**Abstract**

**Keywords:** AC motors, pulse width modulation technique, SVPWM.

In industrial in order to apply energy requirements of motor, converters are used. Pulse Width Modulation technique is a suitable approach that increased in industrial application in last decades. The easy control and implement are the most advantage of PWM. In this paper survey of different techniques for PWM is presented. It is contain single pulse modulation, multiple pulse modulation, and space vector based PWM (SVPWM). In order to better understand the two last techniques are simulated and line voltage and line current of these techniques are presented in their relation part.

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**1. Introduction**

In general, the machines are used to convert one kind of energy to another kind of energy. When the conversions take place from electrical to mechanical, the machine is motor. By this point AC motors are used to convert electrical energy to mechanical energy [1]. In industry, induction motors are widely used because of their advantage. Its advantage is like as: 1. bootstrap, 2. no need for maintenance, 3. low price, 4. simplicity and strength building [2, 3]. There are many methods to control output voltage but the best one is concatenate PWM control within inverter. One of the most popular methods that used to analog circuit control is PWM [4]. Pulse width modulation technique is used in many applications such as measurement and etc. PWM is a technique that controlled the width of pulse [5, 6].

The PWM technique can be used to transmission the information by encoding them, also its used to control the power that
applied to the electrical device, in other word it’s its main use.

In last two decades many kinds of PWM technique have been studied [7]. The descriptions of PWM is contains the different kind of methods, concept and performance. There are many parameters that have effect on their implementation ac drives, such as power level and semiconductor device [8]. The amount of average value of voltage or current that applied to the load can be control by turning on and off the switch. This switch works at the fast speed. In general, the switching will be done several times in a minute and it’s different for each device. In a faint lamp it’s 120 Hz and for motor drive it’s different from few kHz to tens of kHz. Proportion of ‘on’ time to the interval time is defined as duty cycle. The duty cycle has direct proportion with power [9, 10].

Since the power loss in PWM technique is very low, it can be mentioned that is the best advantage of this method. We have power loss when there is voltage or current, so in this technique because of the Absence of voltage or current, power loss is zero.

2. PWM techniques

In this part different kind of PWM technique is presented. These different kinds are containing single pulse modulation, multiple pulse modulations, and Space Vector based PWM (SVPWM).

2.1. Single pulse width modulation

In this technique, in every half-cycle there is just one pulse and width is depends on requirements of output voltage. As it’s clear from figure 1, by this technique the reference signal is converted to square wave signal. To obtain this square wave, the positive output signal is related to the positive input and negative output is related to negative input [11, 12].

![Gating signal production of single PWM](image-url)
The switching frequency of triangle waveform $V_{tri}$ is $f_s$. By this frequency the speed of inverter switching (turning on and off) is controlled. To modulate the switch duty ratio, the control signal, $V_{control}$, by the frequency of $f_c$ is used. This is the fundamental frequency of the inverter voltage output. Since the output of the inverter is affected by the switching frequency it will contain harmonics at the switching frequency [13]. The duty cycle of one of the inverter switches is called the amplitude modulation ratio, $m_a$.

$$m_a = \frac{V_{control}}{V_{tri}}$$  \hspace{1cm} (1)

$$m_f = \frac{f_s}{f_c}$$  \hspace{1cm} (2)

### 2.2. Multiple pulse width modulations

In this technique the amount of harmonic is reduced by applying multiple pulses in each output voltage half cycle. Figure 2 shows the signal for turning on and turning off transistors. This signal is produced by comparing reference signal (with $f_o$ as output frequency) with triangular carrier wave (with $f_c$ as output frequency). Modulation index is varied from 0 to 1. By this variation, pulse be varied from 0 to $\pi/p$ and follow of that, the output voltage variation is from 0 to $V_m$[14].

Where:

$$p = \frac{f_o}{2f_c}$$  \hspace{1cm} (3)

![Fig. 2: Gating signal production of multiple PWM](image-url)
Line voltage and line current of multiple pulse width modulations are presented in figures 3 and 4 respectively.

![Fig. 3: Line voltage of multiple pulse width modulations](image1.png)

![Fig 4: Line current of multiple pulse width modulations](image2.png)

2.3. Space vector pulse width modulations

In power conversion space vector pulse width modulation has essential and viable role. The main goals of gate pulse generating SVPWM are as follow [15]:

1. Wide linear range of modulation
2. Switching loss is minimum
3. The THD is minimum in switching wave form
4. Its implementation is easy and its computational calculations is very low

SVPWM is used to control the output voltage and input current. SVPWM technique is an advantage since it increased the flexibility of switching. Under unbalanced conditions SVPWM can have useful advantage [16, 17].
To implement of SVPWM, voltage equation can be transformed from abs frames to d-q reference frame. Equation 4 and 5 shows its relation. d-q and ABC reference frame is showed in figure 6.

\[ f_{dqo} = K_s f_{abc} \]  
\[ K_s = \frac{2}{3} \begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & -\sqrt{3}/2 & -\sqrt{3}/2 \\ 1/2 & 1/2 & 1/2 \end{bmatrix} \]

And \( f \) can be voltage or current.

Figure 7 shows the responds of line voltage for space vector pulse width modulations and the line current is presented in figure 8.
3. Conclusion

There are many methods to control output voltage but the best one is concatenate PWM control within inverter. By proportion switching and applying fixed dc voltage to inverter, ac output voltage will be produced. Pulse Width Modulation technique is a suitable approach that increased in industrial application in last decades. The easy control and implement are the most advantage of PWM. In all of the methods that are used to controlling AC motors, SVPWM is the best one. Comparison of SVPWM and conventional methods shows that in SVPWM the quality is better, total harmonic distortion (THD) is lesser and torque ripple is reduced.

References


