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Implementation of New Three Phase Modular Multilevel Inverter for Renewable Energy Applications

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Abstract: *This project proposes a new three-phase modular multilevel inverter (MMLI) for renewable applications. The cascaded multilevel inverters are the most favourable topologies of multilevel converters. This project introduces a new multilevel inverter topology in which the numbers of independent dc voltage sources are reduced. Beside the number of dc voltage sources, in the proposed topology the number of switches is also reduced in comparison with that of the conventional cascaded multilevel inverter. A new modified pulse-width modulation method i.e. sinusoidal pulse width modulation is successfully applied to proposed inverter. To verify the applicability and performance of the proposed structure in PV renewable energy environment, simulation results are carried out by MATLAB/SIMULINK.*

Keywords: *Multilevel Inverters ML, Total harmonic distortion, Renewable energy sources.*

I. Introduction

The renewable energy sources are becoming popular for power generation because of depletion of fossil fuels. Fossil fuels are non-renewable, that is, they can get from finite resources that will be too expensive. There are many types of renewable energy resources-such as wind and solar energy-are constantly available. Most renewable energy comes either directly or indirectly from the sun. Sunlight, solar energy, can be used directly for heating and lighting homes and other buildings, for generating electricity, and for hot water heating, solar cooling, and a variety of commercial and industrial uses. In this paper mainly focussing on multilevel inverter circuit for renewable applications.

The voltages 0,+Vdc or –Vdc are produced by Voltage source inverters. It is known as the two level inverter. Requiring high switching frequency along with various pulse-width modulation (PWM) strategies for producing high quality output or current waveform with a minimum ripple content. These two-level inverters have some limitations in operating at high frequency because of switching losses and device ratings in high power and high voltage applications.

Capacitors would get to overcharge or completely discharge, in the condition of the multilevel converter reverts to a three level converter unless an explicit control is devised to balance the capacitor charge.The multilevel converters can overcome the drawbacks of the existing systems that use traditional multi pulse converters without the requirement for transformers. The relationship between the number of levels m, and the number of pulses p, can be formulated by p=6* (m-1) for a three phase system. There are many types of multilevel inverters namely, diode clamped, flying capacitors and cascaded multilevel inverter. The synthesized output waveform has many steps, which produce a staircase wave that approaches a desired waveform. If the number of level increases the harmonic distortion of the output wave decreases, approaching zero as the number of levels increases, if more steps are added to the waveform.Inorder to reduce harmonics produced by the inverter, multilevel inverter is used. A MLI can avoid the usage of step up transformer. For reducing the harmonic content present in the output waveform, multilevel inverter structure was initially introduced. Filtering requirements are reduced if the harmonic content decreases as the number of levels increases [2].If a PWM technique is not present, the switching losses can be avoided. Requirement of increase in rating of the device is not needed if output voltage and power is increased. Variable dc link controls the dc bus voltage V dc and this dc bus voltage sets the fundamental output Voltage of the inverter.. The multilevel converters require balancing the voltage across the series connected capacitors.Single phase configuration [7,3] is simple, but can extend that to get the three phase configuration. The configuration of less switches and simpler structure for three phase is proposed [4]. The switching loss is reduced by incorporating the hybrid control strategy [5].Three phase topologies are developed forreducing the complexity issue [1,6].

II. System Description

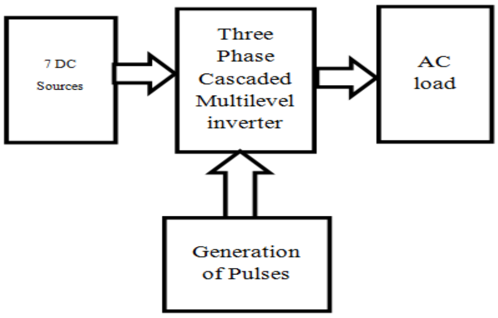

Fig. 1 Block Diagram of Existing System

Fig 1 explains the block diagrams of existing system.7 dc sources are used. Battery act as a DC sources. This DC input is given to the three phase multilevel inverter circuit and the inverter converts DC in to AC. For triggering the switches present in the inverter circuit, square wave pulses are given to the multilevel inverter Circuit. The output of the inverter is given to the AC load.

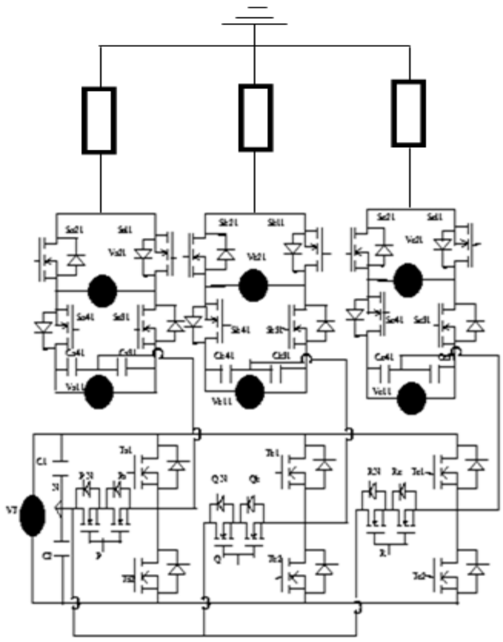

Fig 2 Circuit Diagram of Existing System

Fig 2 shows the two structures MHB and TTL inverters are combined and the hybrid modular MLI is developed. These are the nine voltage levels: $2V$, $3V/2$, V, $V/2$, 0, $-V/2$, $-V$, $-3V/2$, $-2V$ in symmetrical mode that can be produced by the hybrid modular structure. The existing circuit works on the basis of switching table are shown in table 1. From the above circuit (7 sources and 21switches) we can get the 9-level AC output and the total harmonic distortion is 6.24% so the circuit becomes bulky so to overcome this, we go for modified circuit.

Table I Switching Table of Existing Circuit

S.No	Sa 11	Sa 21	Sa 31	Sa 41	Ta1	Ta2	P	VA
1	1	0	0	1	1	0	0	+2V
2	1	0	0	1	0	0	1	+3V/2
3	1	0	0	1	0	1	0	+V
4	0	1	0	1	0	0	1	+V/2
5	1	0	1	0	1	0	0	0
6	1	0	1	0	0	0	1	-V/2
7	0	1	1	0	1	0	0	-V
8	0	1	1	0	0	0	1	-3V/2
9	0	1	1	0	0	1	0	-2V

Table I shows the synthesized output voltage and states of the switches for phase A. The switching table for the other two phases is same, but their switching instants are 120° and 240° apart from phase ‗A‘ . We can get for any number of levels by adding the h-bridge circuit in series but the circuit becomes complex and cost effective. Power semiconductor devices constitutes a multilevel converter is used to synthesize a sinusoidal staircase voltage waveform with several lower DC voltage sources A small changes in output voltage step results in high quality output voltage, reduction of voltage stresses on power switching devices, lower switching losses and higher efficiency. So the existing system works on the basis of the above switching table. The existing circuit consists of 21 switches and 7 sources which gives the three phase ac output with 6.24 % THD. The drawbacks like separate dc sources, switching is not easy in asymmetric MLI, complex circuit, loading effect, to get the three phase output three separate modules are added with phase shift. To overcome these drawbacks, we go for proposed circuit. The proposed circuit consists of 12 switches and 2 sources
which gives 4.69% THD. It has many advantages like modular construction, less power electronic switches, less gate drive circuit requirement. Pulses are generated with the help of PIC microcontroller (PIC 16F877) and optocoupler (TLP250) is used separately for all the 12 switches.

III. Proposed Model

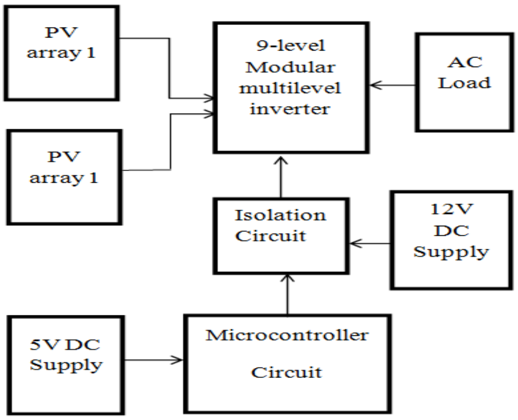

Fig 3 Block Diagram of Proposed System

Fig 3 shows the block diagram of proposed system. 2 PV arrays act as dc sources rating of 12V, 10W is used. This DC input is given to the 9-level modular multilevel inverter and AC output can be obtained. For triggering on the switches in the multilevel inverter circuit, PIC microcontroller (16F877A) is used. 5V DC supply needed for microcontroller circuit that can be obtained by using LM7805 regulator. If any supply fluctuates PIC will become heat that will affect the output to avoid that isolation circuit is used. The modified circuit can be obtained from the conventional circuit by reducing the number of switches and number of sources is as shown in fig 4. The generalized three-phase configuration of the proposed *MMLI* for *n* levels is proposed. The proposed topology consists of (*n-1*)/*2* basic modular cells, (*n-1*) isolated dc-voltage sources, and (*6n-6*) switching devices, and no electrolytic capacitors or power diodes are required. The modified circuit works on the basis of switching table is as shown in table II.The basic cell is constructed by combining two conventional three- phase voltage source inverters (*VSIs*) in distinct manner to build a new cell that able to generate three voltage levels across the output terminals (*T1* and *T2*, *T3* and *T4*, *T5* and *T6*).

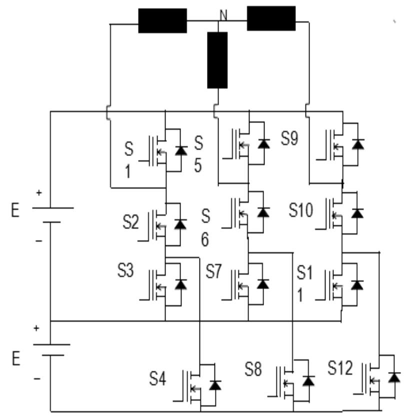

Fig 4 Circuit Diagram of Proposed System

The basic cell utilizes two dc-voltage sources along with twelve switching devices. Through repeating this cell [8,9] in cascading configuration, the output levels number can be increased to *n* levels. It is worth mentioning that increasing the number of cells is not affecting the voltage stresses over the power switches [10].So, in this project two modulation schemes are investigated to achieve the sinusoidal waveforms on the output: (a) low-frequency modulation scheme, (b) sinusoidal pulse-width modulation(*SPWM*)scheme.

Table II Switching Table of Proposed System

Statess	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12
1	0	1	1	0	0	1	0	1	1	0	0	0
2	1	0	0	0	0	1	0	1	1	0	0	0
3	1	0	0	0	0	1	0	1	0	1	1	0
4	1	0	0	0	0	1	0	1	0	1	0	1
5	1	0	0	0	0	1	1	0	0	1	0	1
6	1	0	0	0	1	0	0	0	0	1	0	1
7	0	1	1	0	1	0	0	0	0	1	0	1
8	0	1	0	1	1	0	0	0	0	1	0	1
9	0	1	0	1	1	0	0	0	0	1	1	0
10	0	1	0	1	1	0	0	0	1	0	0	0
11	0	1	0	1	0	1	1	0	1	0	0	0
12	0	1	0	1	0	1	0	1	1	0	0	0

Table II shows the switching table for proposed system. All the 12 switches operate on the basis of the above switching table in which ON and OFF occurs at all the 12 states. The outputs will be
-4E/3,-E,-2E/3,-E/3, 0, E/3, 2E/3, E, 4E/3.

IV. Technical Specifications

Component	Quantity and Value
Optocoupler (TLP 250)	• Input threshold current: IF=5mA (max.) • Supply current (ICC): 11mA (max.) • Supply voltage (VCC): 10−35V • Output current (IO): ±1.5A (max.) • Switching time (tpLH/tpHL): • 1.5µs(max.)
PIC 16F877A	• Operating Frequency DC - 20MHZ • Pin 1,11,32-MCLR/Vpp • Pin 13-OSC1/CLK IN • Pin 14-OSC2/CLK OUT • Pin8,9,10,15,17,22,25,26, 27,29,30 - Connects with optocoupler
IRF 840	8A,500V
LM7805	5V, in excess of 1A

Simulation Analysis
Existing System

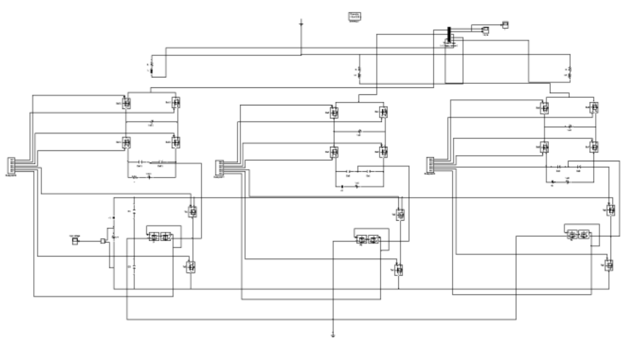

Fig 5 Simulation Diagram for Existing System

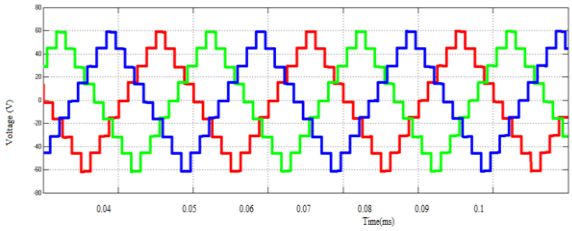

Fig. 6 OutputVoltage of Existing System

Simulation diagram of existing system is as shown in fig 5.To verify the performance of conventional circuit, its correspondingcircuit diagram has been drawn in Simulink library with the help of MATLAB software and simulation results are obtained. It consists of two PV modules, switches like S1 to S12 and scope block is incorporated in the circuit for voltage and current measurement for measuring voltages and currents. All these blocks taken from Simulink library browser, put in Simulink and output has been measured. Three phase 9-level output voltage of multilevel inverter is as shown in fig.6

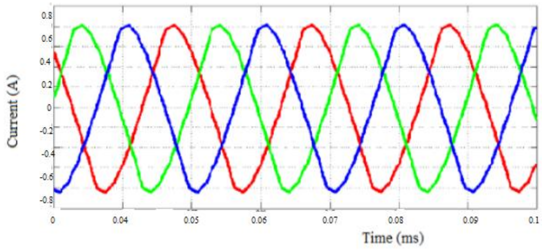

Fig.7 Three Phase Output Current of Existing System

Simulation results have been obtained for conventional circuit and its output current waveform is as shown in fig 7.9-stage output of a multilevel inverter is obtained by direct square wave pulses are given to the inverter circuit for triggering the MOSFET switch.

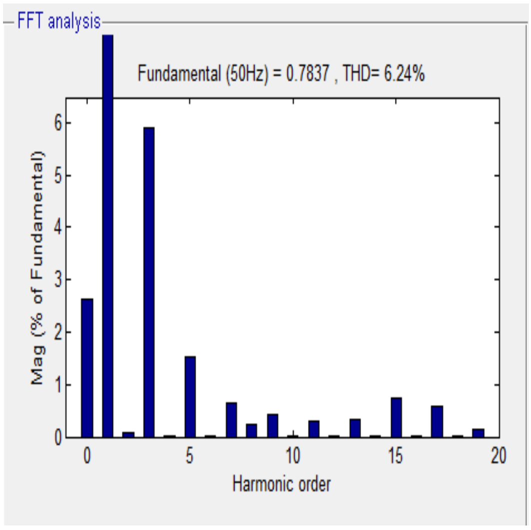

Fig.8 Graph for Total Harmonic Distortion

The graph for Total harmonic distortion is as shown in fig 8. THD value can be measured as 6.24% from the graph.

Proposed System

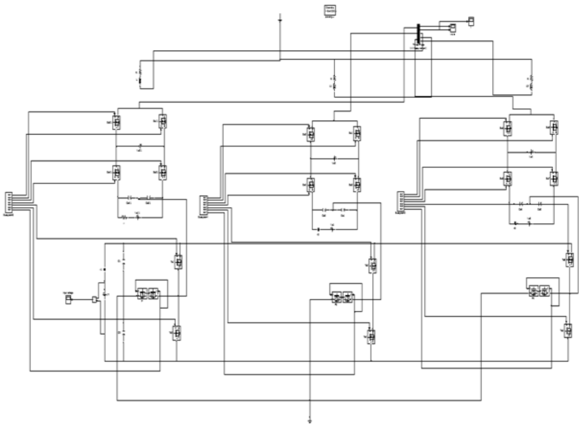

Fig.9 Simulation Diagram for Proposed System

To verify the performance of proposed circuit, its corresponding circuit diagram has been drawn in Simulink library with the help of MATLAB software and simulation results are obtained. Simulation circuit diagram is as shown in fig.9

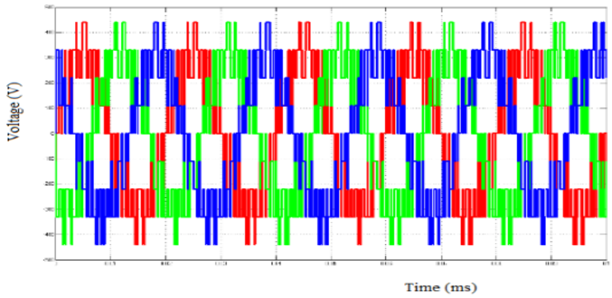

Fig. 10 OutputVoltage of proposed System

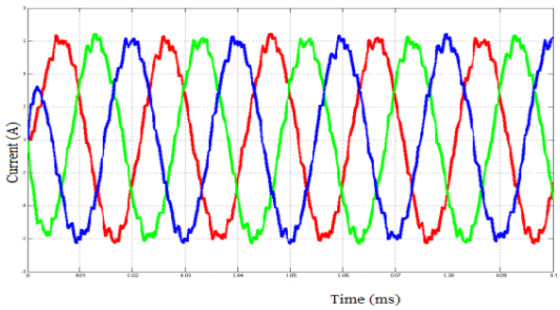

Fig.11 Three Phase Output Current of Existing System

From simulation circuit the output voltage and output current of a multilevel inverter circuit canbe measured and the corresponding graphs are shown in fig. 10 and fig.11

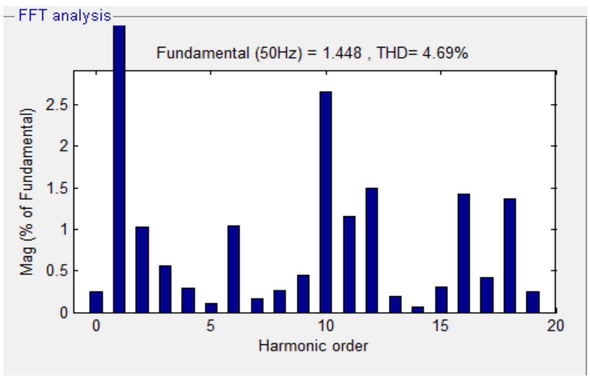

Fig.12 Graph for Total Harmonic Distortion

The graph for Total harmonic distortion is as shown in fig 12. THD value can be measured as 4.69% from the graph. The comparison table between existing and proposed system is as shown in TableIII.

TableIII Comparisonbetween Conventional andProposed System

S.No	Parameters	Conventional method	Proposed method
1.	Voltage sources	7	2
2.	Number of switches	21	12
3.	Total Harmonic Distortion	6.24 %	4.69%
4.	Generation of Pulses	By SPWM technique	By SPWM technique

V. Conclusion

A 9-level modular multilevel inverter for interfacing with renewable energy resources has been presented. The proposed topology results from modifying the conventional structure of a cascaded multilevel inverter. The modified PWM technique has also been developed to reduce switching losses. Also the proposed topology canreduce the number of required switches and number of sources. It also reduced total harmonic distortion when compared to conventional multilevel inverter.

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