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Performance Analysis of Reversing Voltage Multilevel Inverter

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***Abstract*— Multilevel inverters have end up more popular over time in electric excessive power utility with the promise of less disturbances and the possibility to characteristic at lower switching frequencies than everyday two-stage inverters. This paper provides information about, reduced device count multilevel inverter topologies & its modulation schemes. Here also compared the hybrid multilevel inverters (Reversing voltage Multilevel inverter) with and without the usage of SPWM method & shown that, the harmonic distortion of the output Voltage waveform decreases in the RV MLI's.**

These multilevel inverters will also be compared with conventional multi level topologies to investigate the advantages of using hybrid topology. Basic switching, Modulation strategies & component comparison will also be presented in this work.

Keywords—Total harmonic distortion; Cascaded multilevel inverters; PWM Techniques

I. INTRODUCTION

The call for high-voltage excessive-power inverters is increasing, and it is not possible to influence an energy semiconductor switch to a excessive-voltage network without delay. Therefore, multilevel inverters were developed and are being evolved now. With increasingly more dc voltage assets within the input side, a sinusoidal like waveform can be generated on the output [1]. As a result, the total harmonic distortion (THD) decreases, and the output waveform quality will increase, which might be the two principal benefits of multilevel inverters. In addition, lower switching losses, lower voltage strain of dv/dt on switches, and higher electromagnetic interference are the opposite most critical benefits of multilevel inverters. Those sorts of inverters are typically divided into three principal classes, i.e., diode-clamped multilevel inverters, flying capacitor multilevel inverters, and cascaded multilevel inverters .

A multi-level inverter is being utilized for multipurpose packages, such as active strength filters, static var compensators and gadget drives for sinusoidal and trapezoidal contemporary packages. The concept of multilevel converters has been introduced in the year 1975 [2],[3]. A multilevel inverter has several blessings over a conventional 2-stage inverter that uses excessive switching frequency pulse width modulation (PWM). Many Multilevel Topologies has been proposed over final 2 decades. A multilevel converter not best achieves high electricity ratings, however also enables the use of renewable electricity resources. Renewable electricity resources consisting of photovoltaic, wind, and fuel cells can be without problems interfaced to a multilevel converter device for a high energy software.

A multilevel inverter has numerous benefits over a traditional two-level inverter that makes use of excessive switching frequency pulse width modulation (PWM). The attractive capabilities of a multilevel converter can be in brief summarized as follows. Multilevel inverters now best can generate the output voltages with very low distortion, lessen the dv/dt stresses; therefore electromagnetic compatibility (EMC) problems may be reduced. They are able to produce smaller CM voltage; therefore, the strain within the bearings of a motor connected to a multilevel motor drive can be reduced. It must be cited that decrease switching frequency normally means lower switching loss and higher efficiency. Multilevel converters do have a few dangers. One unique downside is the greater number of semiconductor switches are to be used. Even though lower voltage rated switches may be applied in a multilevel converter, each switch requires a associated gate power circuit. This will cause the general system to be more highly-priced and complex.

Considerable modulation techniques and manipulate paradigms have been evolved for multilevel converters which include sinusoidal pulse width modulation (SPWM), selective harmonic elimination (SHE-PWM) [16], space vector modulation (SVM), and others [17].

II. LITERATURE SURVEY

A. Cascaded H-Bridge (CHB) MLI

Cascaded H-Bridge (CHB) configuration has currently emerge as very popular in high-energy AC supplies and adjustable-speed drive applications. A cascade multilevel inverter includes a sequence of H-bridge (single-phase full bridge) inverter gadgets in each of its 3 H-bridge unit has its own dc supply [6],[8],[10]. Each SDC (separate D.C. source) is related to a single-section complete-bridge inverter. The ac terminal voltages of different stage inverters are related in collection through exceptional combinations of the four switches, S1-S4, every converter level can generate three distinctive voltage outputs, $+V_{dc}$, $-V_{dc}$ and zero.

The AC outputs of different complete-bridge converters inside the identical segment are linked in collection such that the synthesized voltage waveform is the sum of the individual converter outputs. Notice that the wide variety of output-section voltage degrees is described in a extraordinary manner from the ones of the two previous converters (i.e. diode clamped and flying capacitor) [14]. On this topology, the variety of output-section voltage levels is described via m= 2N+1, wherein N is the number of DC sources. A seven-level cascaded converter, as an instance,

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includes three DC sources and 3 full bridge converters. Minimal harmonic distortion may be acquired through controlling the undertaking angles at extraordinary converter stages [4],[5],[9]. Each H- bridge unit generates a quasi-square waveform by 'phase shifting its positive and negative phase legs' switching timings. Every switching tool usually conducts for 180° (or half of cycle) irrespective of the pulse width of the quasi-rectangular wave. In the motoring mode, power flows from the batteries through the cascade inverters to the motor. Within the charging mode, the cascade converters act as rectifiers, and electricity flows from the charger (ac source) to the batteries. The cascade converters can also act as rectifiers to assist recover the kinetic power of the automobile if regenerative braking is used [11],[12]. The cascade inverter can also be used in parallel HEV configurations. This new converter can keep away from greater clamping diodes or voltage balancing capacitors.

The aggregate of the 180° conducting technique and the sample-swapping scheme make the cascade inverter's voltage and modern stresses the same and battery voltage balanced. Identical H-bridge inverter units can be applied, consequently enhancing modularity and manufacturability and greatly lowering production prices. Battery-fed cascade inverter prototype using an induction motor at 50% and 80% rated speed each the voltage and contemporary are almost sinusoidal. Electromagnetic interference (EMI) and common mode (CM) voltage also are plenty less than what might result from a PWM inverter because of the inherently low dv/dt and sinusoidal voltage output [13].

A cascaded multilevel inverter is discussed to eliminate the excessively huge range of
(1) Bulky transformers required via conventional multi pulse inverters,
(2) Clamping diodes required with the aid of multilevel diode-clamped inverters, and
(3) Flying capacitors required by means of multilevel flying-capacitor inverters.

Additionally, it has the subsequent features:
1. It is an awful lot more suitable to excessive-voltage, high-electricity programs than the traditional inverters.
2. It switches each tool best once in line with line cycle and generates a multistep staircase voltage waveform coming near a pure sinusoidal output voltage via growing the variety of stages.
3. Because the inverter structure itself includes a cascade connection of many single-segment, full-bridge inverter (FBI) devices and every bridge is fed with a separate DC source, it does no longer require voltage balance (sharing) circuits or voltage matching of the switching devices.
4. Packaging format is lots easier due to the simplicity of shape and lower thing rely.
5. Soft-switching may be used in this shape to avoid bulky and lossy resistor-capacitor-diode snubbers.

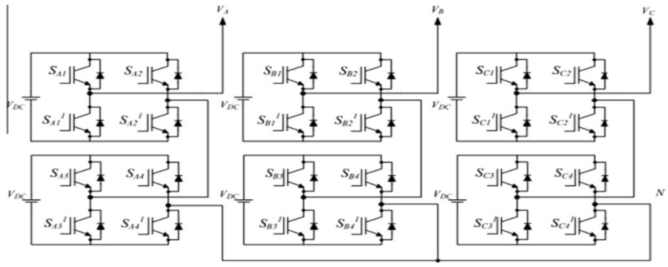

Fig 1. Three phase five level structure of cascaded H bridge inverter

III. REVERSING VOLTAGE TOPOLOGY

A.GENERAL DESCRIPTION

In conventional multilevel inverters, the energy semiconductor switches are blended to provide a excessive frequency waveform in fine and poor polarities. However, there's no need to utilize all the switches for generating bipolar stages. This concept has been positioned into practice by the new topology [7]. The hybrid multilevel topology (Reversing Voltage Inverter) which separates the output voltage into two parts. One of its element is called level generation part and is answerable for level generating in positive polarity. This part requires high frequency switches to generate the required levels. The switches on this element must have excessive-switching-frequency capability. The other part is referred to as polarity generation part and is accountable for producing the polarity of the output voltage, which is the low-frequency element running at line frequency.

This topology easily extends to higher voltage degrees by using duplicating the middle level as proven in Fig.2. Consequently; this topology is modular and can be easily multiplied to higher voltage ranges via adding the middle level in Fig.2. This requires fewer additives in comparison to traditional inverters. It simply requires half of the traditional providers for SPWM controller. The motive is that, consistent with Fig.2, the multilevel converter works simplest in positive polarity and does not generate negative polarities. In evaluation with a cascade topology, it calls for just one-third of isolated power components utilized in a cascade-type inverter.

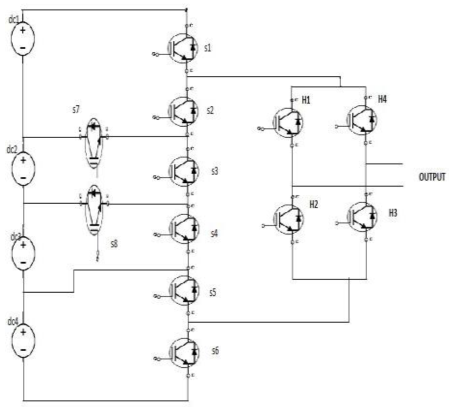

Figure 2. Circuit diagram of 1Φ 9 level RV inverter

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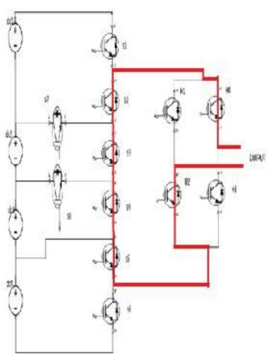
B. MODES OF OPERATION

Switching sequences in this converter are simpler than its counter elements. In keeping with its inherent benefits, it does not need to generate negative pulses for negative cycle manipulate. For that reason, there's no need for extra conditions for controlling the negative voltage. As an alternative, the reversing full-bridge converter performs this challenge, and the desired level is produced via the excessive-switching-frequency aspect of the inverter. Then, this level is translated to negative or advantageous consistent with output voltage necessities.

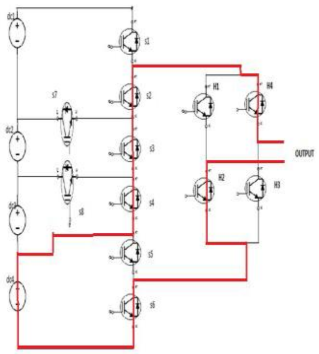
As seen from table I, there are six possible switching styles to control the inverter, that allows you to avoid unwanted voltage stages in the course of switching cycles, the switching modes have to be decided on so that the switching transitions come to be minimal at some stage in each mode transfer, subsequently it'll lessen switching strength dissipation. The series of switches (2-3-4-5), (2-3-4-6), (2-3-8-6), (2-7-6), and (1-6) are selected for levels 0 up to 4, respectively [18].The output voltage level is the total of voltage sources, which are included in the current path that as shown in the following fig.3.

Table.1 Switching states of 1Φ RV inverter

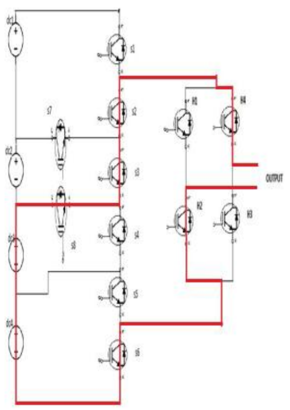
Level / Mode	0	1	2	3	4
1	2,3,4,5	2,3,4,6	2,8,5	2,7,6	1,6



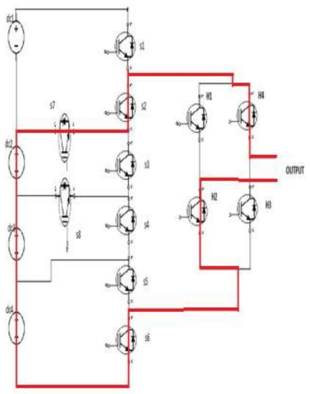
Level 1 = 0Vdc



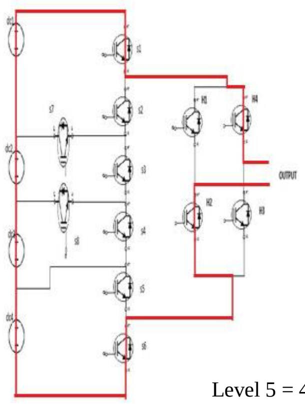
Level 2 = 1Vdc



Level 3 = 2Vdc



Level 4 = 3Vdc



Level 5 = 4Vdc

Fig 3. Switching levels of single phase nine level RV inverter

C. CONTROL STRATEGY

PD (phase Disposition) SPWM is used to control the inverter. Here all carriers are in phase however have exact offset from each other. Conventional multilevel inverter requires N-1 carriers for N level output. On account only positive levels are generated in the proposed topology, we can reduce the wide variety of carriers required to (N-1)/2 . All excessive frequency switches are operated under PDSPWM strategy and the lower frequency switches are to be operated at line frequency [15]. The 3 carriers and sinusoidal modulating signal for inverter control strategies are shown in figure 4.

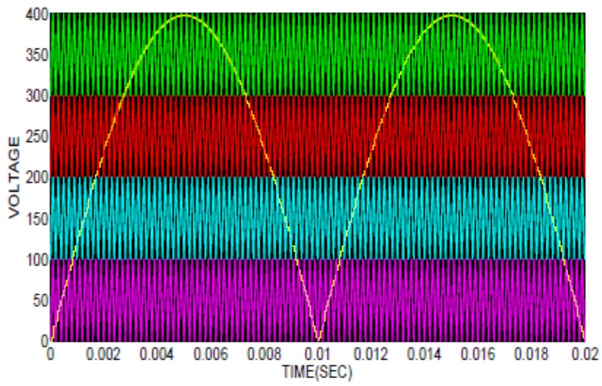


Fig 4. Carrier and modulating signals of single phase nine level RV inverter

D.OBSERVATIONS AND OUTCOMES OF STUDY

The numerous multilevel inverter topologies include diode clamped multilevel inverter, capacitor clamped multilevel inverter and cascaded H bridge multilevel inverter. In diode clamped multilevel inverter a bank of series connected capacitors will divide the entire dc link voltage into smaller steps. Inverter poles can be linked to anyone of these voltage steps to generate the entire multilevel output. Flying capacitor multilevel inverter includes precharged capacitors and this capacitor voltage is brought or subtracted from the dc voltage to obtain the specified tiers. Cascaded H bridge multilevel inverter consists of some of single segment H bridges connected in collection, the output of which is same to the sum of voltage produced by way of each bridge.

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Also the reliability of a system is indirectly proportional to the number of components used. As the variety of excessive frequency switches is increased, the reliability of the converter is decreased. From table.2 it is cleared that RV requires very much less wide variety of switches than different topologies.

Table 2. Number of three phase components required

Inverter Type	NPC	Flying capacitor	Cascade	RV topology
Main switches	6(N-1)	6(N-1)	6(N-1)	3((N-1)+4)
Main diodes	6(N-1)	6(N-1)	6(N-1)	3((N-1)+4)
Clamping diodes	3(N-1)(N-2)	0	0	0
DC bus capacitors	(N-1)	(N-1)	3(N-1)\2	(N-1)/2
Flying capacitors	0	3/2(N-1)(N-2)	0	0
Total numbers	(N-1)(3N+7)	½(N-1)(3N+20)	27/2(N-1)	(13N+35)/2

The N in the table suggests the number of levels. As shown in table, the number of components required for proposed topology is much less in comparison to different topologies. The clamping diodes were used in NPC topology only. The remaining topologies will not use clamping diodes. The flying capacitor is likewise used only in flying capacitor topology most effective.

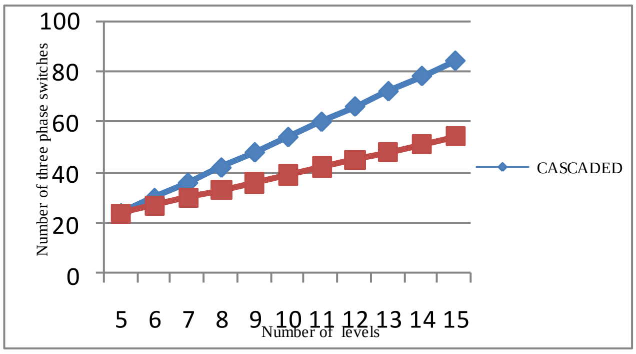

Fig 5. Number of components required

IV MATLAB/SIMULINK MODEL

The hybrid multilevel topology (Reversing Voltage Inverter) which separates the output voltage into two parts. One of its element is called level generation part and is answerable for level generating in positive polarity. The other part is referred to as polarity generation part and is accountable for producing the polarity of the output voltage, which is the low-frequency element running at line frequency.

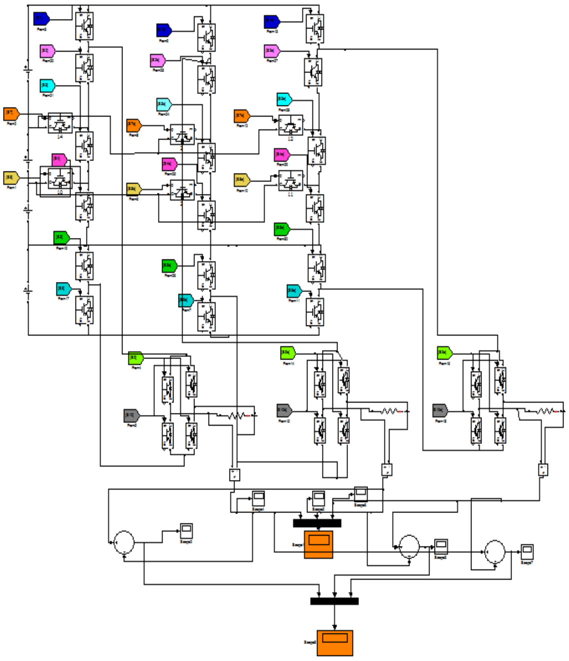

Fig.6. Simulation circuit of nine level Reversing Voltage MLI

Fig.6. shows the simulation circuit of three phase nine level Reversing Voltage MLI. Here a total of 12 switches are required. Half of them are used for level generation & the other half is used for generating the polarity of the output voltage.

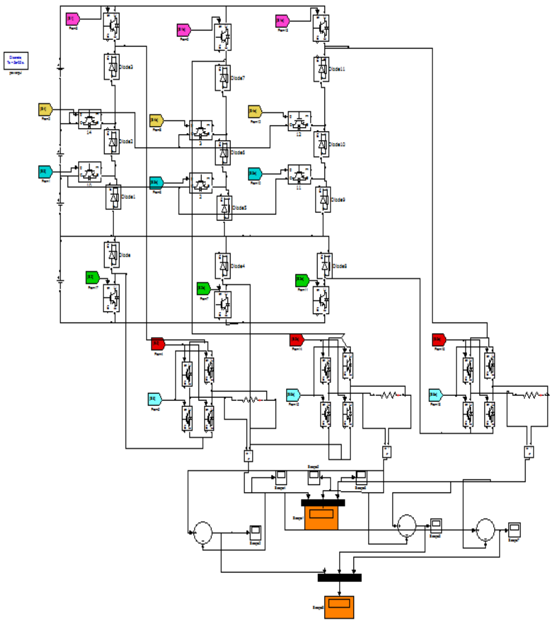

Fig.7. Simulation circuit of modified nine level Reversing Voltage MLI

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Fig.7. shows the Simulation circuit of three phase modified nine level Reversing Voltage MLI. Modification have been done to the basic RV topology is that the number of switches are again reduced. However, there is no need to utilize all the switches for generating bipolar levels. This idea has been put into practice by the modification to the basic topology. This topology also has two parts. One part is named level generation part and is responsible for level generating in positive polarity. The other part is called polarity generation part and is responsible for generating the polarity of the output voltage.

Here a total of 8 switches are required. Four of them are used for level generation & other 4 switches are used for generating the polarity of the output voltage.

V SIMULATION RESULTS

Simulated three phase nine-level output phase Voltages waveform of RV MLI

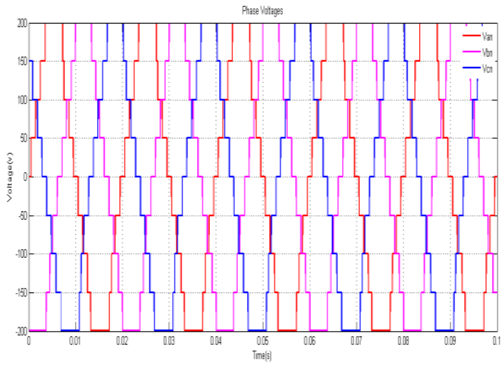

Fig.8. Simulated three phase nine-level output phase Voltages waveform of RV MLI

Fig.8. shows the three phase 9 level output phase voltages waveform of RV MLI , here the input voltage of each cell is 50v dc & the output voltage is 200v ac.

Simulated three phase nine-level Output Line Voltages waveform of RV MLI

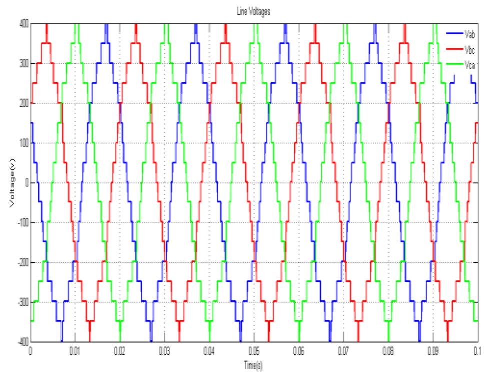

Fig.9. Simulated three phase nine-level Output Line Voltages waveform of RV MLI

Fig.9 shows the three phase 9 level output line voltages waveform of RVMLI , here the input voltage of each cell is 50V dc & the output voltage is 400V ac.

Simulated three phase nine-level Output phase Voltages waveform of RV MLI Using SPWM Strategy

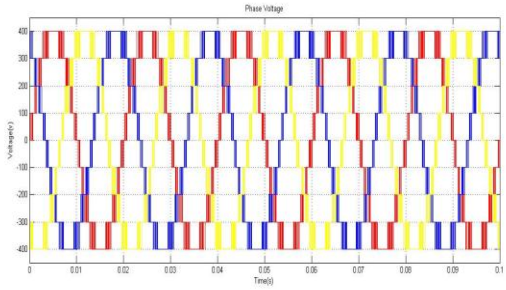

Fig.10. Simulated three phase nine-level Output phase Voltages waveform of RV MLI Using SPWM Strategy

Fig.10 shows the three phase 9 level output phase voltages waveform of H bridge MLI using SPWM , here the input voltage of each cell is 100V dc & the output voltage is 400V ac.

Simulated three phase nine-level Output line Voltages waveform of RV MLI Using SPWM Strategy

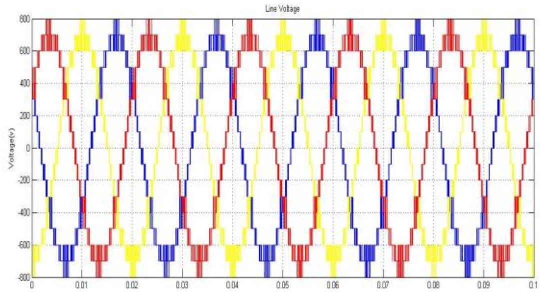

Fig.11. Simulated three phase nine-level Output line Voltages waveform of RV MLI Using SPWM Strategy

Fig.11 shows the three phase 9 level output line voltages waveform of RV MLI using SPWM, here the input voltage of each cell is 100V dc & the output voltage is 800V ac.

Simulated three phase nine-level output phase voltages waveform of modified RV MLI

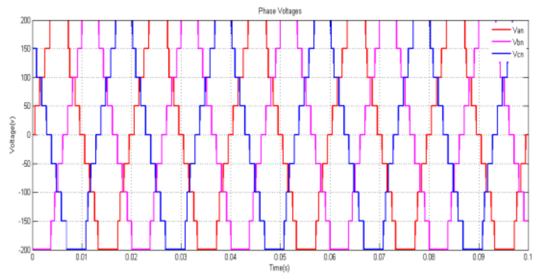

Fig.12. Simulated three phase nine-level output phase voltages waveform of modified RV MLI

Fig.12 shows the three phase 9 level output phase voltages waveform of modified RV MLI ,here the input voltage of each cell is 50V dc & the output voltage is 200V ac.

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Simulated three phase nine-level output line voltages waveform of modified RV MLI

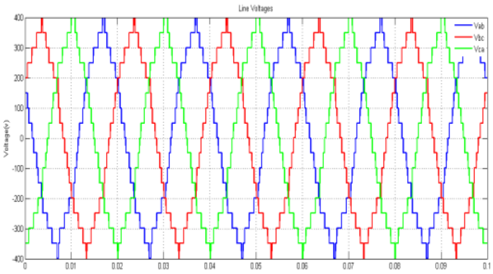

Fig.13 Simulated three phase nine-level output line voltages waveform of modified RV MLI

Fig.13 shows the three phase 9 level output line voltages waveform of modified RV MLI ,here the input voltage of each cell is 50V dc & the output voltage is 400V ac.

Simulated three phase nine-level output phase voltages waveform of modified RV MLI using SPWM Strategy

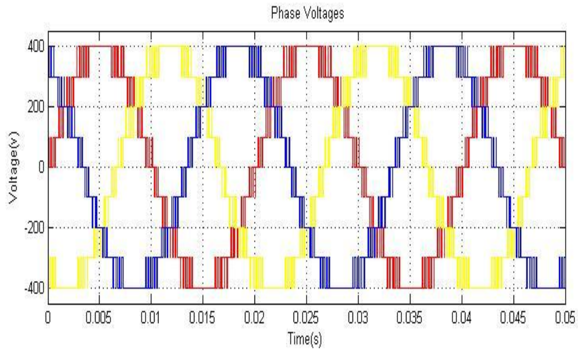

Fig.14 Simulated three phase nine-level output phase voltages waveform of modified RV MLI using SPWM Strategy

Fig.14 shows the three phase 9 level output phase voltages waveform of modified RV MLI using SPWM,here the input voltage of each cell is 100V dc & the output voltage is 400V ac.

Simulated three phase nine-level output line voltages waveform of modified RV MLI using SPWM Strategy

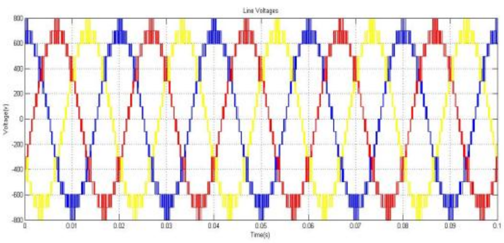

Fig.15 Simulated three phase nine-level output line voltages waveform of modified RV MLI using SPWM Strategy

Fig.15 shows the three phase 9 level output line voltages waveform of modified RV MLI using SPWM,here the input voltage of each cell is 100V dc & the output voltage is 800V ac.

Table 3. THD comparison

TOPOLOGY	THD ANALYSIS (%)	
	Without Modulation	With Modulation (SPWM)
Reversing Voltage MLI	9.82	9.64
Modified Reverse Voltage MLI	9.32	8.70

VI CONCLUSION

The three phase nine level Reversing Voltage MLIs & the modified Reversing Voltage MLIs were simulated with and without SPWM in MATLAB/SIMULINK environment. The following things can be concluded about the modulation techniques and the multilevel inverters:

1.On comparing the three phase nine level RV MLI's & modified RV MLI's using SPWM strategy we can analyse that, the harmonic distortion of the output Voltage waveform decreases in the modified RV MLI's.
2.The presented nine level Reversing Voltage MLI's can eliminate roughly half the number of switches, their gate drivers and also the THD when compared with the existing cascaded MLI counterparts.
3.So the Reversing Voltage MLI's are cost less due to the savings from the eliminated gate drivers and from fewer assembly steps because of the substantially reduced number of components, which also leads to a smaller size and volume.

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