

Total Harmonic Distortion of Dodecagonal Space Vector Modulation

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ABSTRACT

Space vector modulation technique is one of the best PWM techniques which have been implemented to the Multilevel inverter circuit to get the purely sinusoidal current. This is an important algorithm which is implemented in open wind induction motor. This type of I.M has great impact on Electric Drive system. SVM is nothing but the technique of switching algorithm. The Hexagonal space vector modulation has been implemented before, but elimination of higher order harmonics is not possible. Torque pulsation arises. Speed control of Induction motor was not smooth. So Dodecagonal (12) structure developed. A 12 side polygonal space vector structure is meant for eliminating $(6n\pm 1)$ harmonics in the phase current waveform throughout the modulating range. A high resolution of PWM technique is proposed involving multiple 12 sided polygonal (Dodecagonal) structure that can generate highly sinusoidal voltage at a reduced switching frequency. In this paper different values of frequencies have been taken for harmonic analysis. SVM method features a higher level of dc-bus voltage utilization compared to the conventional PWM.

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1. INTRODUCTION

The concept of space vector is derived from rotating field of ac modulating the inverter output voltage. In this modulation technique the three phase quantities can be transformed to their equivalent 2-phase quantity either in synchronously rotating frame or stationary frame presented in phasor diagram, Figure 1. From this 2-phase component the reference vector magnitude can be found and used for modulating the inverter output. These switching states can be represented by active and zero space vectors, respectively. A typical space vector diagram has been shown in Figure 1. In the space vector modulation technique, one leg is acting as a switch, but when we consider the higher modulation range, we are seen the harmonic in phase current and phase voltage of the system. We are not getting purely sinusoidal current which an induction motor required for its speed control. That's why Dodecagonal (12 sided) space vector structure in the higher modulation region came to the research work. The main idea behind SVPWM is to divide the 2D-plane into twelve equal areas each of them is called sector. In the extreme modulation range, voltage vectors at the vertices of the outer dodecagon and the vertices from the outer most hexagons is used for PWM control, resulting in highly suppressed 5th and 7th order harmonics thereby improving the harmonic profile of the motor current. This leads to the 12-step operation at 50Hz where all the 5th and 7th order harmonics are completely eliminated. At the same time, the linear range of modulation extends up to 96.6% of base speed. Because of this, and the high degree of suppression of lower order harmonics, smooth acceleration of the motor up to rated speed is possible. Apart from this, the switching frequency of the multilevel inverter output is always limited within 1kHz. The middle inverter (high voltage inverter) devices are switched less than 25%

of the output fundamental switching period. Consists of three cascaded 2-level inverters. The proposed technology is realized by cascading three conventional two level inverters fed from asymmetrical isolated dc voltage sources value 0.577kV_{dc} , 0.423kV_{dc} and 0.155kV_{dc} as shown in Figure 1

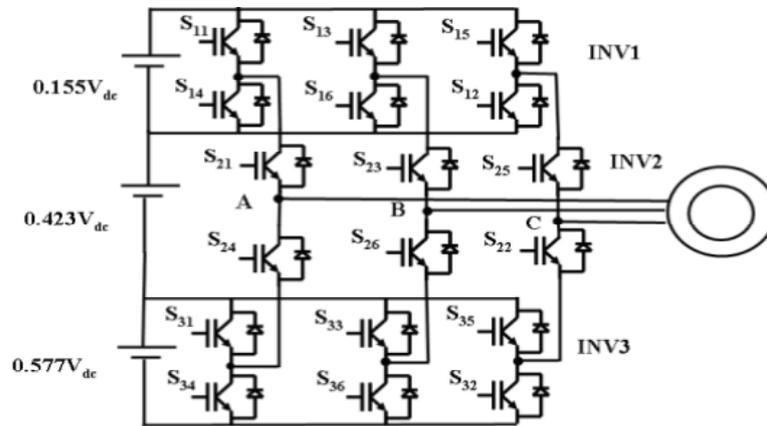


Figure 1. Power circuit of the experimental set up.

The total voltage is 1.155V_{dc} . Each phase can take four different level. Twelve space vector are formed by combination of voltage space vectors along three phases.

2. RESEARCH METHOD

2.1. Evolution of Dodecagonal Space Vector

Inverter circuit topology capable of generating multilevel dodecagonal (12-sided polygon) voltage space vectors by the cascaded connection of two-level and three-level inverters. By the proper selection of DC-link voltages and resultant switching states for the inverters, voltage space vectors whose tips lie on three concentric dodecagons, are obtained. A rectifier circuit for the inverter is also proposed, which significantly improves the power factor. The topology offers advantages such as the complete elimination of the fifth and seventh harmonics in phase voltages and an extension of the linear modulation range. In this study, a simple method for the calculation of pulse width modulation timing was presented along with extensive simulation and experimental results in order to validate the proposed concept. The 12-step operation at rated voltage operation, leading to the complete elimination of $6n\pm 1$ harmonics. ($n=\text{odd}$) from the phase voltage. The total harmonic distortion, or THD, of a signal is a measurement of the harmonic distortion present and is defined as the ratio of the sum of the powers of all harmonic components to the power of the fundamental frequency. By taking the different frequency different phase voltage and phase current has been noted down for the analysis of total harmonic distortion. There should be the measurement of THD for getting pure sinusoidal current. SVM algorithm is Implemented the sequence of switching operation of Inverter so that with overmodulation range we can get pure sinusoidal current. It's implemented on V/F control of Induction motor.

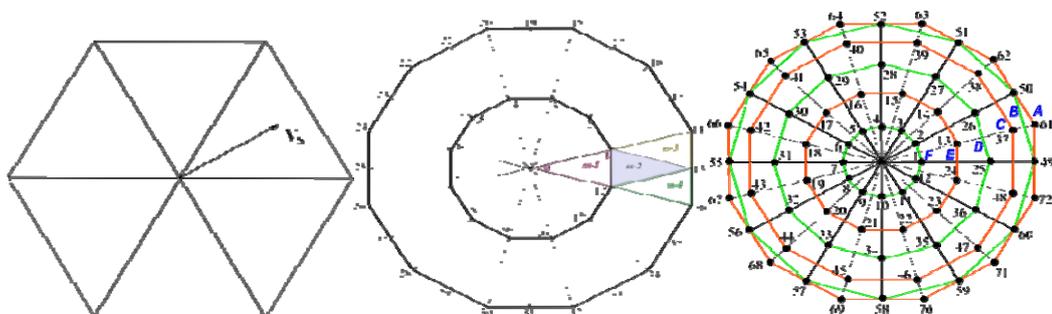


Figure 2. Dodecagonal space vector modulation structure

The switching time and corresponding switch state for each power switch is calculated in Matlab-2012. The matlab code firstly identifies the sector of the reference voltage. The time of application of active and zero vectors are then calculated.

2.2. Programme for 12-sector Identification

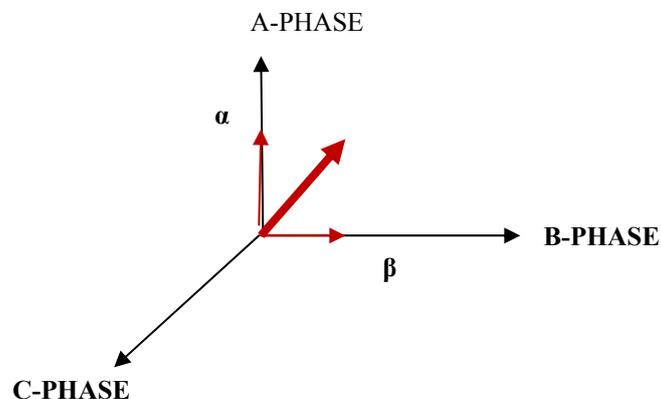
```
Function[ s1,s2,s3,s4,s5,s6,s7,s8,s9,s10,s11,s12]=fcn(n)
```

```
if n=0,s1=1;else s1=0;end.
If n=1 if ,s2=1;else s2=0;end.
if n=2,s3=1;else s3=0;end.
if n=3,s4=1;else s4=0;end.
if n=4,s5=1;else s5=0;end.
if n=5,s6=1;else s6=0;end.+
if n=6,s7=1;else s7=0;end.
if n=7,s8=1;else s8=0;end.
if n=8,s9=1;else s9=0;end.
if n=9,s1=1;else s10=0;end.
if n=10,s1=1;else s11=0;end.
if n=11,s1=1;else s12=0;end.
:S” stands for sector.
```

There are 12 principal voltage space vectors from this topology. A reference vector lying in a sector can be generated by time averaging the two principal voltage space vectors encompassing the sector.

3. RESULTS AND ANALYSIS

The current controllers produce the voltage references in the d-q rotor reference frame. The voltage references V_d and V_q are transformed to the stator two phase ($\alpha\beta$) reference frame to give the reference voltages V_α and V_β . These voltage references are the inputs to the switching intervals.



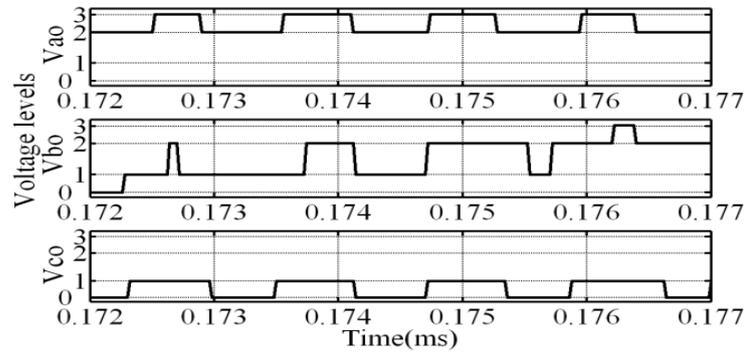
Now to the three phase system is converted to two phase (d-q) system and then start or two phase ($\alpha\beta$) to maintain volt-time ratio constant.

3.1. Switching Status for Different Level of Pole Voltage of One Phase

Pole voltage	level	A-PHASE		
		S11	S21	S31
1.155Vdc	3	1	1	1
1.0kVdc	2	0	1	1
0.577Vdc	1	1	0	1
0 Vdc	0	1	0	0

S11, S21, S31 are the bidirectional self commutating switches and the unsymmetrical dc voltage level has been shown in Figure 1.

3.2. Switching Circuit Simulation



The A, B, C are the three phase voltage supplying to the Induction motor and “o” corresponds to the pole voltage of respective phase. Here Vao, Vbo, Vco are the different pole or leg voltage of the Inverter.

Figure 2. Three pole voltages are shown for 60 degree at 35 Hz operation

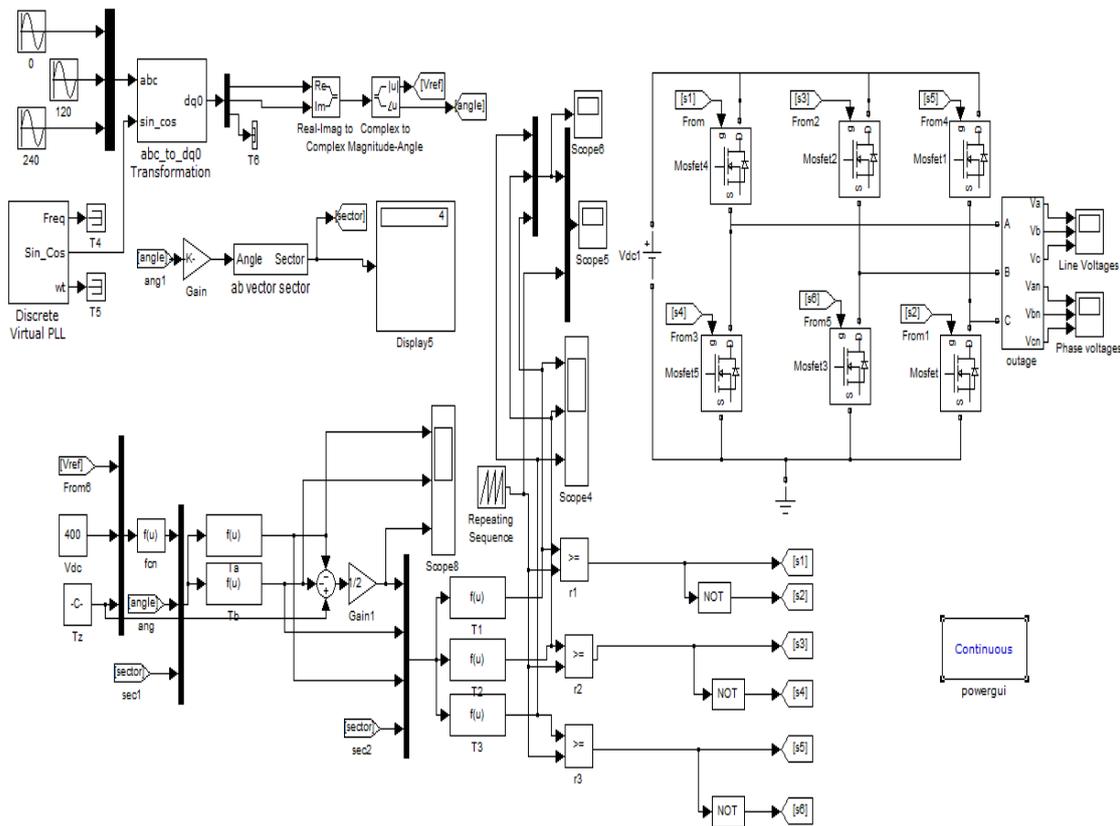


Figure 3. Simulink diagram of Dodecagonal space vector modulation

By taking the frequency at 35Hz, asymmetry pole voltage has been found out. In ‘A’ phase the voltage level fluctuate between levels ‘3’ and ‘2’, and in ‘C’ phase the voltage level fluctuates between levels ‘1’ and ‘0’. A digital signal processor (DSP), TMS320LF2812 is used for experimental verification. For different levels of output in the pole voltage, three carriers are required. However, it is difficult to synthesize three carrier waves in the DSP, as such only one carrier is used and the modulating wave is appropriately scaled and level shifted. This simulation analysis is done by Simulink MATLAB-2012. The sequence in

which the switches are operated are as follows: (200), (210), (211), (311), (321), (311), (211),(210), (211), (311), (321), (211), (221),(321), (221), (210), (220), (221), (321),(331), (221), (220), where the numbers in brackets indicate the level of voltage. This sequence corresponds to 2 samples per sector with the range between 20Hz-40Hz.

2 samples per sector. Beyond 40Hz: 1 sample per sector-extending up to final 12-step mode. Individual inverters are switched less than half of the total cycle. With low switching frequency for high power drives, the $(6n \pm 1)$ harmonics in the current waveform can produce torque pulsation in the drive. The problem is particularly severe in over-modulation region where the $(6n \pm 1)$ harmonics constitute a major portion of the total current. A 12-sided polygonal space vector structure for IM drive has already been proposed using conventional 2-level inverters. This has the advantage of eliminating all $(6n \pm 1)$ harmonics in the phase current waveform throughout the modulating range. However, one drawback of the scheme is the high dv/dt stress on the devices, since each inverter switches between the vertex of the 12-sided polygon and the zero vector at the centre. Thus it has been observed that with increased linear modulation range, less switching frequency and improved harmonic spectrum, the proposed concepts may be considered as an interesting addition to the field of multilevel inverters for high/medium voltage high power applications.

3.3. Harmonic Performance of Phase Voltage and Phase Current which is Feeding to Induction Motor

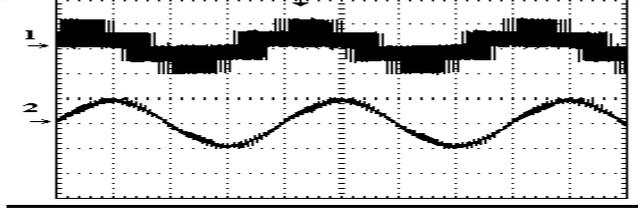
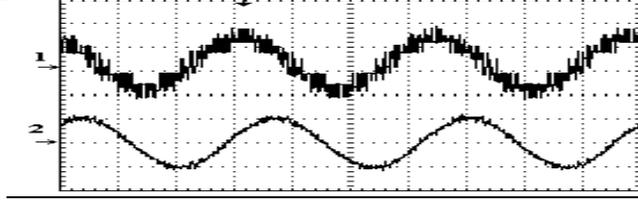
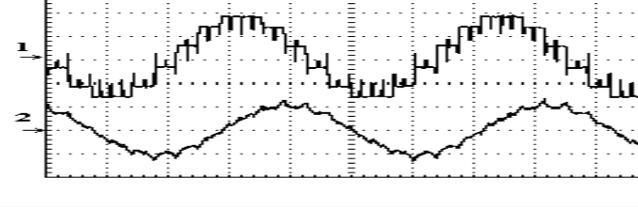
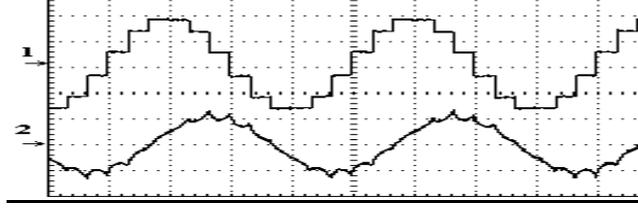
Wave form	Frequency	T.H.D.on Vp Ip
	15	Vp=75.4% Ip=24.49%
	30	Vp=27.5% Ip=10.59%
	45	Vp=13.47% Ip=14.6%
	50	Vp=17.54% Ip=19.54%

Figure 4. THD analysis can be studied by taking different frequencies

This Total Harmonic Distortion gives the idea about the different spectrum and represent that outer envelop of waveform at lower frequencies become inner envelop of at higher frequency. The Harmonic spectrum of phase voltage and phase current shows the absence of peaky harmonic through out the range. complete absence of the $6n\pm 1$ ($n=\text{odd}$) harmonics is observed. The motor current at rated frequency operation is nearly a pure sinusoidal waveform as the harmonics are very low.

4. CONCLUSION

By the proper selection of DC-link voltages and resultant switching states for the inverters, voltage space vectors whose tips lie on three concentric dodecagons, are obtained. A rectifier circuit for the inverter is also proposed, which significantly improves the power factor. The topology offers advantages such as the complete elimination of the fifth and seventh harmonics in phase voltages and an extension of the linear modulation range. In this study, a simple method for the calculation of pulse width modulation timing was presented along with extensive simulation and experimental results in order to validate the proposed concept. SVM is a popular choice in the inverter control. A trade-off is required to maintain the quality of the inverter output voltage without resorting to higher switching frequency. In this regard, a dodecagonal space vector diagram is very desirable that eliminates all the 5th and 7th order harmonics from the phase voltage, leaving the next set of harmonics at $(12n\pm 1)$, $n=\text{integer}$. But the main disadvantage is it will show more dv/dt stress which will lead to EMI (Electro Magnetic Interference) Problems. Generally we are implementing on Electric Drives system only.

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Mrs. Babita Nanda received the B.E. in Electrical Engineering from KITS, Utkal University, Odisha in 2001. M.Tech. in Power Electronics and Machine Drives from the Indian Institute of Technology Delhi, India, in 2008. She is a Life member of ISTE. Presently working as HOD in the Electrical and Engineering Department. Malla Reddy College of Engineering for Women, Hyderabad, Andhra Pradesh.