converted into a variable alternating voltage and variable frequency. In contrast to a half-bridge or six pack, an NPC topology offers an additional voltage level at the output. The potential not only jumps to DC+ and DC, it can also have a status of 0.

The inner IGBT switches are called NP (neutral point) and the centre-point of the DC-link is switched to the output. At real or active power, these are switched at just 50 Hz and thus correspond to the positive or negative sinusoidal half-wave. Usually operated at a higher frequency, the outer switches generate the sine wave. This requires from components half the blocking voltage capability needed for conventional topologies.

A. BLOCK DIAGRAM

Figure 5shows the overall operation of multilevel inerter using Neutral Point Clamped Inverter. PV module is directly connected to the DC to DC converter using MPPT converter. MPPTtracks the maximum voltage using incrementalconductance algorithm. The output voltage from the PV module is given to the boost which increases the output voltage to the maximum

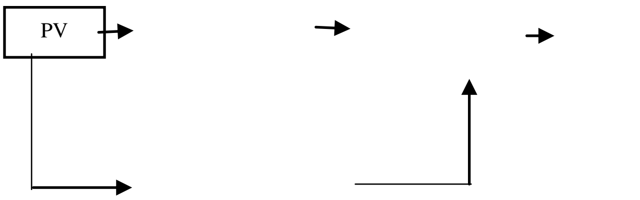

Figure 5 block diagram of multilevel inverter using Neutral Point Clamped Inverter

The output voltage is given as input to the NPC inverter connected in cascade across a floating capacitor (FC) H-bridge. The PWM pulse is generated and is given to the NPC inverter through the MPPT controller. From the inverter, it is then given to the load or grid. It is mainly used in industrial applications.

B. OPERATION OF NEUTRAL POINT CLAMPED INVERTER

A hybrid, two-bridges, multilevel structure with asymmetrical sources of Neutral Point Clamped Inverter has key advantages over the VSC-NPC and Flying Capacitor VSC. For instance, it can provide a higher number of voltage levels with fewer switches. In addition, the hybrid topology has no need of capacitors or transformers for its basic operation.

As a consequence, using the latter configuration, a sine waveform can be reproduced with lower harmonic distortion than with other multileveltopologies. The generation of different voltage levels in *V*out, from the cascade cell converter, is shown in Figure 6.

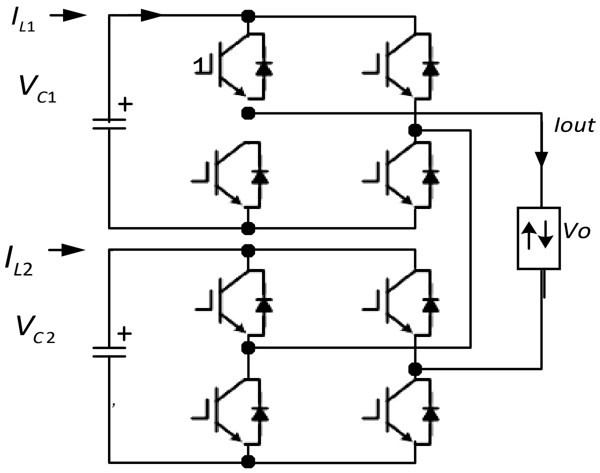

Figure 6 circuit diagram of Neutral Point Clamped Inverter

This voltages are obtained based on the algebraic sum of voltages $V_{C1}$and V_{C2}as shown in Table 4.1, where $H_1$and H_2bridges generate combinations independent of voltage versus time, being $V_{H1}\epsilon$ {+ V_{C1}, 0, − V_{C1}}; and V_{H2}, {+ V_{C2}, 0, − V_{C2}};respectively. Finally, the magnitude and phase shift of I_{out} depend on the type of load connected to converter, which can be an independent load or a distribution electrical grid. The voltages of each H-bridge converter (VH1 and VH2) can be defined by Equations

$$V_{H1} = V_{C1}[S_{1,1} - S_{1,3}]$$

$$V_{H2} = V_{C2}[S_{2,1} - S_{2,3}]$$

The currents of each H-bridge converter (IH1 and IH2) can be d

$$I_{H1} = I_{C1}[S_{1,1} - S_{1,3}]$$

$$I_{H2} = I_{C2}[S_{2,1} - S_{2,3}]$$

Figure 6 shows the nine levels DC/AC cascaded hybrid topology implemented in this research. It should be mentioned that for the topology employed specifically here, the voltage levels V_{C1} and V_{C2} have to satisfy the followingratio

$$V_{C1} = \frac{3}{2}V_{C2}$$

Where $V_{c1} \approx V_{in}\cdot D_1$ and $V_{c2} \approx V_{in}\cdot D_2$. Based on Equation, it is possible to calculate the duty cycle D_1 and D_2 and applied in Boost converters. As V_{c1} and V_{c2} depend of $D_1$and D_2, a larger or shorter of the latter will deform *V*out. The generation of voltage levels V_{out} is performed based on switching states in Table 4.1. To obtain the correct control pulses to be applied to inverter power switches connected in cascade is necessary to implement a multilevel modulation Sine-Pulse Width Modulation (SPWM) process.

IV. SIMULATION RESULTS

A single phase grid connected shown in the figure1 is simulated using MATLAB/ Simulink to verify its performance of the NPC inverter with its sensorless control.

The simulation of multilevel inverter Using Neutral Point Clamped Inverter with the reduced switches. The output voltage from the boost converter is given as input to the NPC inverter connected in cascaded H-bridge. PWM pulse is generated and given as input pulse to the MOSFET switches and it is connected to the load.

The resistor value is R_1=1mH and the capacitor value of the NPC inverter is $C_{1,}C_2$=6000 µF.

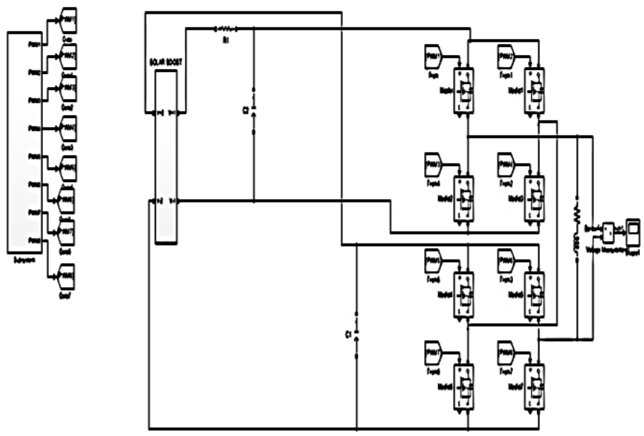

Figure 7 simulation of multilevel inverter using Neutral Point Clamped Inverter

Figure 8 shows the simulation of DC to DC converter connected to a PV module. PV module is connected to MPPT converter which tracks the maximum output voltage and is given to the boost converter. The boost converter step up the voltage to the maximum which is given as input to the NPC inverter.

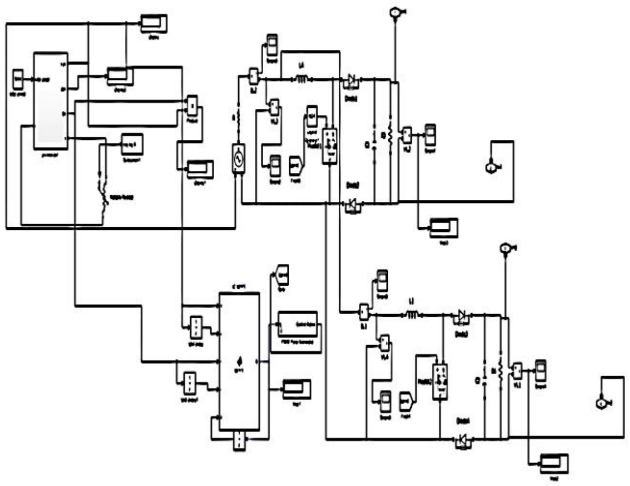

Figure 8 simulation of DC – DC Converter

A. OUTPUT WAVEFORM

Figure 6.3 shows the output waveform of multilevel inverter using Neutral Point Clamped Inverter. The output waveform shows the nine level as an output across the time (T) and voltage(V). The input voltage from the PV panel is 14V and the output voltage is 40v

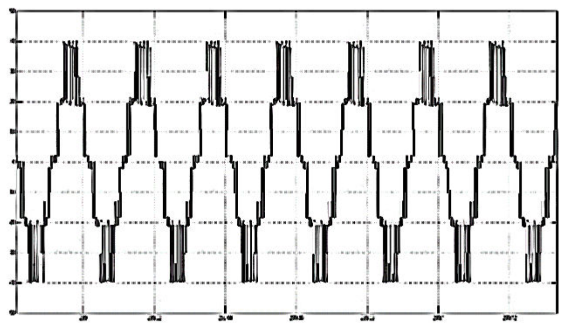

Figure 9 simulation waveform of multilevel inverter using Neutral Point Clamped Inverter

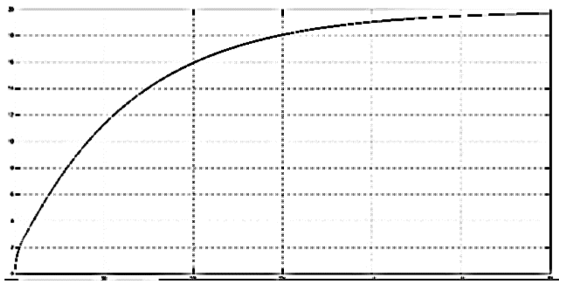

Figure 10 Simulation waveform of DC – DC converter

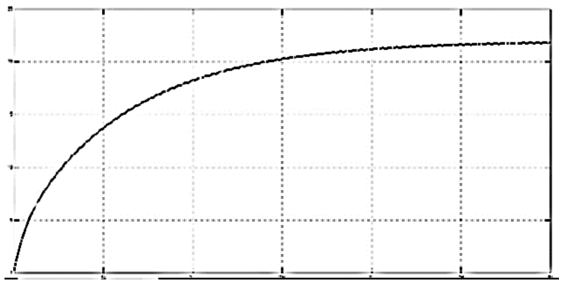

Figure 11 Simulation waveform of DC – DC converter

V. HARDWARE RESULT

Figure 12 shows the hardware implementation of multilevel inverter using Neutral Point Clamped Inverter with the reduced switches. The output voltage from the boost converter is given as input to the NPC inverter i.e.,.

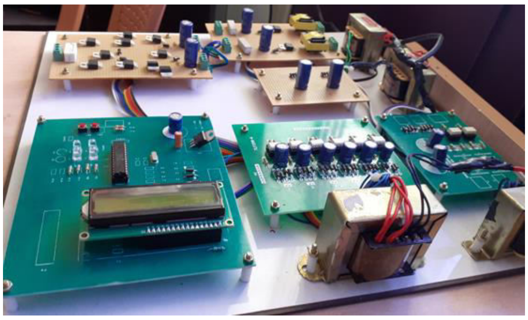

Figure 12 Multilevel inverter using Neutral Point Clamped Inverter

TLP 250 is a driver circuit connected in cascaded H-bridge. PWM pulse is generated in pic microboard and displayed in DSO

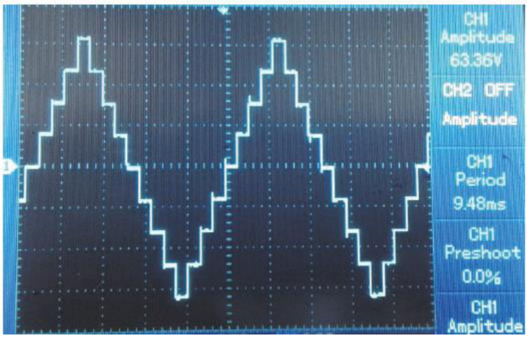

Figure 13 Output waveform of multilevel inverter using Neutral Point Clamped Inverter

Figure 13 shows the output waveform of multilevel inverter using Neutral Point Clamped Inverter. The output waveform shows the nine level as an output across the time (T) and voltage(V). The input voltage from the PV panel is 9v and the output voltage is 63.36V.

VI. CONCLUSION

Multilevel inverters are being developed and extensively exploited for generating high quality output voltages for numerous medium-voltage application fields. Application surging a higher number of voltage level escalate the number of components required. But use of high number of part counts in conventional multilevel inverters increases both the circuit intricacies as well as the control scheme involved, thereby resulting in higher cost implications and reduced reliability. Therefore, to subdue these disadvantages, a hybrid 9L inverter topology formed by cascading aANPC and FC connected across the dc link. In the proposed method i.e. Active Neutral PointClamped Inverter, twelve switches have been reduced to eight switches resulting in reduced harmonic ripples, less disturbance and switching losses when compared to conventional method. Further, the proposed inverter structure has improvedreliability and by cascading additional FCs, it can be effortlessly extended to obtain even higher number of voltage levels.

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