Relative analysis of PD, POD and APOD SwitchingSchemes for 5 level, 7 level & 11 level Cascade H Bridge Inverters

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***Abstract*— In order to achieve higher voltage, input to DC Drives Multi level Inverters(MLI) are adopted. Various Switching Schemes are available to operate the Drive Circuits with Multilevel Inverters. Due to the increased no of switches and frequency of switching operation, multilevel inverters are resulting in switching losses, stress on switches. Multilevel inverters are reducing the level of Total Harmonic Distortion but at the same time its operation is resulting in more switching losses. To overcome the limitations specific modulation techniques like SPWM, SHEPWM & SVM are implimented. SHEPWM is comparativly complicated and require high voltage levels. SHEPWM is capable of eliminating only lower order harmonics. These limitations of multi-level inverters are forcing to depend on filters to address the disadvantages of multi-level inverters.**

In the present paper a thorough analysis of multi-level inverter, with respect to various switching schemes for a given Drive load is presented. Voltage THD and Current THD for different switching Schemes for a range of Modulation index are obtained. This analysis will help in identifying the optimum switching scheme and Modulation Index for a given Drive Load. Which will avoid the dependency on complex control strategies in order to obtain lesser current and voltage Total Harmonic Distortion.

Keywords:Multilevel Inverters, Current THD, Voltage THD, PSWM, SHEPWM and SVM. Cascade H Bridge Inverter, Modulation index

I. INTRODUCTION

The advantages of Multi-Level Inverters such as high voltage with low dv/dt stress, high efficiency, lower electromagnetic interference, lower harmonic distortion and lower switching losses are expanding its application into Flexible AC Transmission, High Voltage DC Transmission and Renewable Energy Sources. In this Paper 5th, 7th and 11th level Cascade H Bridge Multi Level Inverters are connected to Drive load is simulated. Analysis of its THD Response along with Modulation index with respect to load variation is carried out. With this analysis, it gives more clear idea of safe and proper operating zone for a particular drive system. Operating drive in over modulation zone will result in increased harmonics. Once this analysis is carried out then identification of optimal operating point for various load conditions on the drive load without obtaining over modulation zone achieved. Thus This analysis will help in identifying critical operating point of Multi-Level Inverter for given load without scarifying the significance of Multi-Level Inverters.

II. MULTILEVEL CONVERTER – SWITCHING STRATEGIES

Cascade Multi Level Inverter (MLI) consists of series Of single phase full bridge inverter units. The modularity of this structure allows easier maintenance and provides a very convenient way to add redundancy into the system. The multilevel inverter using cascaded-inverter with separate DC sources synthesizes a desired voltage from several independent sources of dc voltages, which may be obtained from batteries, fuel cells, or solar cells. This configuration recently becomes very popular in ac power supply and adjustable speed drive applications. This new inverter can avoid extra clamping diodes or voltage balancing capacitors. For multilevel inverters, there are several Pulse Width Modulation (PWM) methods available, which can be classified as follows.

Sinusoidal PWM (SPWM), Phase Opposition PWM, (APOD) PWM, Alternative Phase Opposition , Disposition(APOD) PWM, Phase Disposition(PD) PWM, Selective harmonic elimination PWM (SHEPWM), Space vector PWM (SVPWM)

Multi carrier pulse width modulation is implemented in this simulation. This modulation technique is the one suitable modulation technique in case of robotics applications, where PWM signals are used to control the speed of the robot by controlling the speed of motor. SPWM (Sine–triangle pulse width modulation) signals are used in micro-inverter design which is used in solar or wind power applications.

Modulation index is the ratio of peak magnitudes of the modulating wave form and the carrier wave form m= Vm / Vc. If any converter enters in to the over modulation zone lower frequency harmonics crop in the output which leads to output waveform leads towards square wave form instead of output pattern nearer to sinusoidal (fundamental component) [6]-[7]. Thus it is very much important to operate the MLI in the proper operating zone otherwise the very purpose of implementing the multilevel converters instead of bridge converters is of no significance.

As the level of voltage is increasing, we have to identify minimum modulation index to reduce the losses in the converter. The below formula will give minimum modulation index for each level of inverter.

Minimum Modulation Index m min = m-3/m-1

Below table gives the sample values of minimum modulation index for different level of inverter.

Table I. Sample values of minimum modulation index

Levels	Min	Max
3	0	1
4	0.333	1
5	0.5	1
6	0.6	1
7	0.667	1
8	0.714	1
9	0.75	1
10	0.778	1
11	0.8	1
12	0.818	1

III. SIMULATION

5th, 7th and 11th level cascaded H Bridge converters are simulated in the MATLAB with Multi Carrier PWM Technique. Each converter is analyzed for APOD, POD and PD Switching Scheme.

Eleven level H bridge inverter simulation model consisting of five cascaded H bridges which results in seven level output by implementing generated pwm pulses is shown in the Fig:1.

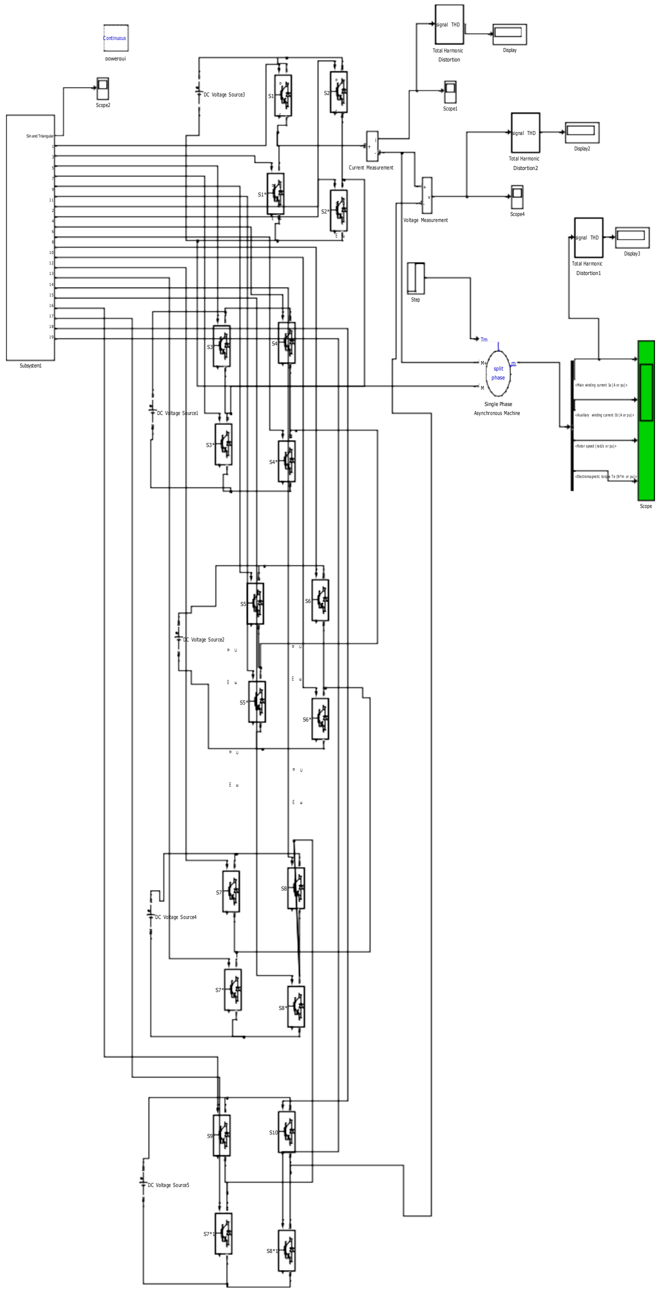

Fig 1: Simulation model of eleven level cascaded H BridgeMulti level inverter.

Table II indicates the information about the simulation parameters, that are used in the circuit

Table II .Simulation parameters

S. No	Parameter	Value/Rating
1	Carrier Frequency	1200 Hz
2	Sine wave frequency	50 Hz
3	Input DC Voltage	100V
4	IGBT/Diode (mask)	R internal: 1e^{-2}ohms. R snubber: 1^{e5}ohms C Snubber:infinity
5	Load	Asynchronous machine

IV. Simulation Results:

Fig: 2 & 3 shows the multicarrier sinusoidal pulse width modulation for1.2KHZ carrier wave frequency and reference wave frequency is 50Hz using POD, PD and switching Schemes respectively. Comparative THD values of five, seven and leven level H bridge cascaded inverter with respective to Modulation index are tabulated in the below tables, which give the variation of THD with respect to

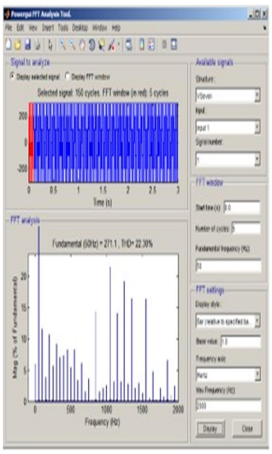

Fig 6: Voltage THD of 7 level Multi level inverter using APOD Scheme

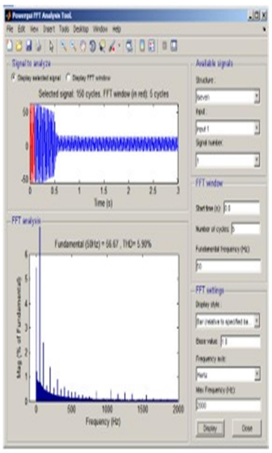

Fig 7: Current THD of 7 level Multi level inverter using APOD Scheme.

Modulation index from which optimal efficient operating point of a drive can be obtained for five, seven and eleven levels of cascaded H-bridge inverter.

5 level Inverter:

	POD		APOD		PD	
MI	V_{Thd}	I_{Thd}	V_{Thd}	I_{Thd}	V_{Thd}	I_{Thd}
0.6	44.23	33.25	44.18	93.84	44.77	33.04
0.8	37.8	29.71	37.39	71.84	38.38	29.46
0.9	33	28.69	33.18	64.2	33.66	28.46
1	26.5	27.82	27.07	59.76	27.02	27.64
1.2	21.73	26.82	20.75	51.8	22.33	27.32
1.5	22.01	26.37	21.85	42.5	23.1	27.32

7 level Inverter:

	POD		APOD		PD	
MI	V_{Thd}	I_{Thd}	V_{Thd}	I_{Thd}	V_{Thd}	I_{Thd}
0.6	33.09	28.54	33.29	28.55	33.62	28.45
0.8	24.37	26.69	23.71	23.69	24.59	26.62
0.9	21.77	26.47	21.71	26.48	22.48	26.4
1	17.87	26.27	17.18	26.29	18.56	26.3
1.2	14.57	26.47	16.37	26.52	15.99	26.55
1.5	20.34	26.25	19.67	26.21	19.56	26.14

Comparative THD values of five, seven and seven level H bridge cascaded inverter with respective to Modulation index using various schemes is tabulated in the above table.

	Voltage THD(%)			Current THD (%)		
	POD	APOD	PD	POD	APOD	PD
5 level	33	33.13	33.33	5.76	3.27	3.08
7 level	21.57	22.3	22.21	2.77	5.9	2.59
11 level	14.99	13.43	13.42	9.8	9.95	10.29

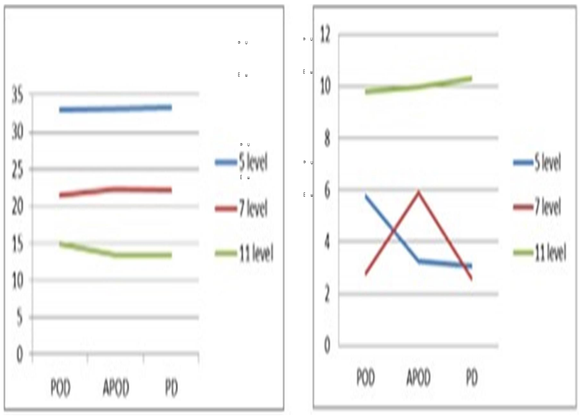

Fig 3. Comparison of voltage and current THDs

Fig 3: Comparision of Voltage and current THD of 5, 7 and 11 level inverters using APOD, POD and PD Switching Schemes

The above Fig 8 give the variation of THD with respect to Modulation index from which optimal efficient operating point of a drive can be obtained for five seven and seven leves of cascaded H bridge inverter using APOD,POD and PD switching Schemes.

V. CONCLUSION

Simulation model of five, seven and eleven levels of Cascaded H bridge connected to Drive load is developed. For each level voltage and current THD's with respect to Modulation index is carried out.

The analysis is carried out for POD, APOD and PD PWM techniques. Out of these, Phase Disposition technique results in less THD compared with other switching schemes. This analysis of Five, Seven and eleven level Cascaded H bridge inverters, will help in identifying the more efficient operating point of a particular drive.

For 5 level H Bridge Configuration, PD Switching scheme is resulting in lower values of VThd of 33% and IThd of 3.08%. For 7 level, POD Switching Scheme is resulting in lower values of VThd and I Thd and for 11 level, PD Switching Scheme is resulting in lower values of VThd and I Thd.

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