ISSN 2394-3777 (Print)
ISSN 2394-3785 (Online)
Available online at www.ijartet.com

International Journal of Advanced Research Trends in Engineering and Technology (IJARTET)
Vol. 5, Special Issue 8, March 2018

A NOVEL POWER SEMICONDUCTOR REDUCED SWITCH MULTILEVEL INVERTER FOR RENEWABLE ENERGY ENVIRONMENT

N.Sathish Kumar[1] K.Kalpana[2]
PG Scholar, Department of EEE, Arasu Engineering College, Kumbakonam, India[1]
Assistant Professor, Department of EEE, Arasu Engineering College, Kumbakonam, India[2]

Abstract: This paper proposes a new solar power generation system, which is composed of a DC/DC power converter and a new nine-level inverter. The DC/DC power converter integrates a DC–DC boost converter and a transformer to convert the output voltage of the solar cell array into three independent voltage sources with multiple relationships. This new nine-level inverter is configured using a capacitor selection circuit and a full-bridge power converter, connected in cascade. The capacitor selection circuit converts the three output voltage sources of DC–DC power converter into a four-level dc voltage, and the full-bridge power converter further converts this four-level dc voltage into a nine-level ac voltage. In this way, the proposed solar power generation system generates a sinusoidal output current that is in phase with the utility voltage and is fed into the utility. The salient features of the proposed nine-level inverter are that only nine power electronic switches are used, and only one power electronic switch is switched at high frequency at any time. A prototype is developed and tested to verify the performance of this proposed solar power generation system.

Keywords –Capacitor Selection Circuit, Nine Level Inverter, Full Bridge Power Converter, Renewable Energy System, MATLAB Software.

I. Introduction

The extensive use of fossil fuels has resulted in the global problem of greenhouse emissions. Moreover, as the supplies of fossil fuels are depleted in the future, they will become increasingly expensive. Thus, solar energy is becoming more important since it produces less pollution and the cost of fossil fuel energy is rising, while the cost of solar arrays is decreasing. In particular, small-capacity distributed power generation systems using solar energy may be widely used in residential applications in the near future. The power conversion interface is important to grid connected solar power generation systems because it converts the dc power generated by a solar cell array into ac power and feeds this ac power into the utility grid. An inverter is necessary in the power conversion interface to convert the dc power to ac power. The active devices and passive devices in the inverter produce a power loss. The power losses due to active devices include both conduction losses and switching losses. Conduction loss results from the use of active devices, while the switching loss is proportional to the voltage and the current changes for each switching and switching frequency. A filter inductor is used to process the switching harmonics of an inverter, so the power loss is proportional to the amount of switching harmonics. The voltage change in each switching operation for a multilevel inverter is reduced in order to improve its power conversion efficiency and the switching stress of the active devices. Therefore, multilevel inverter technology has been the subject of much research over the past few years. In theory, multilevel inverters should be designed with higher voltage levels in order to improve the conversion efficiency and to reduce harmonic content and electromagnetic interference (EMI).Conventional multilevel inverter topologies include the diode clamped, the flying-capacitor, and the cascade H-bridge types. Diode-clamped and flying capacitor multilevel inverters use capacitors to develop several voltage levels. But it is difficult to regulate the voltage of these capacitors. Since it is difficult to create an asymmetric voltage technology in both the diode-clamped and the flying capacitor topologies, the power circuit is complicated by the increase in the voltage levels that is necessary for a multilevel inverter. For a single-phase nine-level inverter, 12 power electronic switches are required in both the diode-clamped and the flying-capacitor

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topologies. Asymmetric voltage technology is used in the cascade H-bridge multilevel inverter to allow more levels of output voltage, so the cascade H-bridge multilevel inverter is suitable for applications with increased voltage levels. This paper proposes a new solar power generation system. The proposed solar power generation system is composed of a dc/dc power converter and a nine-level inverter. The nine level inverter is configured using a capacitor selection circuit and a full-bridge power converter, connected in cascade. The nine-level inverter contains only seven power electronic switches, which simplifies the circuit configuration. Since only one power electronic switch is switched at high frequency at any time to generate the nine-level output voltage, the switching power loss is reduced, and the power efficiency is improved. The inductance of the filter inductor is also reduced because there is a nine level output voltage.

II. EXISTING SYSTEM

The existing hybrid cascaded Modular (HCM) MLI is constructed from a modified H-bridge module and T-type three leg inverter structure (TTL).

A) Block Diagram of Existing System

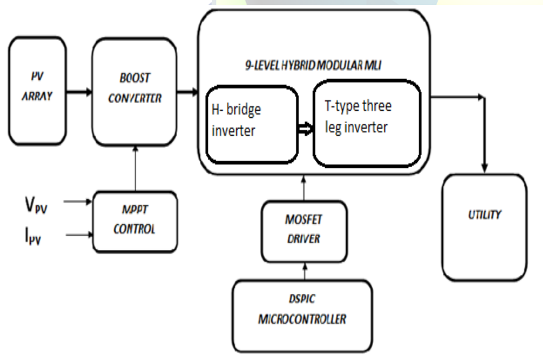

Fig 2.1 existing block diagram

B) Modified H-bridge module

Each module is basically constructed from four unidirectional-blocking-bidirectional-conducting MOSFET power electronic switches $S11$, $S21$, $S31$ and $S41$. The switch pair in both arms ($S11$, $S21$) and ($S31$, $S41$) is complimentary in nature. It can produce four levels $+3V/2$, $+V/2$, $-V/2$ and $-3V/2$ with proper switching combinations. Generally, each module requires three sources to produce the aforementioned levels in the output. This is not an effective approach to design each module of MLI to have more sources. In order to reduce one source, two capacitors and one DC source are employed

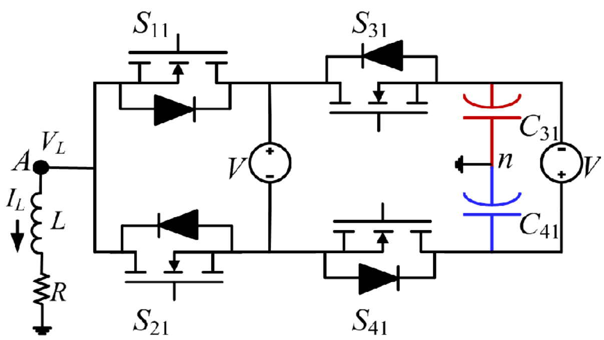

Fig 2.2 MHB module of proposed MLI.

C) T type three leg (TTL) inverter structure

The TTL inverter structure consists of six unidirectional switches ($Ta1$, $Ta2$), ($Tb1$, $Tb2$) and ($Tc1$, $Tc2$) in the respective phases a, b and c. In addition, the structure is incorporated with three bidirectional switches P, Q and R, which are formed by back-to-back configuration of two switches (PN, Pa), (QN, Qb) and (RN, Rc), with a single gating signal control. The DC link voltage is provided by two naturally balanced capacitors $C1$ and $C2$ connected across one source VT. This inverter structure in each phase can produce three voltage levels: 0, $V/2$ and $-V/2$ with switching combinations

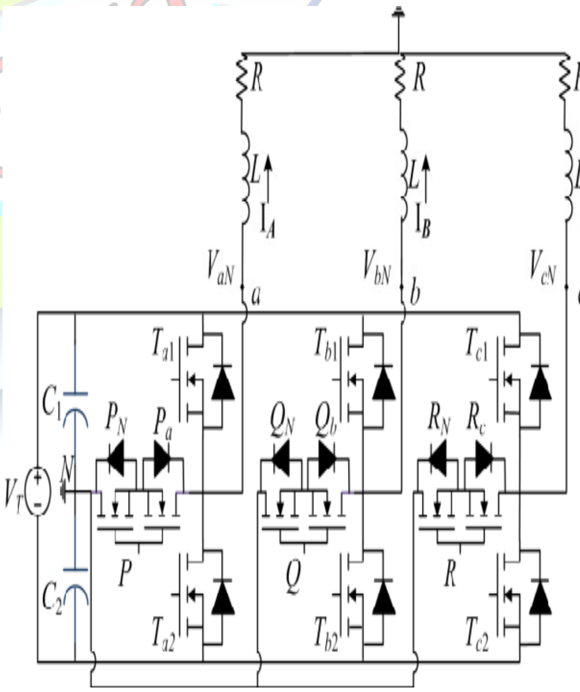

Fig.2.3. TTL inverter structure.

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D) Proposed hybrid modular inverter structure

By combining the two structures MHB and TTL inverters, the hybrid modular MLI is developed as shown in Fig. 5. This hybrid modular inverter structure in each phase can produce nine voltage levels: $2V$, $3V/2$, V, $V/2$, 0, $-V/2$, $-V$, $-3V/2$, $-2V$ in symmetrical mode. This topology can easily be extended to any desired level _L' by just cascading the MHB modules in each phase as illustrated in Fig.4. This modularity in construction feature facilitates the renewable system planning.

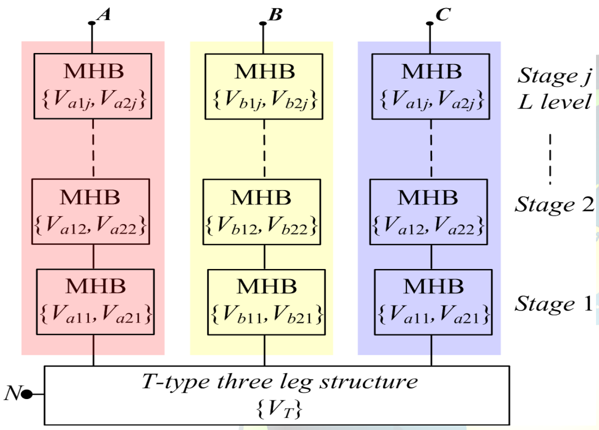

Fig.2.4. Proposed three phase L-level hybrid cascaded modular (HCM) MLI structure.

E) LIMITATIONS OF EXISTING SYSTEM

1. Required minimum 2 dc sources
2. Power loss will be high in switches due to frequent switching.
3. Efficiency will be reduced.
4.Not suitable for renewable application.

III.PROPOSED SYSTEM

This paper proposes a new Nine Level Inverter for a photovoltaic system. The nine level inverter is configured using a capacitor selection circuit and a full-bridge power converter, connected in cascade. The inverter contains only seven power electronic switches, which simplifies the circuit configuration. The proposed inverter reduced the switching losses (because of all switches operate with fundamental frequency), complexity and control circuit. The output voltage of a PV array is low; a dc–dc power converter is used to boost the output voltage of the PV array. The output waveforms of multilevel inverters are in a stepped form; therefore they have reduced harmonics compared to a square wave inverter.

F) proposed block diagram

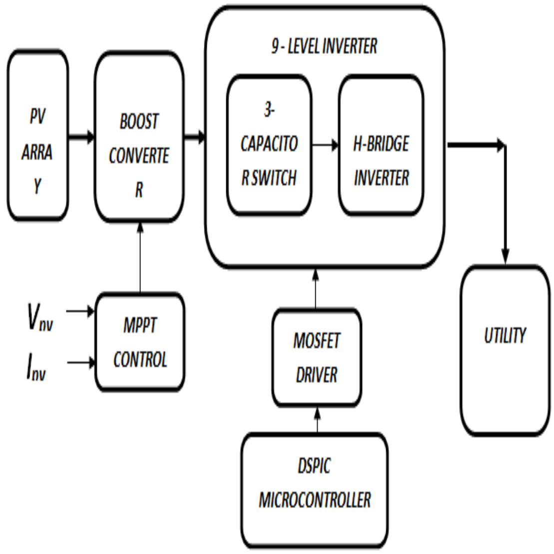

Fig 3.1 block diagram for proposed system

The proposed solar power generation system is composed of a dc/dc power converter and a nine-level inverter. A nine level inverter is configured using a capacitor selection circuit and a full-bridge power converter, connected in cascade. The nine-level inverter contains only seven power electronic switches, which simplifies the circuit configuration. Since only one power electronic switch is switched at high frequency at any time to generate the nine-level output voltage, the switching power loss is reduced, and the power efficiency is improved. The inductance of the filter inductor is also reduced because there is a nine level output voltage

F) CIRCUIT DIAGRAM PROPOSED SYSTEM

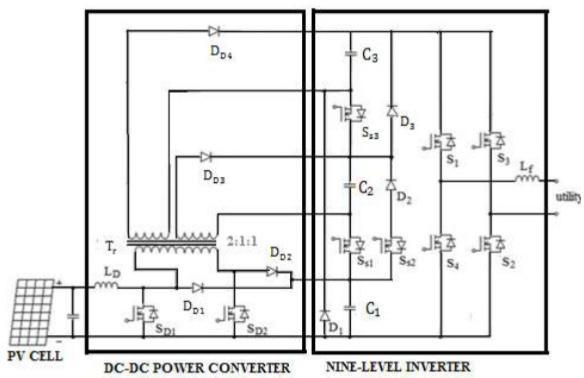

fig 3.3 proposed circuit diagram

G) DC–DC Power Converter

The DC-DC converters can be used as switching mode regulators to convert an unregulated dc voltage to a regulated dc output voltage. The regulation is normally achieved by PWM at a fixed Frequency and the switching device is generally BJT, MOSFET or IGBT. There are several different types of dc-dc converters, buck, boost, buck-boost and cuk etc. Buck converters will produce ripples on the PV module side currents and thus require a larger value of input capacitance on the module side. On the other hand, boost Converters produces low ripple on the PV module side, so in this experimental work, boost converter is used to verify the outputs. Here the DC–DC power converter consists of a boost converter and a current-fed forward converter. A boost converter is a switch mode power supply that has an output voltage higher than its input voltage. The switching in a boost converter is done through a MOSFET or IGBT. When the switch is closed the current flows

in the first loop only, and the current through the inductor grows. The switch then opens, and the voltage across the inductor and the input combine in series to charge up the output capacitor to a higher voltage than the input. In the proposed system, boost converter is consists of an inductor L_D, a power electronic switch S_{D1} and a diode D_{D1}.The boost converter charges capacitor C_1 of the nine-level inverter. The current-fed forward converter is consists of an inductor L_D , power electronic switches S_{D1} and S_{D2}, a transformer, and diodes D_{D2} , D_{D3} and D_{D4}. The current-fed forward converter charges capacitor C_2 and C_3 of the nine-level inverter.

H) Nine-Level Inverter

The nine-level inverter is consists of a capacitor selection circuit and a full-bridge power converter,which are connected in cascade. The operation of the nine level inverter can be divided into the positive half cycle and the negative half cycle of the utility. For the analysis, the power electronic switches and diodes are assumed to be ideal. Let Vdc be the total output voltage of the DC-DC converter. The voltages of capacitors C1 , C2 and C3 in the capacitor election circuit are constant and equal to 2Vdc /4, Vdc /4 and Vdc /4 respectively. the output voltage of the nine-level inverter has the voltage levels: Vdc , 3Vdc /4, 2Vdc /4, Vdc /4, 0, -Vdc /4, -2Vdc /4, -3Vdc /4,- Vdc .Since only seven power electronic switches are used in the proposed nine-level inverter, the powercircuit is significantly simplified compared with a conventional nine level inverter. It can be seen that the change in the output voltage of the nine-level inverter for each switching operation is Vdc/4, so switching power loss is reduced.

I) DIFFERENT MPPT TECHNIQUES

There are different techniques used to track the maximum power point. Few of the most popular techniques are:

1) Perturb and observe (hill climbing method)
2) Incremental Conductance method
3) Fractional short circuit current
4) Fractional open circuit voltage
5) Neural networks
6) Fuzzy logic

The choice of the algorithm depends on the time complexity the algorithm takes to track the MPP, implementation cost and the ease of implementation

V.MODELING OF PV CELL

PV panel directly converts solar energy into electricity in the form of DC with the help of PN junction. The quality of electricity directly depends on the solar intensity as well as the environmental conditions. It executes two non-linear characteristics such as *P-V* curve and *I-V* curve. To extract the maximum energy from the PV source, a controller is required to monitor the dynamic behaviour, accordingly maximum power point is tracked and updated. The output voltage level of a PV panel may not always satisfy the desired value. Therefore, it is a good practice to connect a step-up DC/DC converter to full fill the load requirement. A PV panel can be mathematically build and simulated in software to observe the dynamic behavior by changing various parameters such as irradiance, temperature etc. An algorithm is implemented for the tracking of maximum power by sensing the PV panel voltage *VPV* and current *IPV*. The equivalent model of PV panel consists of photo current *Iph,* diode, a series resistor Rs and a parallel resistor *Rsh*

The key equation for *I-V* characteristic based on the single diode model is given by

$$vt = \frac{KATns}{q}$$

Where *q* is an electron charge (1.6x10-19 C),
k is Boltzmann's constant (1.38x10-23 J/K),
A is the ideal factor of diode,
T is the working temperature,
ns is number of series connected cells.

VI. SIMULATION RESULT

MATLAB is a high-performance language for technical computing. It integrates computation, visualization, and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation. MATLAB is an interactive

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system whose basic data element is an array that does not require dimensioning. This allows you to solve many technical computing problems, especially those with matrix and vector formulations, in a fraction of the time it would take to write a program in a scalar non interactive language such as C or FORTRAN. The name MATLAB stands for matrix laboratory.

MATLAB was originally written to provide easy access to matrix software developed by the LINPACK and EISPACK projects. Today, MATLAB engines incorporate the LAPACK and BLAS libraries, embedding the state of the art in software for matrix computation MATLAB has evolved over a period of years with input from many users. In university environments, it is the standard instructional tool for introductory and advanced courses in mathematics, engineering, and science.

i) SIMULATION DIAGRAM

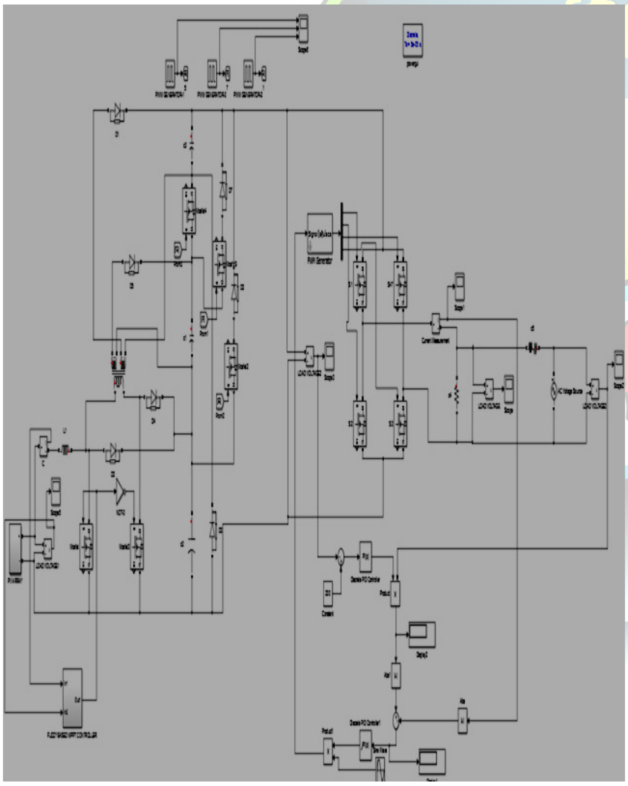

Fig 6.1 Proposed simulation diagram

ii) SIMULATION RESULTS

OUTPUT VOLTAGE

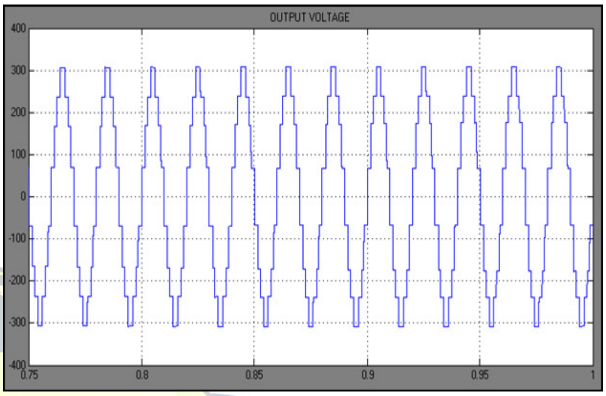

Fig 6.2 Output voltage waveform

OUTPUT CURRENT

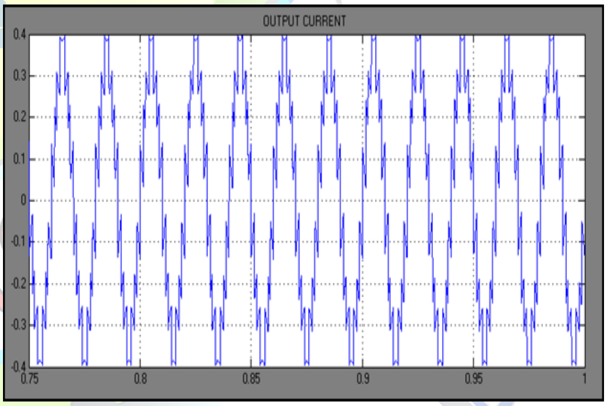

Fig 6.3 Output current waveform

GRID VOLTAGE

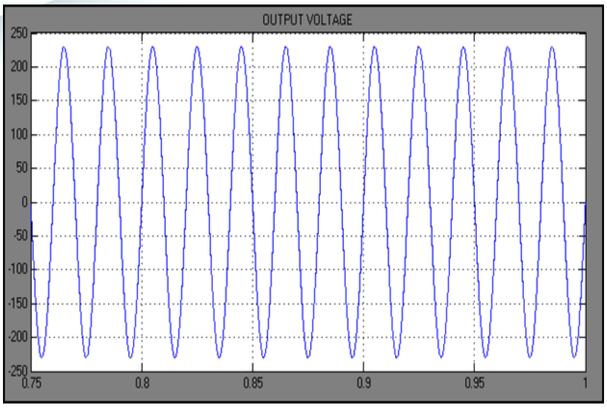

Fig 6.4 Grid output voltage

VII.CONCLUSION

In this paper, a new nine level inverter is developed from a modified H bridge inverter. It reduces the switch count by 50%, gate drive requirements by 43.75%, energy source requirement by 55.33%is compared with the existing system. The fuzzy logic control method have been discussed and evaluated for proposed topology interfaced with PV res. The simulation result are validated by conducting experiment on proposed nine level inverter. The experimental results shows the ability of a proposed inverter to generate nine level while maintaining the natural balancing of all capacitor voltage in each module. Due to the modular structure, it can be easily interfaced with PV connected micro grid

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