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Modeling and Analysis of Asymmetrical Modified Hybrid Thirty One Level Inverter with Reduced THD

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Abstract: This paper proposes a 1Φ 31 level inverter using minimum number of switching devices and improved THD level. Multi Carrier based Pulse Width-Modulation (MC-PWM) control method is used to control MOSFET switches in input and load side. In this paper a modified hybrid asymmetrical multilevel inverter using eight numbers of switching devices driven by the multicarrier modulation technique is proposed. This inverter produces thirty one levels at output from four different dc voltage sources. Also THD level is taken into consideration to maintain the power quality. The proposed 31 level inverter is verified through MATLAB simulink.

Index Terms: Multi Carrier based Pulse Width Modulation (MC-PWM), Multi-Level Inverter (MLI), Total Harmonic Distortion (THD).

I. INTRODUCTION

Large size inverters are satisfying the increase in demand of high power requirement in various applications, which currently ranges from the few megawatts to hundreds of megawatts. Some examples of this fact are the medium voltage range (2.3 to 13.8 KV) AC motor drives. Due to the high voltage ranges a single power semiconductor switching device cannot be directly connected to the grid. As a solution for this problem a new converter type need to be introduced. Multilevel Converters uses high speed switching devices. These converters makes solutions to this problem by connecting power semiconductor switching devices directly to the grid using only one switching device between multiple DC voltage sources [1], [2]. Multilevel Converters are used in various applications like industrial drives, utility interfaces for renewable power sources (Solar, wind energy and fuel cells), FACTS devices, high voltage direct current transmission (HVDC), and traction drives systems. Several Multilevel topologies are proposed and established in previous decades. They are more difficult to operate and control than the traditional two level Inverters [3]-[5]. It is identified that asymmetrical multi-level inverters have more benefits than symmetrical inverter topologies [6]-[8].

Furthermore, numerous Pulse Width Modulation (PWM) methods have been developed and implemented for these types of inverters [9]-[12]. The modulation technique comprises of Sinusoidal Pulse Width Modulation (SPWM), selective harmonic elimination (SHE-PWM) and Space Vector Pulse Width Modulation (SVPWM) [13]-[14]. The recent and most favourable PWM control method is the Modular Multilevel Converter (M2C). Various modulation methods have been recommended for this inverter control topology. The aim of this paper is to deeply scrutinize and estimate one of them, based on a carrier phase-shifted Pulse Width Modulation (PWM) technique. Four different control topologies using Phase Shift PWM techniques on Modular Multilevel Converters are studied and explored in this work.

These types of control methods could have three control loops namely averaging Control, Individual Balancing Control and Arm Balancing Control. These topologies are easy to implement and do not demand high processing levels as in [15]-[17]. This paper proposes a switching frequency that encounters the following two conditions: adequate to maintain the cost possibility, and high enough to meet the harmonic performance. Also the proposed work creates an analytic equation for the output voltage waveform of the inverter.

II. EXISTING SYSTEM

The circuit diagram of the existing system is shown in figure 1. The number of switches used in the existing asymmetrical multi-level inverter is 12. This circuit will generate eleven levels of output voltage. It also requires filtering circuit to get the approximate sinusoidal output voltage. The output voltage and current waveforms of the existing system is shown in figure 2.

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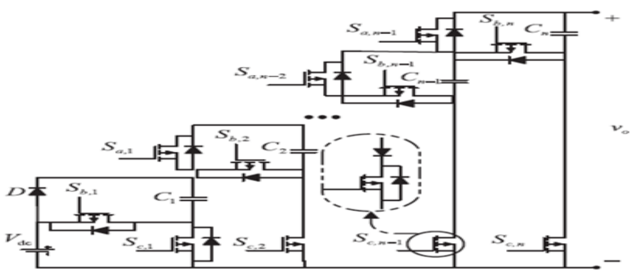

Fig.1 Simulation Diagram of the existing System

The output current is not in phase with the voltage. So a power factor correction (PFC) circuit is also needed while using the existing multi-level inverter. The value of THD is also high. Because of twelve switches the switching losses also in a considerable level. The control circuit required to generate PWM pulses also becomes more complex.

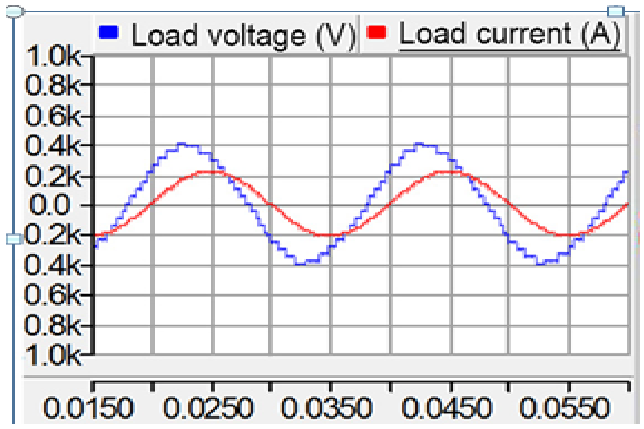

Fig.2 Output voltage and current of the existing system

So a new multi-level inverter topology is required to rectify all the above mentioned complications. In this paper a new modified asymmetrical hybrid multi-level inverter is proposed for the above mentioned problems. The proposed system will operates only with eight switches including four switches on source side and four on the load side. By using a new PWM method the switches are going to be controlled.

III. PROPOSED SYSTEM

A new modified modulation method for such type of Inverter is presented here. This proposed method delivers a wide operational range with high frequency modulation and this method can be implemented digitally. The mathematical calculation required also much reduced. This method produces a phase voltage consists of a rectangular signal overlaid on the quasi-square shaped reference signal. The reference signals are well-defined such that the usage of dc link voltage is maximized, while the dv/dt of the switching device is continuously retained as much as minimum value.

This proposed method can be implemented by setting an update time which is very short duration when compared to the ultimate time duration. It is also defined in the procedure for updating the rectangular signal of the reference voltage. The performance of the proposed method is compared with several existing methods and finally identified that this new PWM method can be suitable to control multilevel inverters.

IV. BLOCK DIAGRAM OF THE PROPOSED INVERTER

The proposed single-phase thirty one-level inverter is designed from the existing system. It includes a basic Single phase H-bridge inverter, four different DC voltage sources and four switches. The switching devices used here is MOSFET. Since its operating frequency is higher and produces lower switching losses as compared to the other transistors like BJT and IGBT. Also it is small in size and economical.

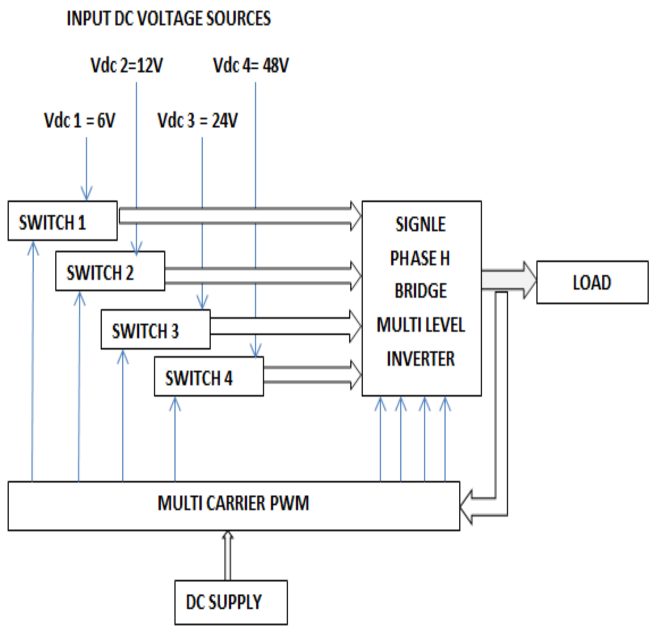

Fig.3. Proposed Multilevel inverter block diagram.

This H-bridge topology has more beneficial than the other topologies, i.e., lesser the number of power semiconductor switching devices, power diodes, and preferably no capacitors as compared to the inverters of the same number of levels. Proper switching of the inverter can produce thirty one output-voltage levels from four different dc voltage levels. To make simulation part as easier here four different DC supplies are used. In future it can be modified with different sources like solar, wind or any other similar renewable energy sources. Using this technique any number of levels can be achieved with reduced number of switching devices. But here a thirty one level inverter topology is implemented. For simplicity of implementation resistive load is used. Input and output switching of the proposed multi-level inverter is controlled by using multi carrier PWM technique.

V. PWM GENERATION

Pulse signals to the MOSFET switches are generated using Multi carrier Pulse Width Modulation technique. By comparing sinusoidal reference signal with Multi-carrier triangular signals, the required PWM signals can be generated. The generated signals are given to the switches which are connected in parallel with input DC voltage sources.

Again by comparing two sinusoidal signals having 180 degree displacement with the carrier triangular signal, Multi-carrier PWM signals are generated. These generated Multicarrier PWM signals are given to the MOSFET switches of the single phase inverter circuit. The Simulink model of multi carrier PWM technique is shown in figure 4.

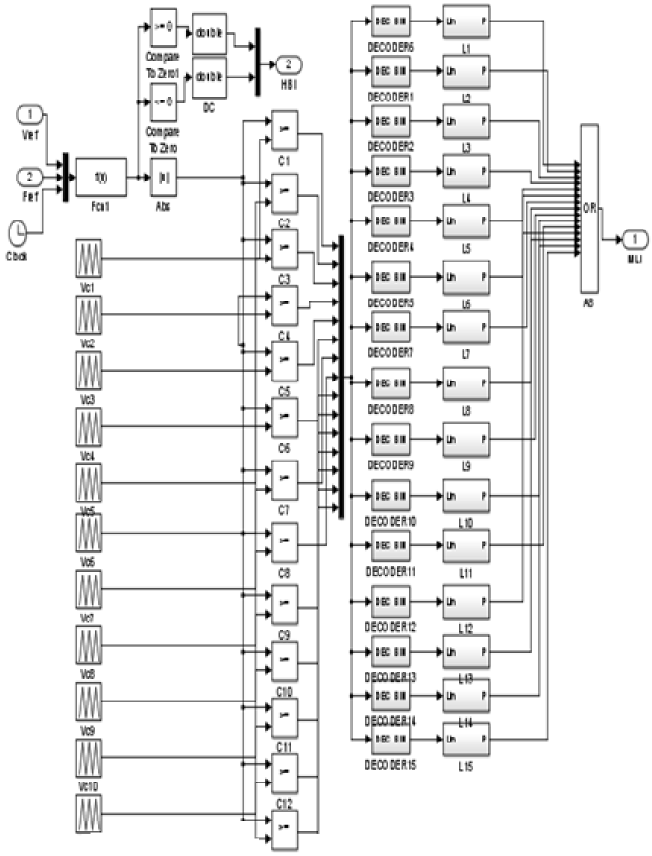

Fig 4. Simulink model of Multi Carrier PWM.

The figure 5 shows the multi carrier modulation pulses, these pulses are given to the additional switches S1, S2, S3, S4 which has switching frequency 5 KHz. The proper operation of these switches will control the voltage input to the inverter switches. This will used to create the sinusoidal output waveform at the load side of the inverter.

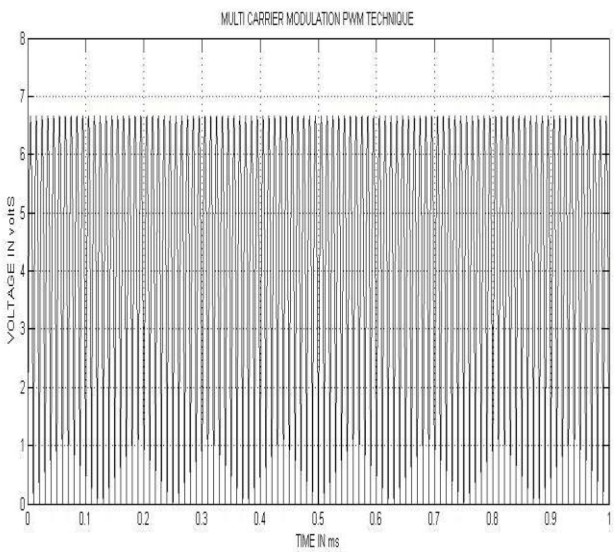

Fig. 5. Proposed system MCM comparison

The Multi Carrier Modulation technique will generate pulses for all the switches used in this proposed inverter. The figure 6 shows the PWM pulses to the additional switches which are connected in series with the DC voltage sources.

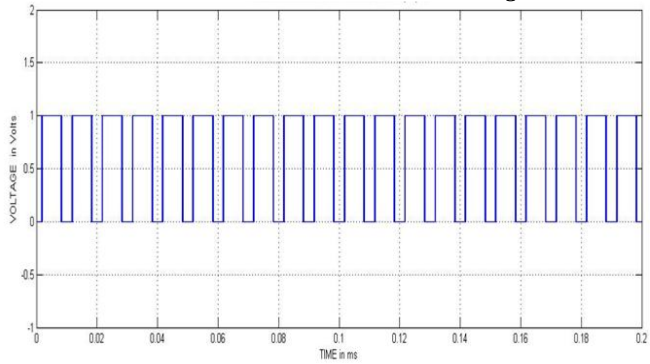

Fig.6. PWM pulse to inverter switches.

The switches are going to be operated according to the required instantaneous voltage value at the output side. In a particular instance only one switch or any combinations of multiple number of switches will be switched on. This switching sequence can be modified according to the required output. The modulation index of the MCM PWM technique is 0.95.

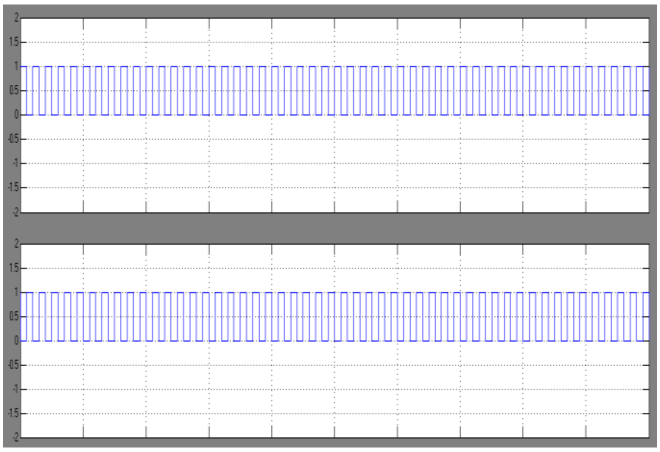

Fig.7.PWM pulse to the H bridge inverter

The figure 7 shows the PWM pulses to the H bridge inverter switches, the pulses are having 180° displacement. At any instant only two switches will be switched ON at the output side. So the maximum conduction period of a switch will be 180°. The output voltage and output current of the inverter is measured across the resistive load of the proposed inverter.

VI. PROPOSED SYSTEM SIMULINK

The proposed asymmetrical modified hybrid thirty one level inverter has designed using MATLAB SIMULINK. The Simulink model of the proposed system is shown in figure 5.1. Four different DC voltage sources with the voltage levels of 6V, 12V, 24V, and 48Vare connected in series with each MOSFET switches respectively.

This voltage source and MOSFET switch combination is again connected parallel with a diode. The diodes are used to avoid return current to the supply.

The Multi carrier modulation technique is used to produce the PWM pulses. This multi carrier PWM pulses are used to control the input MOSFET switches as well as the switches on the load side. Four MOSFET switches are connected on the load side to create the phase sequence.

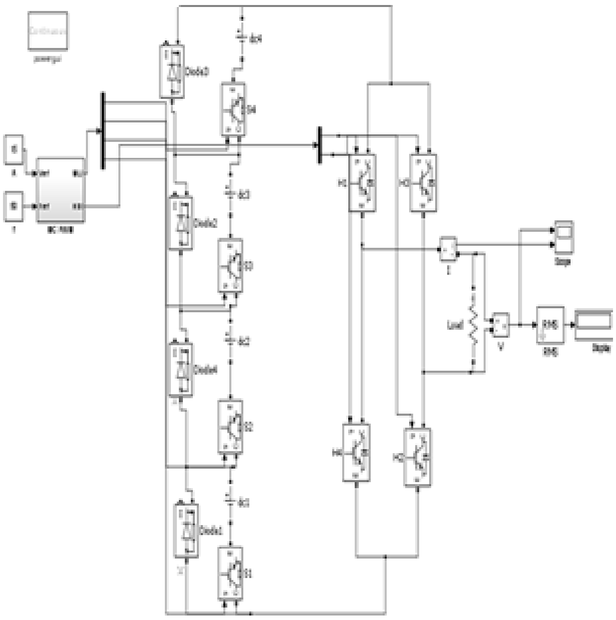

Fig.8. Simulink model of the proposed inverter.

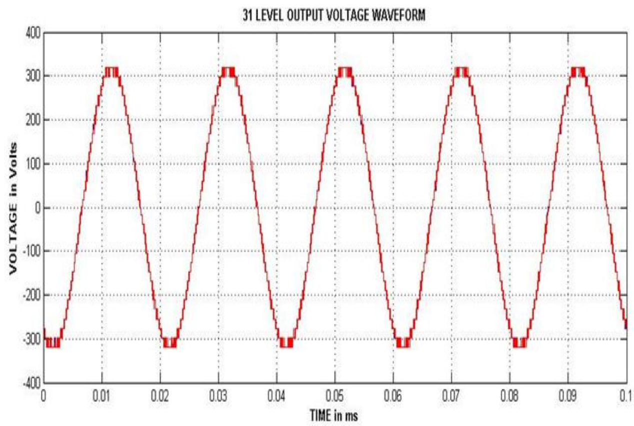

Fig.9. Proposed thirty one level inverter output voltage waveform.

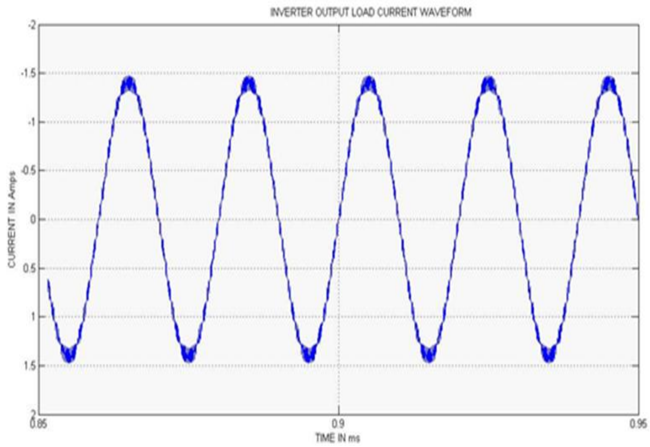

Fig.10.Proposed inverter output current waveform

The figure 9and 10shows the thirty one level inverter output voltage and output current waveforms respectively. Only by using eight switches this purity in sinusoidal voltage and current waveforms are generated. Filtering circuits are not used in input and output side.

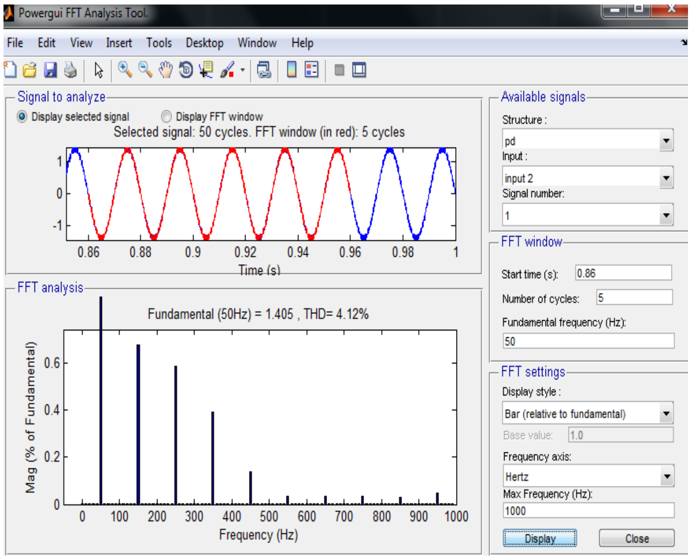

Fig.11. THD level

The figure 11 shows the THD value of the proposed inverter's output voltage. Even though the output voltage level is increased the THD value of output voltage is maintained at 4.12%.

VII. CONCLUSION

Four different input DC voltage levels are used in this multi-level inverter. Totally eight MOSFET switches are used. Four switches are used to control input DC voltages and the remaining four switches controls the output respectively. Among different PWM methods, Multicarrier PWM technique is used to generate pulses for the switching operation of MOSFET switches. The proposed asymmetrical modified hybrid multilevel inverter gives single phase AC output voltage with thirty one levels only by using eight MOSFET switches. The THD level of output voltage is reduced up to 4.12%. The proposed system is simulated using MATLAB Simulink and the output waveforms are given. This method can be improved to generate three phase output in future.

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