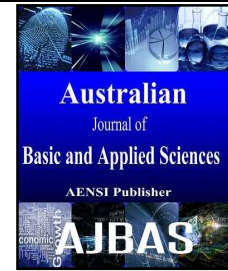




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Harmonic Minimisation in Six Switch and Nine Switch Inverter Using SHE-PWM

¹M. Nirmala, ²K. Baskaran and ³R. Jebakumari

¹Electrical and Electronics Engineering, Kumaraguru college of technology, India.

²Electrical and Electronics Engineering, Government College of Technology, Coimbatore, India.

³Electrical and Electronics Engineering, Kumaraguru college of technology, India.

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ABSTRACT

Harmonics are non- power frequency pollutants present in the PWM inverter output. However harmonics from the PWM output have to be eliminated because they are source of many power quality problems. Selective Harmonic Elimination Pulse Width Modulation (SHE-PWM) technique is one of the elimination of lower order harmonics by optimal firing angle selection using iterative methods. A simple algebraic Newton Raphson Method optimization technique is proposed to obtain the notching angles and it is applied to a three phase six switch voltage source inverter and nine switch voltage source inverter for reducing 5th, 7th, 11th, 13th, 17th and 19th harmonics. By using this scheme the Total Harmonic Distortion (THD) is reduced. The SHE-PWM based three phase six switch and nine switch inverters are compared and simulated using MATLAB/SIMULINK model.

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INTRODUCTION

Present day available PWM schemes can be broadly classified as carrier modulated sine PWM and pre calculated programmed pulse width modulation (PPWM) schemes. If the switching losses in an inverter are not a concern (i.e., switching on the order of a few kHz is acceptable), then the sine-triangle PWM method and its variants are very effective for controlling the inverter. This is because the generated harmonics are beyond the bandwidth of the system being actuated and therefore these harmonics do not dissipate power. On the other hand, for systems where high switching efficiency is of utmost importance, it is desirable to keep the switching frequency much lower. In this case, another approach is to choose the switching angles such that a desired fundamental output is generated and specifically chosen harmonics of the fundamental are suppressed. This is referred to as selective harmonic elimination or programmed harmonic elimination. This is also called as Computed Pulse Width Modulation (CPWM) or Programmed Pulse Width Modulation (PPWM). However, each one of the programmed PWM techniques is associated with the difficult task of computing specific PWM switching instants. This difficulty is particularly encountered at lower output frequency range due to the necessity of large number

of PWM switching instants. Since a three-phase inverter provides adjustable frequency power than any other type of inverters it is preferred for industrial applications. In order to minimize unwanted harmonic content i.e. THD, a number of PWM techniques have been developed. The main aim of the project is to mitigate the lower order harmonics by using SHE PWM. A simple algebraic Newton Raphson Method optimization technique is proposed to obtain the notching angles and it is applied to a three phase six switch voltage source inverter and nine switch voltage source inverter for reducing 5th, 7th, 11th, 13th, 17th and 19th harmonics.

II. Three Phase Six Switch Voltage Source Inverter (VSI):

The schematic diagram for a basic three phase Voltage Source Inverter (VSI) is shown in Fig.1. A Three phase voltage source inverter circuit changes DC input voltage to a three phase variable frequency, variable voltage output. The input DC voltage can be from a DC source or rectified AC voltage. A Three phase inverter can be constructed by combining three single phase half bridge inverters. It consists of six power switches with six associated freewheeling diodes. The switches are opened and closed periodically in the proper sequence to produce the

desired output waveform. Basically, there are two possible schemes of gating the devices.

- i) Each switch conducts for 180°
- ii) Each switch conducts for 120°

But in both these schemes, gating signals are applied and removed at 60° intervals of the output voltage waveform. The 180° conduction mode each switch conducts for a period of 180° mode or half cycle electrical. Switch pair in each leg i.e. S1, S4, S3, S6 and S5, S2 are turned ON with a time interval

of 180° . It means that switch S1 conducts for 180° and switch S4 for the next 180° of a cycle. In this 120° conduction mode, each switch conducts for 120° at any instant of time, only two switches remain ON. The gate pulse indicates the conduction period of each switch and six commutations per cycle are required. In this mode two switches conduct at a time, one from the upper group and the other from the lower group.

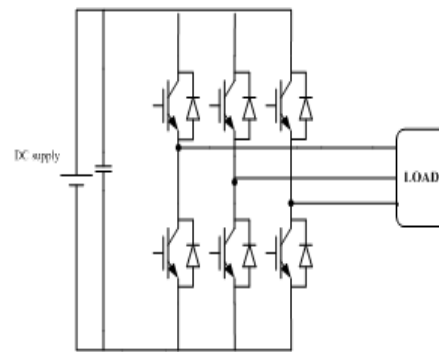


Fig. 1: Circuit diagram for three phase voltage source inverter.

III. Nine Switch Inverter:

Three-phase ac/dc/ac and ac/ac converters with variable frequency (VF) and variable voltage operation have found wide applications in the industry. This configuration features low cost and reliable operation due to the use of a diode rectifier, but it generates highly distorted input line currents and does not have regenerative or dynamic braking capability. These problems can be mitigated by using a back-to-back two-level voltage source converter (B2B 2L-VSC) where a pulse width modulation

(PWM) voltage source rectifier is used to replace the diode rectifier. The B2B 2L-VSC requires a relatively high number (12) of active switches such as insulated gate bipolar transistors (IGBTs). It also needs a dc-link capacitor that is responsible for a limited lifespan and increased cost. To solve these problems, a dual output inverter has been presented using nine semiconductor switches, Fig 2. This inverter is known as Nine-Switch Inverter. The main benefit of such a topology is reduced cost.

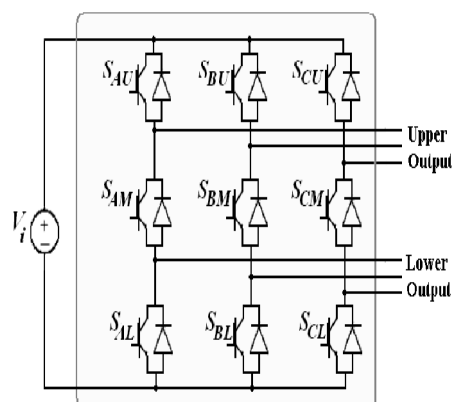


Fig. 2: Circuit diagram for Nine-switch inverter.

IV. Principles Of Harmonic Elimination Technique:

The two-state output waveform of the inverter is approached from an analytical point of view and a generalized method for theoretically eliminating any number of harmonics is developed. The basic square

wave is chopped a number of times and a fixed relationship between the number of chops and possible number of harmonics that can be eliminated is derived. Fig 4 shows a generalized output waveform with N chops per half-cycle. It is assumed

that the periodic waveform has half-wave symmetry and unit amplitude.

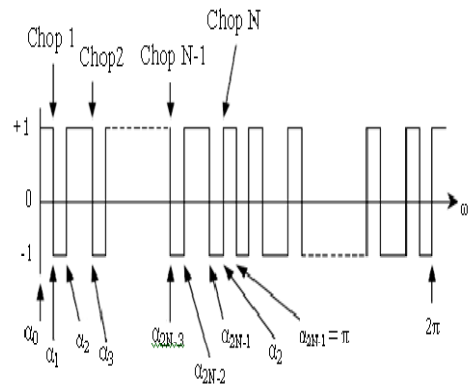


Fig. 3: Generalized output waveform of the single phase inverter.

Therefore,

$$f(\omega t) = -f(\omega t + \pi) \quad (1)$$

where, $f(\omega t)$ is a two state periodic function with N chops per half cycle.

Let $\alpha_1, \alpha_2, \alpha_3, \dots, \alpha_{2N}$ define the N chops as shown in Fig 3.

A Fourier series can represent the waveform as follows:

$$f(\omega t) = \sum_{n=1}^{\infty} (a_n \sin(n\omega t) + b_n \cos(n\omega t)) \quad (2)$$

$$a_n = 1/\pi \int_0^{2\pi} f(\omega t) \sin(n\omega t) d\omega t \quad (3)$$

$$b_n = 1/\pi \int_0^{2\pi} f(\omega t) \cos(n\omega t) d\omega t \quad (4)$$

Substituting for $f(\omega t)$ in equation (3) and using half wave symmetry property,

$$a_n = 2/\pi \sum_{k=0}^{2N} (-1)^k \int_{\alpha_k}^{\alpha_{k+1}} \sin(n\omega t) d\omega t \quad (5)$$

From 5, evaluating the integral,

$$a_n = 2/n\pi \sum_{k=0}^{2N} (-1)^k [\cos(n\alpha_k) - \cos(n\alpha_{k+1})]$$

$$a_n = 2/[\cos(n\alpha_0) - \cos(n\alpha_{2N+1}) + 2 \sum_{k=1}^{2N} (-1)^k \cos(n\alpha_k)]$$

$$\cos(n\alpha_0) = 1, \cos(n\alpha_{2N+1}) = (-1)^n$$

Equation (5) reduces to,

Utilizing the half wave symmetry property of the wave form, $a_n = 0$ and $b_n = 0$ for even n . Therefore for odd n , from equations (6) and (7) are functions of $2N$ variables.

$$b_n = -4/n\pi \left[\sum_{k=1}^{2N} (-1)^k \sin(n\alpha_k) \right] \quad (6)$$

$$a_n = 4/n\pi [1 + \sum_{k=1}^{2N} (-1)^k \cos(n\alpha_k)] \quad (7)$$

In order to obtain a unique solution for the $2N$ variables, $2N$ equations are required. By equating any N harmonics to zero, $2N$ equations are derived from equations (6) and (7).

V. Selective Harmonic Elimination Technique:

Selective harmonic elimination control has been a widely researched alternative to traditional pulse-width modulation technique. The elimination of

specific low-order harmonics from a given voltage/current waveform achieved by Selective Harmonic Elimination (SHE) technique (Wells, J.R., 2008). In this method there is need to calculate the firing angles for placing notches. The notch angles are calculated using Newton Raphson method. This method is well known for its fast convergence, (Chiasson J.N., 2004) provided that the method is supported by good initial guess.

The Newton's method defines the solution procedure for the set of equations given by,

$$J(\alpha) \times \Delta\alpha = f(\alpha)$$

Then the iteration procedure is as follows:

1. The values of initial angles $\alpha = \alpha_0$ are substituted in the matrices J and f .
2. The value of $\Delta\alpha$ is found by, $\Delta\alpha = J(\alpha)^{-1} f(\alpha)$
3. The values of $\Delta\alpha$ obtained are compared with the tolerance error value.
4. If the value of $\Delta\alpha$ is lesser than the error tolerance, then exit the loop.
5. If not, the new values of α are found by $\alpha(\text{new}) = \alpha(\text{old}) - \Delta\alpha$
6. The new values of α are substituted in the matrices J and f . Then the loop is repeated from step (2).

VI. Simulation And Results:

The Simulink model of open loop selective harmonic elimination technique for six switch and nine switch inverter fed induction motor is shown in figure 5 and figure 7. The output voltage and current are shown in figures 6 and 8.

Finally performance of SHEPWM of six switch inverter and nine switch inverter has been compared. The % THD for six switch and nine switch inverter are measured and tabulated as shown in table. Therefore from the parameters measured the current THD% of closed loop PWM is reduced when compared with open loop.

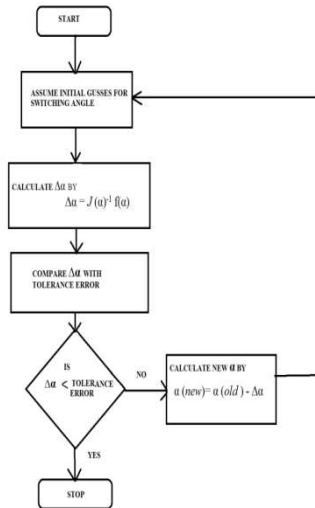


Fig. 4: Flow chart for Newton Raphson Method.

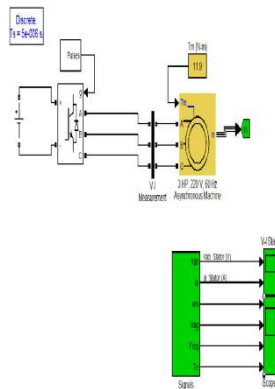


Fig. 5: Simulation model of open loop SHE-PWMsix switch inverter.

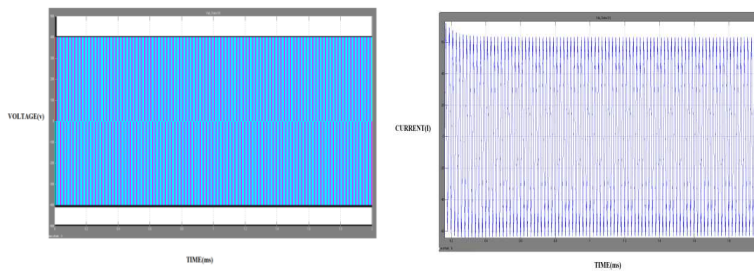


Fig. 6: Output voltage and current for six switch inverter.

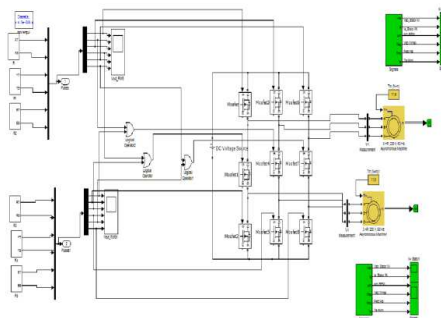


Fig. 7: Simulation model of open loop SHE-PWM nine switch inverter.

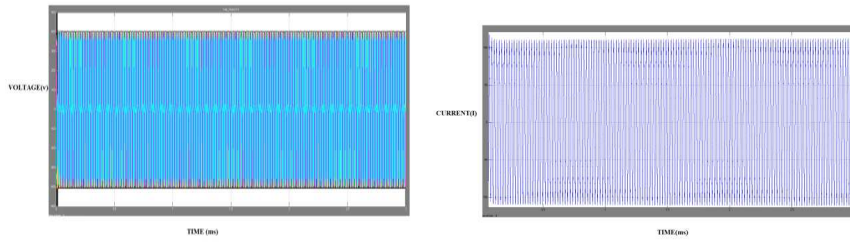


Fig. 8: Output voltage and current for nine switch inverter.

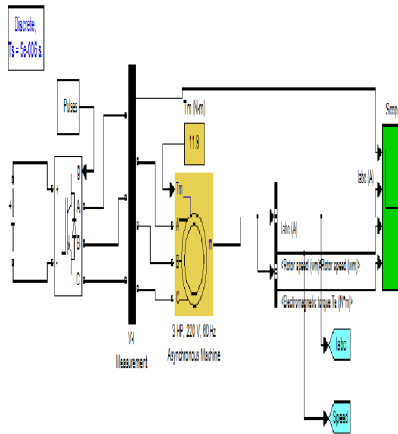


Fig. 9: Simulation model of closed loop SHE-PWM six switch inverter.

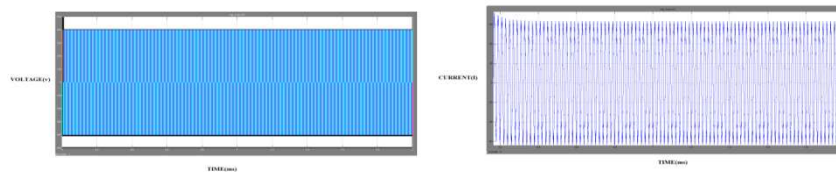


Fig. 10: Output voltage and current for six Switch inverter.

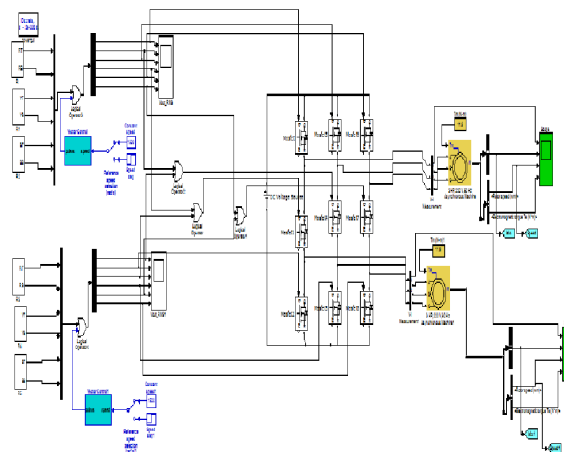


Fig. 11: Simulation model of closed loop SHE-PWM nine switch inverter.

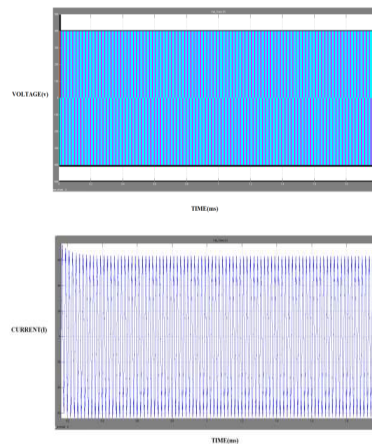


Fig. 12: Output voltage and current of nine switch inverter.

Table 1: Comparison Of Open Loop And Closed Loop She-Pwm.

CONTROL TECHNIQUE	% VOLTAGE THD	% CURRENT THD
OPEN LOOP- SIX SWITCH	102.32	5.73
OPEN LOOP-NINE SWITCH	100.37	3.73
CLOSED LOOP- SIX SWITCH	95.63	4.46
CLOSED LOOP- NINE SWITCH	83.54	2.98

VII. Conclusion:

Selective harmonic elimination control has been a widely researched alternative to traditional pulse-width modulation technique. The elimination of specific low-order harmonics from a given voltage/current waveform achieved by SHE technique. The switching angles are obtained by Newton Raphson optimization technique. It is applied to three phase six switch voltage source inverter and nine switch inverter where 5th, 7th, 11th, 13th, 17th and 19th harmonics and THD are reduced using MATLAB / SIMULINK. The open loop and closed loop techniques are compared and their THD are tabulated. Thus the harmonics are reduced to nearly 3% by using SHE-PWM technique.

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