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Research Article

Simulation of Seven Level H Bridge Cascade Inverter Based on Space Vector Pulse Width Modulation Technique using Simulink

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Abstract

Multilevel inverters with cascade connection are the priorities for High power adjustable speed drives. The losses reduction created by harmonics and efficient controlling are the main advantages of proposed model. Paper gives the compressed work created for simulation of seven levels H bridge cascade inverter using Space Vector Pulse Width Modulation technique through Simulink. This paper presents a approach for above with carrier frequency scheme, their brief introduction and literature review too.

Keywords: *PWM, SPWM, SVPWM, Cascade H Bridge, Multi Level Inverter*

1. Introduction

Earlier the energy conversion work is quit simple and limited &its consumption was a linear process but in today's era electrical power system is one of the complex networks in the world with invention of new techniques of power control and equipment which have better energy efficiency and efficient control with fast and smart switching.

The Multilevel inverters have been showing its significance for the purpose of controlling and handling high power high voltage since it was introduced in decade of 1980s.

The inversion process of converting DC into AC has take place for many applications such as renewable energy technology, HVDC transmission, Adjustable speed drives and high frequency industrial heating processes. The applications using variable frequency inviters are increasing day by day due to its user friendly approach for common men while the technology behind this is very advance.

The aim of this paper is to simulate Space vector pulse width modulation technique with carrier frequency sending for Multilevel Hybrid cascade Inverter. The control strategy for different uses in electrical engineering systems with SVM is more complicated than other techniques but harmonic distortion and efficient control, use of DSP is possible with SVPWM. Different approaches and classification for PWM techniques has been shown in fig. 1:

Figure shows a detailed classification of PWM strategies for different application using unique strategies as per requirement of supply and end user profile. The two basic types of PWM; current & Voltage are presented in figure 1 with detailed sub classification. The voltage PWM schemes are much preferable due to maintain voltage of system and use of VSI.

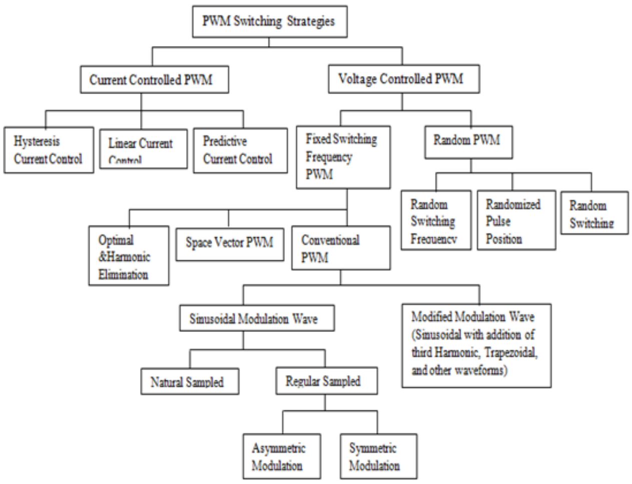

Figure 1 Classification of PWM Technique

Pulse width modulation is the method of choice to control modern power electronics circuits while the multi level converters are the first choice for high power applications where single stage inverter is not capable to handle the power supply and control it. The basic idea is to control the duty cycle of a switch such that a load sees a controllable average voltage. To achieve this, the switching frequency or repetition frequency for the PWM signal is chosen high enough that the load cannot follow the signal is chosen high enough that the load cannot follow the individual switching evens. Switching, rather than linear operation of the power semiconductors is of course done to maximize the efficiency because the power dissipation in a switch is ideally zero in both states. In a

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typical case, the switching events are just a blur to the load, which reacts only to the average state of the switch. There are a number of different methods to generate periodic rectangular waveforms with varying duty cycle. A standard method is the so called carrier-based PWM technique, which compares a control signal with a triangular (or saw tooth shaped) waveform. . By comparing this signal with a reference level, which can vary between 0 and 1 V, a PWM signal with a duty cycle between 0 and 100% is generated. Because of the triangular carrier, the relation between the reference level and the resulting duty cycle is linear. This method works very well for duty cycles in the range from 5% up to 95% However, if the reference signal exceeds 100% or falls below 0%, the resulting PWM signal would be always on or always off, respectively. This is called over modulation. This regime must be avoided by proper conditioning of the control signal. In addition, for control signals resulting in PWM signals with duty cycle values as high as 99% or as low as 1%, the switch may never fully reach the opposite state and spend an undue amount of time in transitions. Therefore, it is typically recommended to limit the control signal to a range, which avoids over modulation as well as extremely narrow pulses.

2. Space Vector Pulse Width Modulation technique

It should be reminded that, due to the switching speed of modern power semiconductors, the carrier frequency can be chosen sufficiently high that the harmonics can be easily filtered with capacitors and inductors of small size.

The Space Vector Pulse Width Modulation is a fast advanced and efficient Pulse width modulation technique among all other for VSI fed loads with superity of good DC utilisation voltage and less harmonic problems as compared to other techniques. SVPWM is a method where the switching states are viewed in the voltage reference frame. It has special on off switching sequence of the upper three power devices of three-phase voltage source inverters applicable for 3phase loads. It is a more soft technique for generating sine wave that provides a higher voltage to the load side with lower total harmonic distortion. Space Vector Pulse Width Modulation is better to use as a whole for switching frequency rather than choosing separate modulator for each phase. As the Space Vector Pulse Width Modulation is more complicated than SPWM than too it's easy to use with modern DSP based control circuits for emerging applications.

We may understand the concept of Space Vector Pulse Width Modulation by considering three phase waves with phase displacement 120 degree and voltage levels *Gravy,*

Vb as follows.

$$V_R = V_m Sin\omega t$$
$$V_Y = V_m Sin\left(\omega t - 120^0\right) \quad (1)$$
$$V_B = V_m Sin\left(\omega t + 120^0\right)$$

These three vectors may represent by single one space vector

$$V_S = \frac{3}{2}V_m\left[Sin\omega t - jCos\omega t\right] \quad (2)$$

Vs rotates with speed ω rad/sec as represented in fig. 2

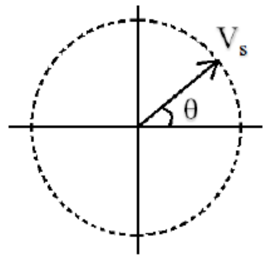

Figure 2

Consider a conventional 3 phase bridge VSI which has six switches three upper and three lower; total 6 switches hence there are 8 possible combinations (0,0,0), (0,0,1),(0,1,0), (0,1,1), (1,0,0), (1,0,1),(1,1,0),(1,1,1) as shown in table the different switching strategies for inverter.

Table Different Switching Strategies

State	On Device	Vrn	Vyn	Vbn	Space Voltage Vector
0	S4S6S2	0	0	0	(0,0,0)
1	S1S6S2	2Vd/3	-Vd/3	-Vd/3	(1,0,0)
2	S1S3S2	Vd/3	Vd/3	-2Vd/3	(1,1,0)
3	S4S3S2				(0,1,0)
4	S4S3S5				(0,1,1)
5	S4S6S5				(0,0,1)
6	S1S6S5				(1,0,1)
7	S1S3S5	0	0	0	(1,1,1)

From above 8 states 6 states are active while 2 states (0,0,0) and (1,1,1) are short circuited due to switching . Figure shows the Space vector trajectory and adjustment:

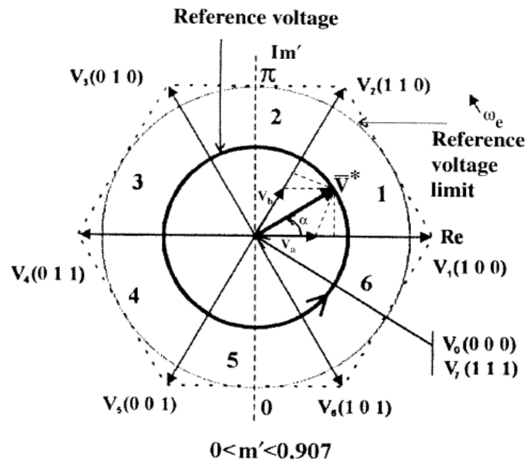

Figure 3

The total harmonic distortion in space vector pulse width modulation based inverter is the ratio of the root mean square of the harmonic content to the root mean square value of the fundamental quantity, expressed as a percentage of the fundamental When the value of current have a harmonic.

$$THD = \sqrt{\sum_k^\infty I_{krms}^2} / I_{rms} * 100 \quad (3)$$

Here the harmonic distortion is shown only for current waveform but in the proposed model there is no load connected on end side that's why current result has not shown.

3. Cascade H Bridge Seven Level Inverter

The cascade H-bridge converters consist of a number of H-bridge power conversion DC Sources, each supplied by an isolated source series-connected on the AC side. In some systems these sources may be available through batteries or photovoltaic cells but in most drive systems transformer/rectifier sources are used for two stage conversion system. Combined in series, an effective switching state can be related to the switching states of the individual cells.

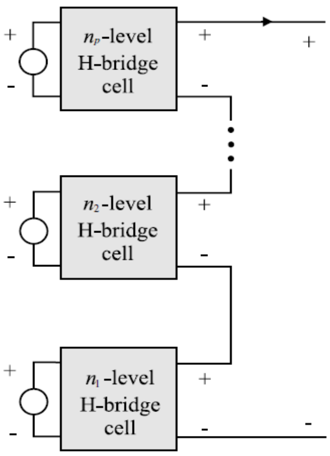

Figure 4 Cascade Multi Level H Bridge Inverter Concepts

For this converter, the effective number of voltage levels is the product of the voltage levels of the individual cells or DC voltage applied to each cell is set to the same value, then the effective number of voltage levels may be related to the number of cells by

$$n = \prod_{i=1}^{i=p} n_i \quad (4)$$

Assuming that the DC voltage of cell *i* is set based on the adjacent cell. The modulation index for H bridge inverters is:

$$m_H = \frac{\sqrt{2} v_S}{v_{DC}} \quad (5)$$

Where *Vs* is voltage magnitude of inverter output and *Vdc* is the DC supply voltage to inverter. The value of modulation index varies between ranges:

$$0 \le m_H \le \frac{2}{\sqrt{3}}$$

4. Simulation using Simulink

To verify the validity of the proposed scheme, a Seven-level three phase H Bridge Cascade inverter is designed to implement the scheme. Each phase of the main topology is a seven level H-bridge as shown in Figure 5, where the IGBT, Diode, dc bus voltage. The figure also shows the cascading of different inverters as explained with figure 4.For supply frequency and corresponding carrier frequency in the form of three signals which should supply to each inverter in synchronizing form as to attain appropriate output. The modulation index for above model is set on 0.8.

The inner sub block of one inverter scheme is shown in figure 6 where separate DC source is shown of 100 volt. The Seven level SVPWM based Cascade H Bridge Inverter implemented respectively, and the results are shown in Figure 7, 8 and 9, 10 where frequency of modulated wave and carrier wave are 50 Hz and 2500Hz, respectively. The results include output voltage waveform, FT and distortions.

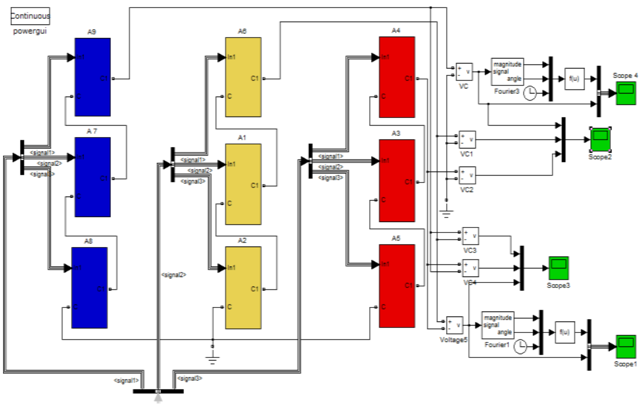

Figure 5 Seven level H Bridge Cascade Inverter

Figure 6 shows the sub block of inner part of individual inverters where a separate DC source of 100volt is applied for power and H Bridge is develop using IGBTs and signals from carrier frequency source.

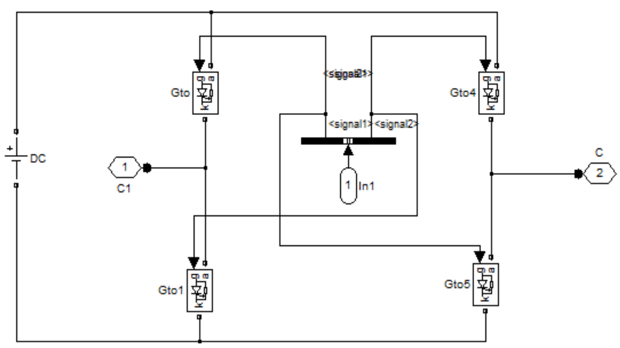

Figure 6 Inner sub block of inverters

Figure 7 is the graphical representation of obtained from scope 4 of model shown in figure 5 which represent wave form and forier analysis result through built in block. Figure also represents seven levels of voltage.

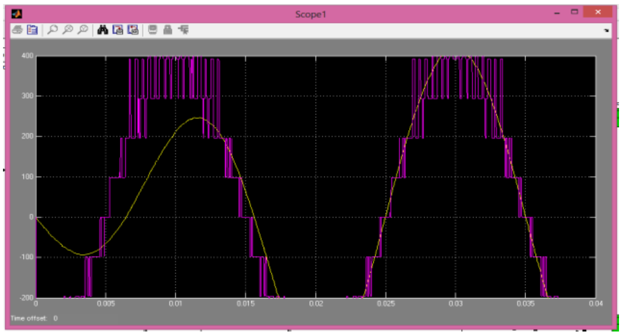

Figure 7 Scope 4 result of waveform with FT

Figure 8 represent the voltage waveform of three phases output through inverter through scope 3 used in model.

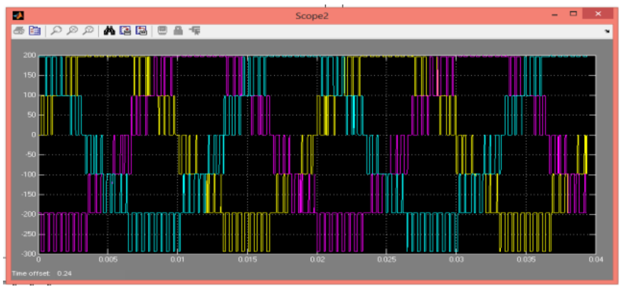

Figure 8 Scope 3 result of voltage waveform

The figure 9 shows the result of output voltage shown by scope 2 of model

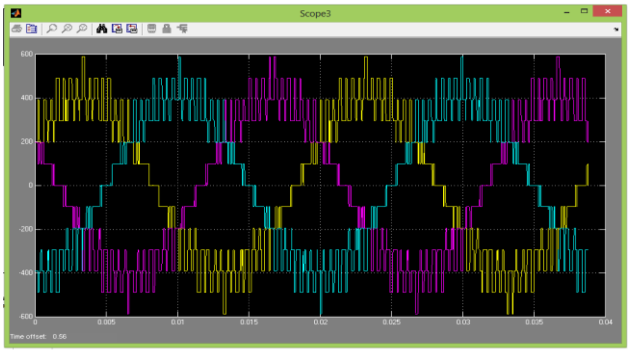

Figure 9 Scope 2 result of output voltage waveform

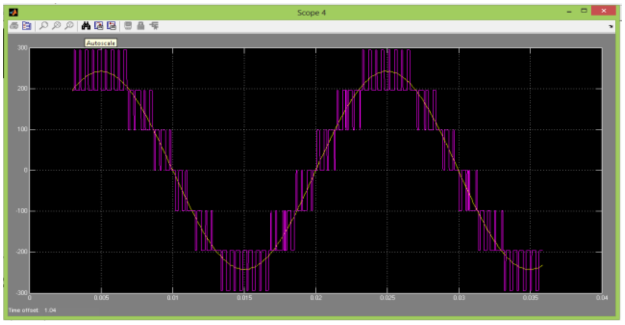

Figure 10 Scope 1 result of waveform with FT

Conclusion

The paper present simulation of seven level H bridge cascade inverter using SVPWM technique with carrier frequency; the recent trend in the area of SVPWM. Focus is centered to create appropriate output results. The out put result is obtain on fixed modulation index 0.8 while better result may possible with different one which is a matter of further research in future. The paper also presented a salient feature of SVPWM. This paper will serve as a valuable resource to any future worker in this important area of research. The uncovered subject material on SVPWM based is available in books and papers.

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