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Review Article

A MULTILEVEL INVERTER WITH REDUCED SWITCH COUNT ANALYSED BY VARIOUS SWITCHING TECHNIQUES

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Abstract
This paper is mainly aims at comparing the reduced switch inverter with general switching and three PWM techniques. Reducing switch count helps to gets cost cut down of inverter by large scale. This also makes compact, logic easy and also easy control. These kinds of inverters are very useful for low power rating or medium power ratings[1]. But high power rating requirements we have to use normal inverters. Here in this paper we are testing the proposed model by 4 different techniques. Such as normal switching and 3 of level shift PWM techniques.

Keywords: Level Shift PWM, Reduced Switch Inverter.

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INTRODUCTION

We know that PWM techniques are widely used in H- Bridge inverters. In H- Bridge inverters we will have multiple DC sources depending on number of levels of switching. So that we will have DC offset obtained by switching of specified sources, which will not be present in reduced switch inverter model used in this paper because of its switching pattern. So, the switching pattern will make PWM output to touch zero at every instant of pulse.

Reduced switch inverters are generally considered for small level or medium level voltage applications. They came to picture because of using it we can reduce number of switches in a multi-level inverter. And we can also reduce inverter size by a large scale not only because of reduction in switches but also reduction in a large size of cooling equipment or fan size. In the simulation the values used are voltage is 10 V for source 1 and 30V for source 2 and 3, resistance of 10 Ohm, inductance of 0.03 Henry. And carrier frequency used in the simulation is 2000Hz.

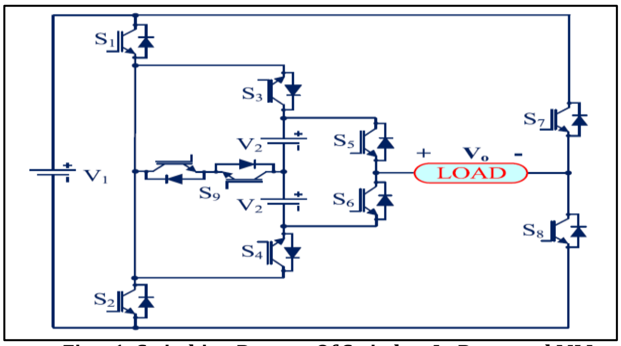

Fig – 1: Switching Pattern Of Switches In Proposed MLI

METHODOLOGY

Here the switching sequence shown in fig is having only one switching pattern for each level. So that we will have repetitive or duplicate switching patterns for any level, which is beneficial.

The results of the analysis of scientific research indicate that Here we are comparing a sine wave with its Ma

S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9	V_o
1	0	0	1	1	0	0	1	0	$7V_{dc}$
0	1	0	1	1	0	0	1	0	$6V_{dc}$
0	1	0	1	1	0	1	0	0	$5V_{dc}$
1	0	0	0	1	0	0	1	1	$4V_{dc}$
0	1	0	0	1	0	0	1	1	$3V_{dc}$
0	1	0	0	1	0	1	0	1	2_{dc}
1	0	1	0	1	0	0	1	0	V_{dc}
1	0	1	0	1	0	1	0	0	0
0	1	0	1	0	1	1	0	0	$-V_{dc}$
1	0	0	0	0	1	0	1	1	$-2V_{dc}$
1	0	0	0	0	1	1	0	1	$-3V_{dc}$
0	1	0	0	0	1	1	0	1	$-4V_{dc}$
1	0	1	0	0	1	0	1	0	$-5V_{dc}$
1	0	1	0	0	1	1	0	0	$-6V_{dc}$
0	1	1	0	0	1	1	0	0	$-7V_{dc}$

Fig – 2: Simulated MLI Model

(amplitude modulation). So we have to split the Ma into 14, so we can compare with sine wave. But maximum Ma is 1, if we divide it the decimal point accuracy may miss. That is why, we have multiplied Ma by 7 because positive and negative cycles contains 7 levels each. So, we can compare every level with 1 as a new Ma.

We have made Ma multiplied by 7 and sine wave is compared with increased Ma value at instance of 1. So, we compare sine wave at all 7 top levels and 7 bottom levels to get the pulse generated to turn on respective switch by comparing it with switching table.

In inverters with PWM we generally use a carrier wave mostly triangular to compare with sine wave to produce PWM output. So in Simulink we have block called repeating sequence in which we can define our own carrier. We will define frequency of carrier wave to be very much higher than sine wave so that we can get fine PWM, as it compares with more points on sine wave. In the simulation described in the paper we defined the frequency of carrier wave frequency to be 2k Hz. Similar to non PWM switching described above we will multiply Ma of sine wave with 7 and we will compare each level with a carrier frequency which will be bounded between any two Ma's like between Ma=1 and 2, or Ma=2 or 3.

Non PWM Switching:

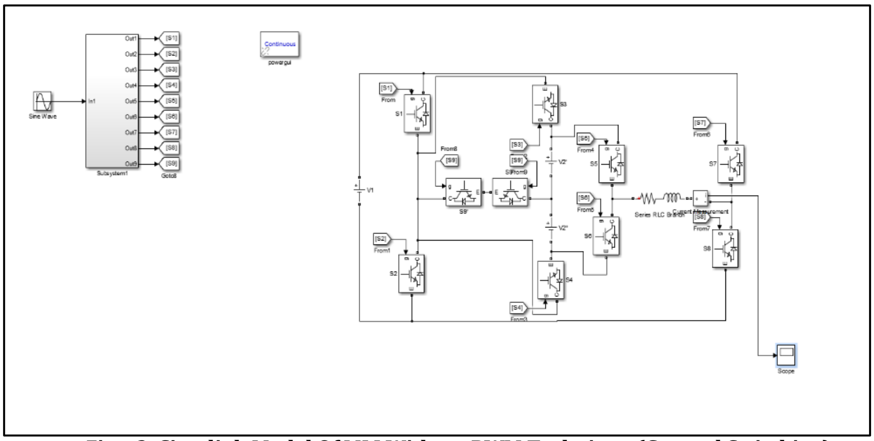

Fig – 3: Simulink Model Of MLI Without PWM Technique (General Switching)

MLI's are generally better than conventional square wave inverter of 3 levels because of they are generally having good control over harmonics, better wave form, and control[1]. They have many applications in renewable energy generation, HVDC applications, etc. Neutral point clamping, flying capacitor, cascaded H- bridge as basic kinds of MLI[1-4]. But here we are used a new methodology i.e., reduced switch MLI

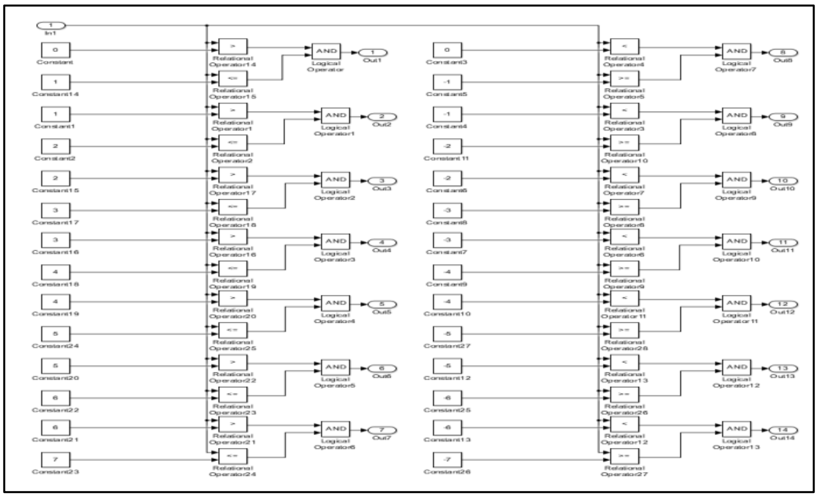

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Fig – 4: Switching Logic Of Non PWM Model

This circuit carried by various techniques and current THD is observed. The FFT analysis (Fast Fourier Transformation) is carried to get to know about THD and harmonic profile[5]. This paper helps to analyse the PWM techniques of level shift and non PWM switching method by comparing their THD's, harmonic profile, wave form etc. Matlab 2014 B version, intel i5 processor, 8 GB 64 Bot RAM is used for simulation.

Phase disposition PWM technique used inverter

This is the simulation diagram of phase disposition PWM used inverter. In phase disposition technique we will have the level of PWM carrier pulse as shown above. They will be parallel to each other and every level will be in phase with each other. So, we made a triangular pulse with repeating sequence and then we will add 1 to both upper and lower limits to get higher wave forms and add -1 to get lower triangular waveforms. Then it is compared with sine wave of Ma of 7 to obtain PWM. Then we will give the pulse to respective switches to turn on inverter.

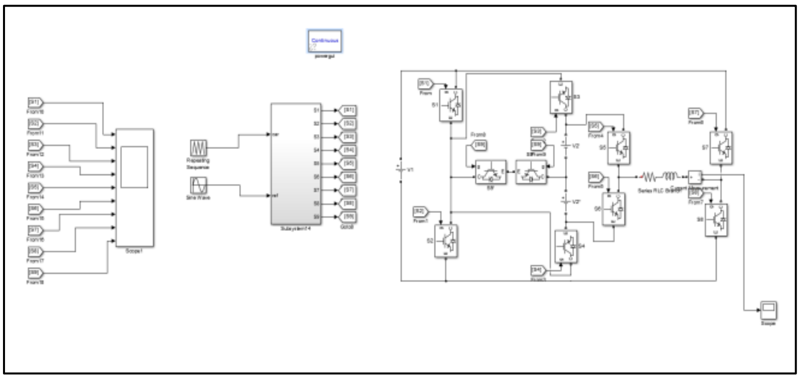

Fig – 5: Simulink Model Of MLI With Phase Disposition PWM Technique

We have generated a triangular pulse of positive half with lower limit as zero and upper limit as one. Then we have taken it and added one to both upper and lower limits to get positive levels and added -1 to get negative levels. Then it is compared to sine and the result will be generation of PWM pulses. Then we have to see at that particular level which switches are turned on. By that we will add all PWM pulses required for a switch to turn on with a gate. As there were no repeating voltage levels or duplicate voltage levels we have no problem.

Phase opposition disposition PWM technique used inverter

This is the simulation diagram of phase opposition disposition

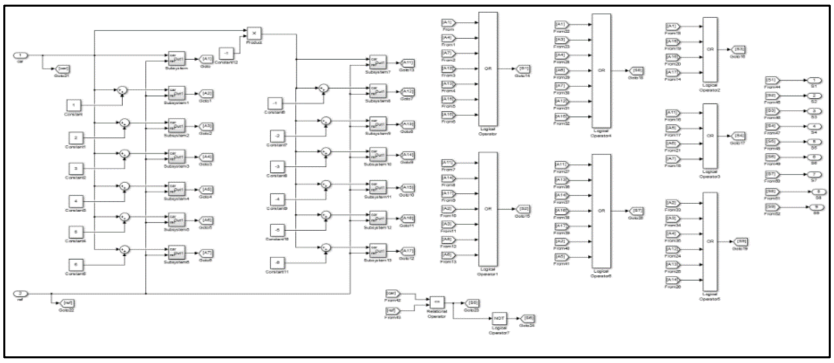

Fig – 6: Simulink Model Of MLI With Phase Opposition Disposition PWM Technique

PWM used inverter. In phase opposition disposition technique we will have the level of PWM carrier pulse as shown above. They will be parallel to each other and every level will be in phase with each other. But, the positive and negative cycles have opposite wave forms. So, we made a triangular pulse with repeating sequence and then we will add 1 to both upper and lower limits to get higher wave forms and multiply -1 to get lower triangular waveforms of negative cycle. Then it is compared with sine wave of Ma of 7 to obtain PWM. Then we will give the pulse to respective switches to turn on inverter.
We have generated a triangular pulse of positive half with lower limit as zero and upper limit as one.

Then we have taken it and added one to both upper and lower limits to get positive levels and multiplied -1 to get negative first level. Then we have to add -1 to upper and lower limits to get negative sequence levels. Then it is compared to sine and the result will be generation of PWM pulses. Then we have to see at that particular level which switches are turned on. By that we will add all PWM pulses required for a switch to turn on with a or gate. As there were no repeating voltage levels or duplicate voltage levels we have no problem.

Alternate opposition disposition PWM technique used inverter

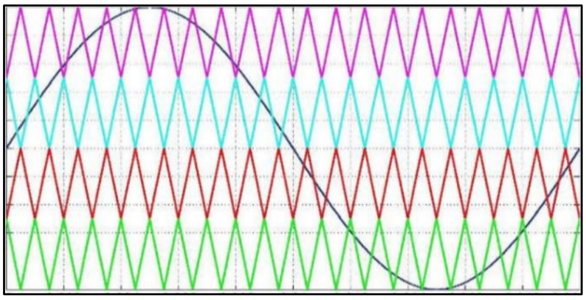

Fig – 7: Alternate Opposition Disposition PWM logic

This is the simulation diagram of alternate opposition disposition PWM used inverter. In alternate opposition disposition technique we will have the level of PWM carrier pulse as shown above. The alternate levels will be parallel and every immediate level will be in opposite with each other. But, the positive and negative cycles have opposite wave forms. So, we made 2 triangular pulse with repeating sequence and then we will add 2 to both to get upper and lower limits to get all other. Then it is compared with sine wave of Ma of 7 to obtain PWM. Then we will give the pulse to respective switches to turn on inverter.

Then it is compared to sine and the result will be generation of PWM pulses. Then we have to see at that particular level which switches are turned on. By that we will add all PWM pulses required for a switch to turn on with a or gate. As there were no repeating voltage levels or duplicate voltage levels we have no problem.

RESULTS

With PWM

The load is RL, so we will have inductor effect which is opposing sudden change in current. So that current is not touching zero. If the load is RC we will have good voltage profile and waveform of voltage is almost sinusoidal. But current profile will be bad as DC offset is not present and inductor is absent. But most of the are RL, so the change of having very bad current profile is very low.

Alternate opposition disposition:

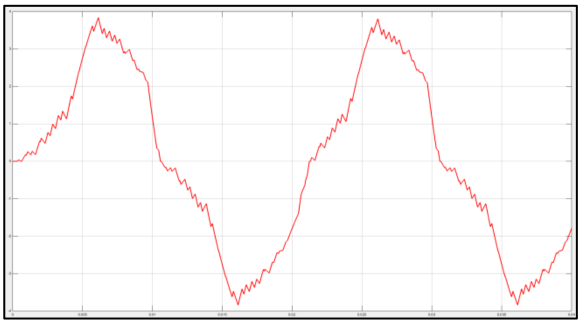

Fig – 8: Output Current Waveform Of Alternate Opposition Disposition PWM

In alternate opposition disposition we have every level oppositeto each other. This means by using this method we have already eliminated even harmonics. By using this method at carrier frequency of 2000 Hz we will have the THD of 21.39%. So, we will have only dominant odd harmonics and lightly shown even harmonics are present because of absence of DC offset

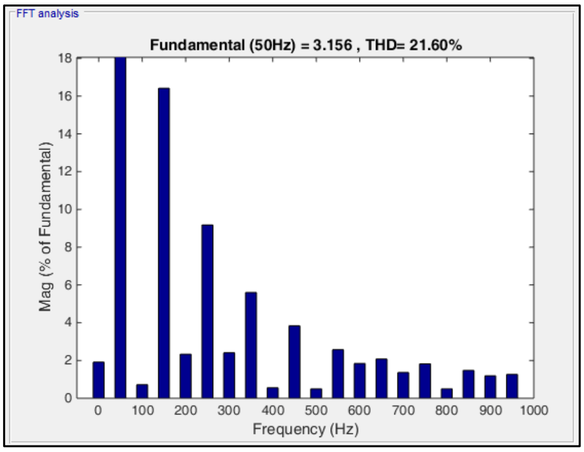

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Fig – 9: FFT Analysis of Alternate Opposition Disposition PWM

Phase disposition:

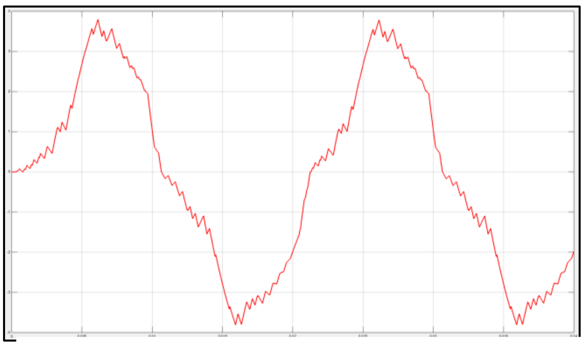

Fig – 10: Output Current Waveform Of Phase

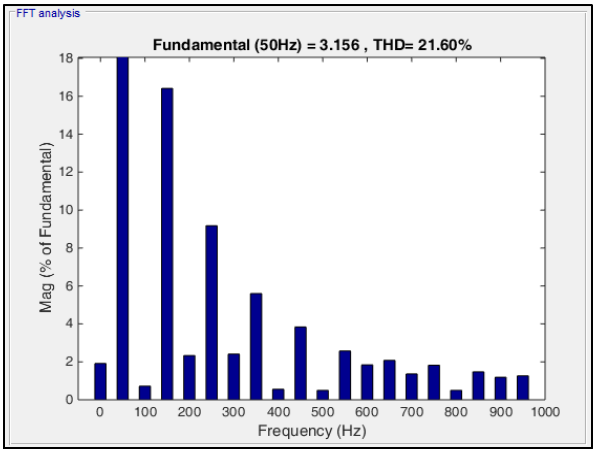

Fig – 11: FFT Analysis of Phase Disposition PWM

In Phase disposition we will have every level similar and parallel to each other. By using this method to inverter we have THD of 21.60%. In this method even harmonics will not get eliminated as alternate opposition disposition or phase opposition disposition technique. So we can see more dominant 2nd, 4th ,6th harmonics.

Phase opposition disposition:

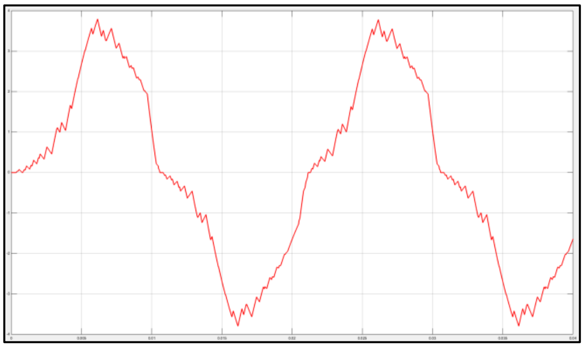

Fig – 12: Output Current Waveform Of Phase Opposition Disposition PWM

In this phase opposition disposition we have same levels parallel to each other in positive side and opposite to them we will have negative side pulses. In this method we got THD of 22.83% . We can see the even harmonics getting eliminated as the PWM pulses are opposite for positive and negative levels. But THD profile may not be good as the DC offset is not present.

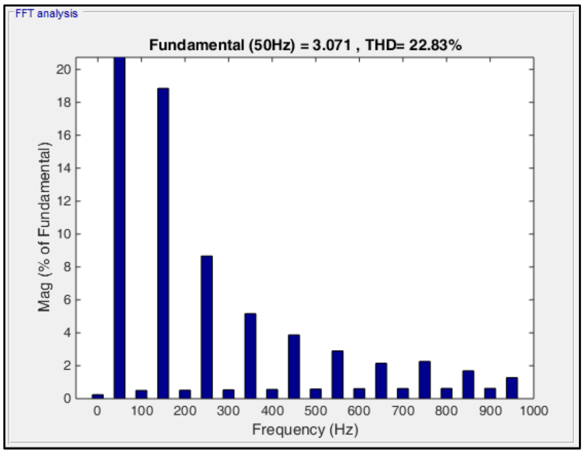

Fig – 13: FFT Analysis of Phase Opposition Disposition PWM

Without PWM Switching:

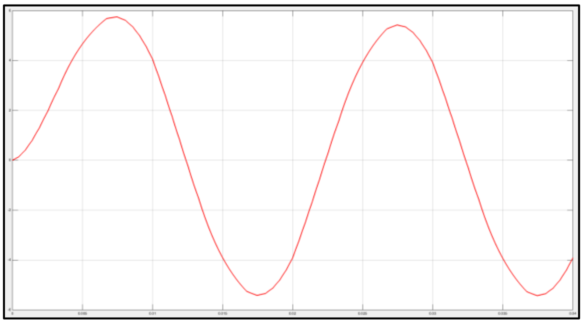

Fig – 14: Output Waveform Of Normal Switching Without PWM

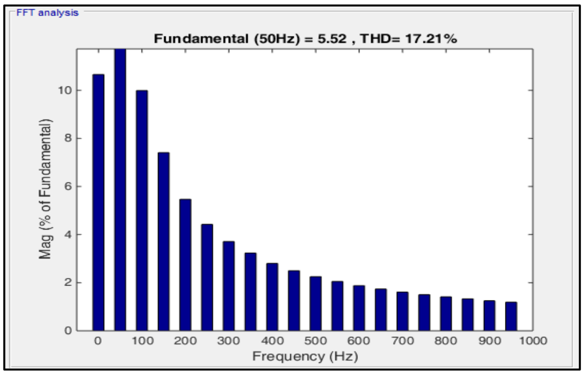

Fig – 15: FFT Analysis of General Switching

In this method we will have no PWM and we will switch the respective switches described in the switching table to obtain respective voltage levels. We will trigger between the switches based on comparing the sine wave with Ma which is described above. We can see less THD than PWM techniques because of absence of DC offset in circuit switching sequence. But we can notice the lower order harmonics in the output which are both even and odd harmonics. Current profile in this output is good as RL load is considered. RL load is considered because it is the maximum seen load in the real time scenario.

CONCLUSION

The reduced switch inverter is not widely used in general purpose application. Basically the higher level inverters are not generally preferred in industries. But using this switch reduction will become advantage by reducing size and cooling equipment. But by the simulation it is concluded that the reduced switch inverter with no DC offset it is preferable to use general switching than PWM techniques.

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