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Analysis of Different Topologies of Multi-Level Inverter Using Sine PWM Technique

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Abstract:

Generally, three phase and single-phase inverters consisting more distortions and high value of THD. To increase more efficiency in Sinusoidal signal with less THD and output voltage nearly equals to sinusoidal for that Multilevel inverters (MLIs) are preferred. It also reduces switch stress. Various topologies are reported in recent decades. Multilevel inverters mainly second-hand implementation for average voltage and extreme power applications, in order to control Multilevel inverters different Pulse width modulations like Phase disposition pulse width modulation (PDPWM), Phase opposition disposition pulse width modulation (PODPWM), Alternative Phase Opposition disposition pulse width modulation (APODPWM), Phase shifting PWM are existing methods. Multilevel inverters are mostly second-hand in renewable, HVDC transmission, VFD drives.

Keywords: - MLIs, VFD drives, PWM, THD

1. Introduction:

Now a day's multilevel inverters are mostly second-hand implementation for average voltage and extreme power applications. these multilevel inverters are reducing THD, low switching stresses across the switches, no electromagnetic interference compare conventional inverter [1]. Universally most of the loads works on sinusoidal voltage so that's way these inverters are preferred [1-2]. As per cost multilevel inverters produces stair case output voltage nearly equals to sinusoidal voltage and as the more levels increases the waveform superiority increases and also filter condition gets reduces [3].

Fundamentally there are four types of inverters neutral clamped/diode clamped multilevel inverters, flying capacitor multilevel inverters, Cascaded multilevel inverters [4]. In these types of multilevel inverters cascaded multilevel inverters are most commonly used because low THD with better quality waveform compare to other multilevel inverters [5-7].

There are various modulation techniques are used to minimize total harmonic distortion and regulate the output voltage inverter, so it is carrier based PWM technique and also we call it as sine PWM. Generally different sine PWM are used [8-9].

Generally multi-level inverters output voltage is almost equal to sinusoidal signal with less loss due to this main reason these multi-level inverters used in so many applications like drives, hybrid electric vehicle, solar PV system etc. [10].

As compare to all basic MLIs cascaded H-bridge is more used now a days because no requirement of extra diode and capacitors and loss also less in the converter and now a days these cascaded inverters using HVDC system and distribution system [11].

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In MLIs more number of switches are used to get sinusoidal signal. The number switches, diodes, capacitors used based on formulation which mentioned in Table1. “n” is number of levels.

Topology	Power Semi-Conductor Switches	Diodes	DC bus Capacitors	Separate DC Sources	Voltage balancing Capacitors
Diode Clamped	2(n-1)	(n-1)(n-2)	n-1	n-1	0
Flying capacitor	2(n-1)	0	n-1	n-1	(n-1)(n-2)/2
Cascaded	2(n-1)	0	(n-1)/2	n-1	0

Table1:-Formulation of number of switches used MLI

2. Different types of MLIs:

2.1. Single phase diode clamped five level MLI

Diode clamped multilevel inverter mainly used for low frequency applications. Diode consisting at each leg of inverter and clamped to the input midpoint capacitor so that’s way it also called as neutral clamped multilevel inverter. This inverter reduces the harmonic distortions of the load and rate of change of voltage stresses across switches, common mode voltages are reduced. But for balancing voltages across the diodes is difficult as levels increases and THD is more in these inverters. So other inverters are classified to eliminate these problems.

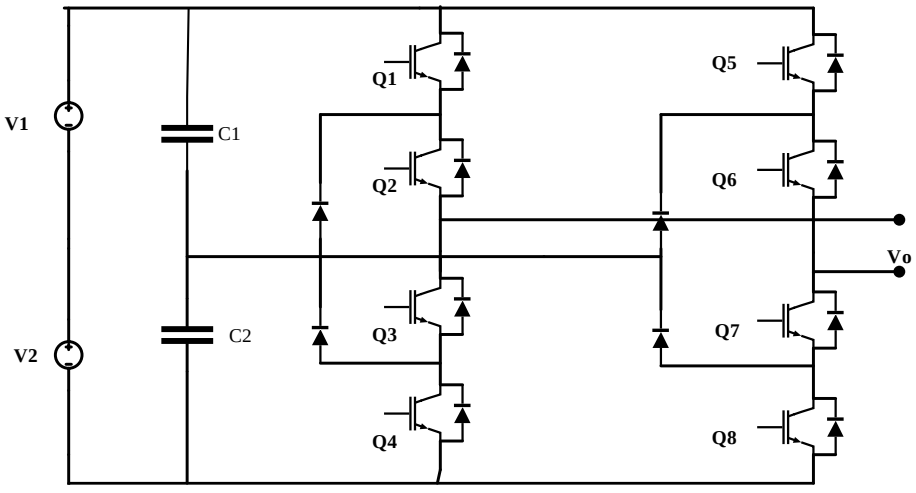

Fig1:- Single phase five level diode clamped inverter

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Level of voltage	Switch number to operated
$2V_{dc}$	Q_1, Q_2, Q_7, Q_8
V_{dc}	Q_1, Q_2, Q_6, Q_7
0	Q_1, Q_2, Q_5, Q_6
$-V_{dc}$	Q_2, Q_3, Q_5, Q_6

Table 2. Switching Sequence of single phase five level diode clamped MLI

2.2. Single phase five level flying capacitor MLI

Flying capacitor is another topology of multilevel inverter and in this we use capacitor to reduce voltage. These capacitors share input voltage equally. Half of the supply voltage appear across each capacitor. Generally, each leg capacitors are connected in series with other capacitors. Switching states almost equal to the diode clamped multilevel inverter, any extra diode is not required in this flying capacitor multilevel inverter. As the levels increases capacitors increases in the converter and also balancing each level capacitor voltage also difficult to overcome these problems Cascaded H- bridge MLI. Losses also increases because of capacitor internal resistance (R_c), Switches internal resistances (R_{sw}).

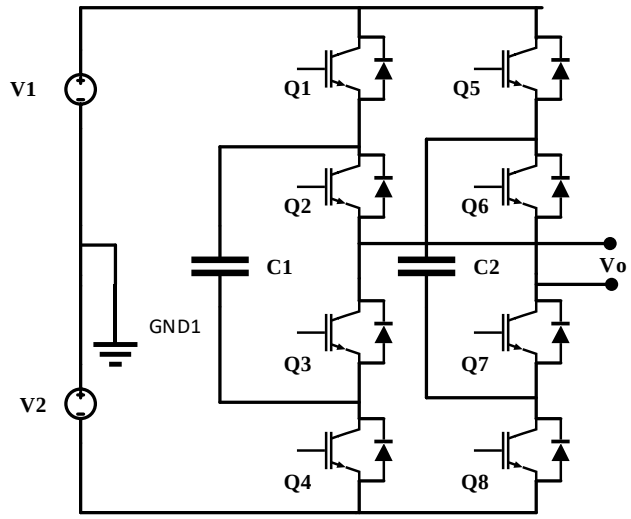

Fig2:- Single phase five level flying capacitor inverter

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Level of voltage	Switch number to operated
$2V_{dc}$	Q_1, Q_2, Q_7, Q_8
V_{dc}	Q_1, Q_3, Q_8, Q_7 Q_1, Q_2, Q_6, Q_8
0	Q_3, Q_4, Q_8, Q_7 Q_1, Q_2, Q_5, Q_6
$-V_{dc}$	Q_3, Q_4, Q_5, Q_7 Q_2, Q_4, Q_5, Q_6
$-2V_{dc}$	Q_3, Q_4, Q_5, Q_6

Table 3. Switching Sequence of single phase five level flying capacitor MLI

2.3. Single phase five level cascaded H-bridge MLI

Cascaded H-bridge multilevel inverter means single phase H-bridge inverters are connected in cascaded connection. These multilevel inverters not required any extra capacitances and diodes so the complexity of the circuit gets reduces. Because of the main advantage harmonic distortion is lo compare to other multilevel inverters. This multilevel inverter are mainly used in the renewable power applications.. But main disadvantage of this multilevel inverter is the requirement of the separate DC for each H-bridge. Each H-bridge inverter providing 0, +V, -V so according number of H-bridge output level voltage increase with low distortions, so main useful inverter is cascaded H-bridge multilevel inverter compare to other multilevel inverters. In these inverters no extra diodes and capacitors not required.

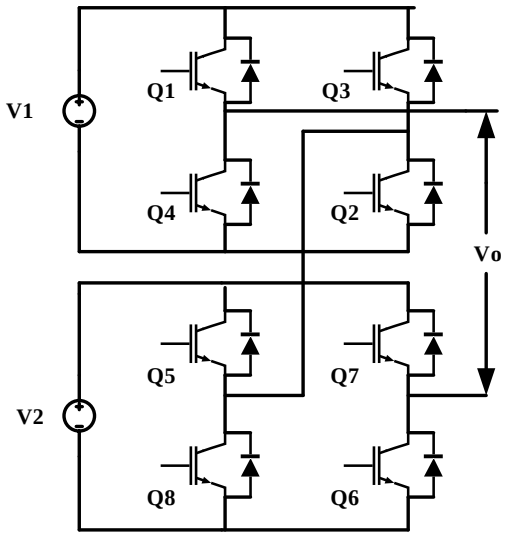

Fig3:- Single phase five level cascaded H-bridge MLI

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Level of voltage	Switch number to operated
$2V_{dc}$	Q_1, Q_2, Q_5, Q_6
V_{dc}	Q_1, Q_2, Q6, Q8
0	Q_1, Q_3, Q_8, Q_6 Q_2, Q_4, Q_5, Q_7
$-V_{dc}$	Q_3, Q_4, Q_6, Q_8
$-2V_{dc}$	Q_3, Q_4, Q_7, Q_8

Table 4. Switching Sequence of single phase five level cascaded H-bridge MLI

3. Different types of PWM technics:

3.1. Sinusoidal PWM:

Sinusoidal pulse width modulation is the based on two signals one is reference or modulating signal. Generally modulating signal is sine signal frequency of 50Hz. Reference signal indicates the frequency of output waveform. Another signal is carrier signal with frequency range of kHz and this signal mainly indicates about number of pulses in output signal. both signals compared by using comparator after comparison pulses generates that pulses appear across the output voltage. Main benefit this PWM technique is difficulty is low and effective response better for inverter operation.

Modulation index is the ratio of peak value of reference signal to the peak vale of high frequency carrier signal. Modulation index formula as given below.

$$\text{M.I} = \frac{\text{peak value of reference signal}}{\text{peak vale of high frequency carrier signal}}$$

In this paper level shifted sinusoidal PWM technique used which are classified as three types that are explained below.

3.2. Phase opposition and Disposition (POD)

In this PODPWM technique high peak magnitude reference signal mirror image signal to the lower peak magnitude signals below common line.

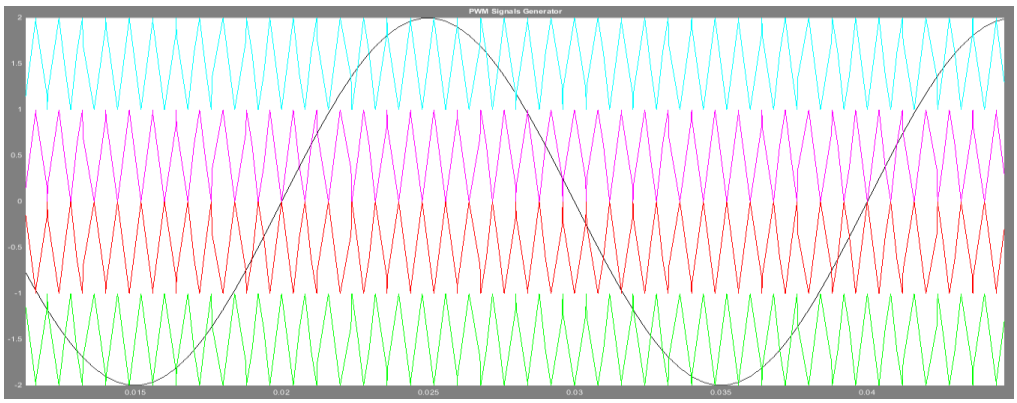

Fig4:- PODPWM

3.3. Phase Disposition (PD):

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In this PWM all high frequency carrier signals are in same phase, and modulating signal compared to generates the pulses for switches.

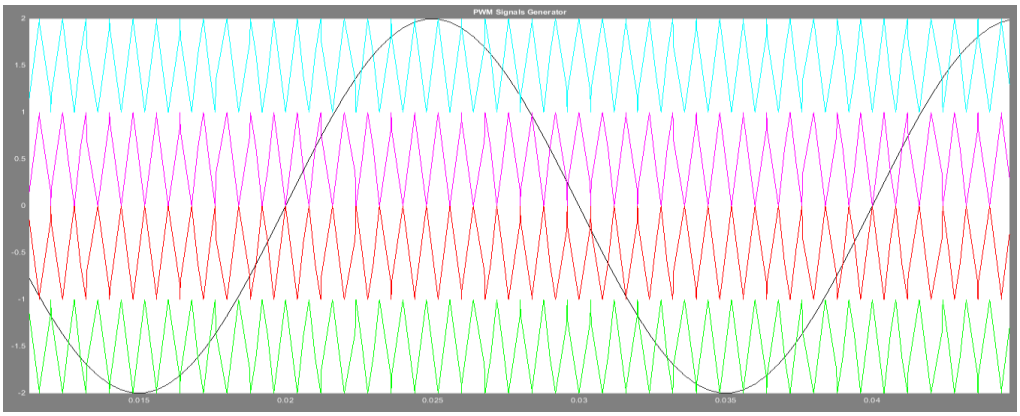

Fig5:- PDPWM

3.4. Alternate Phase Opposition Disposition (PD):

In this PWM each high frequency carrier signal mirror phase with adjacent neighbour carriers.

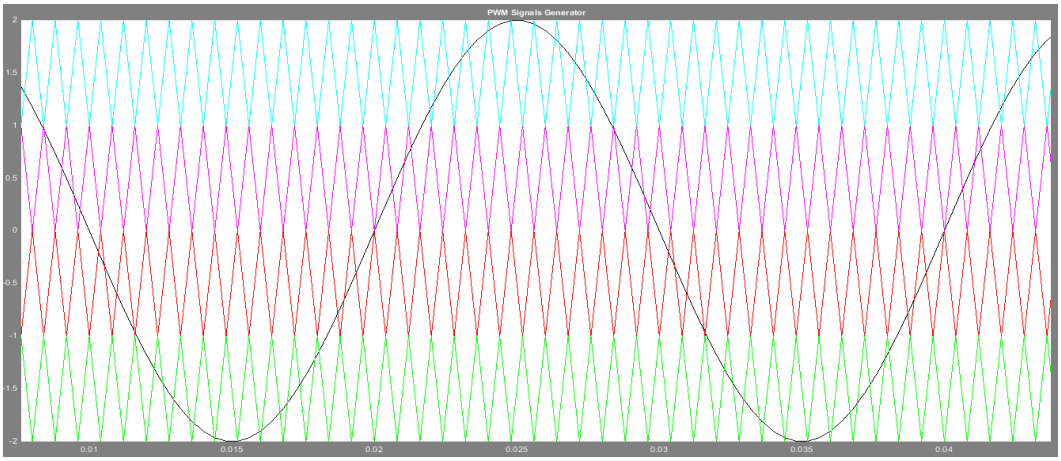

Fig6 APODPWM

4. Solution Methodology:

The proposed solution methodology is divided into two ways one is proposed block diagram of MLI second is THD analysis of the topologies of MLI.

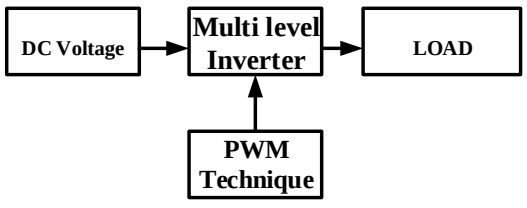

Fig7. Proposed block diagram of MLI

Now a days MLI are most popular in industrial and high power applications but the main problem of this MLI as the level increases switching losses increases and reduces inverter efficiency. Research work is going on MLI with new topologies to get pure sinusoidal signal

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with less THD and also with less power semiconductor switches. So cost reduces and effectiveness of inverter also increases. Reliability of waveform also improves.

5. Simulink model and result:

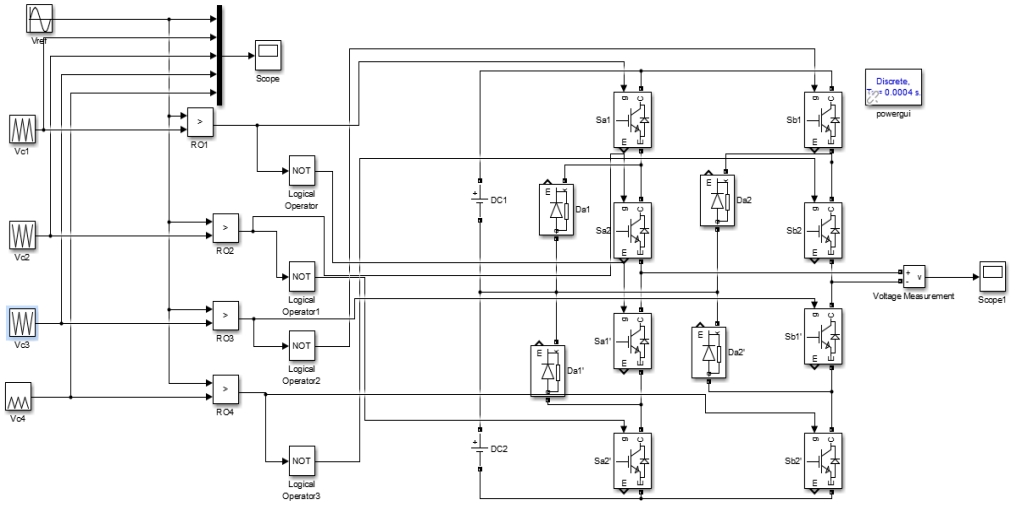

Fig8 Simulink model of single phase five level diode clamped MLI

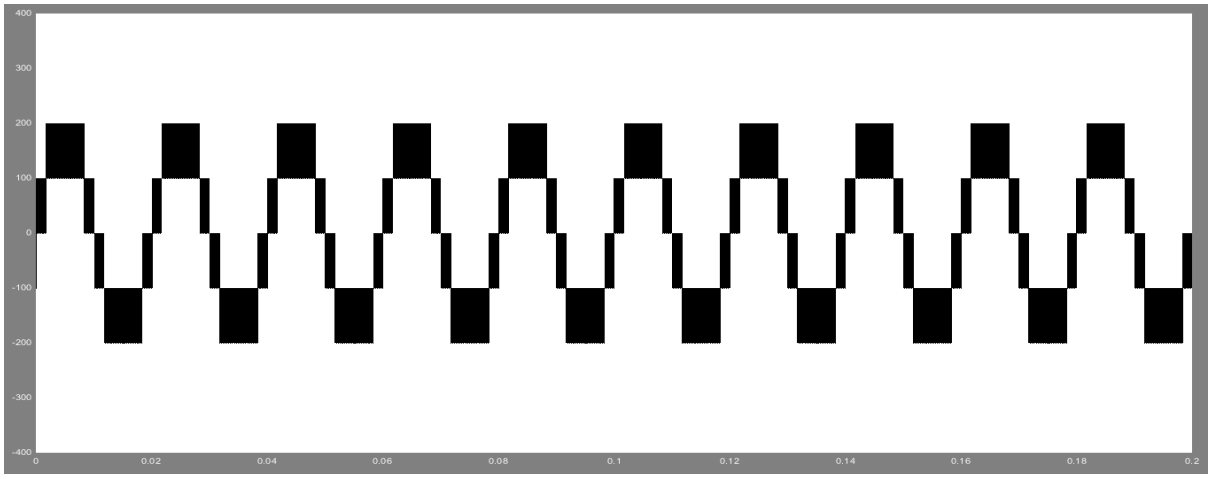

Fig9 Result of single phase five level diode clamped MLI

6. Conclusion:

This report mainly explains about the basic topologies of MLIs and their existing switching techniques. MLIs mainly explain about advantages over H-bridge and 180 and 120 degree inverters. The main advantage of these MLIs is improving load harmonic, electromagnetic interference, rate of change of voltage stress across switches. MLIs produces less distortions in the output so that's new proposing inverters with less power semiconductor switches. MLIs are also much popular in HVDC transmission system.

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