Generation of PWM signals for full range speed control of three –phase induction motor simulation by using a computer

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الخلاصة

العمليـة الأساسـية لأنظمـة السيطرة علـى السـرعة تعتمـد أساسـا علـى مـدى واسـع مـن التـرددات المتولـدة مـن المعـالج الـدقيق والـذي اسـتخدم لتوليـد الـPWM أو الإشـارة المضـمنة بسـت مراحـل للمحافظة على نسبة الترددات إلى الفولتية. بسبب التحديدات في حساب السرعة باستخدام الحاسوب الـدقيق سـابقا لـذا تـم إجـراء الحسـابات عبـر الحاسـوب الشخصـي والـذي اسـتخدم لأغـراض المراقبـة والسيطرة لكونـها أكثر كفاءة وفعالية في التطبيقات

Abstract

The principle operation of speed control systems is depended upon a wide range of generated frequencies a microprocessor was used to generate PWM or a six-steps modulated signal to maintain a constant voltage/frequency ratio. Because of speed computation limitations found in many available microcomputers previously, it was concluded that the on-line computation of switching patterns was not practical. The control and monitoring by using PC is more efficient and active.

Introduction:

The technique of the pulse width (PWM) has found wide acceptance for controlling electronic switching power inverters. PWM control signals were originally generated with the help of electronic hardware, but recently microcontrollers have begun to play an important role in the design and control of signal generation for power inverters.

In earlier systems, the microcomputer was used to generate the reference signal, while the timing signal and the actual PWM signals were produced by electronic hardware [1]. Later systems were developed with a microcomputer, used to compute switching points for PWM patterns with selected harmonic elimination and to retrieve recomputed patterns from look-up tables. In speed control systems, with a wide range of generated frequencies a microprocessor was used to generate PWM or a six-step modulated signal and to maintain a constant voltage/frequency ratio.

Sinusoidal Pulse - Width Modulation:

The principal idea of pulse-width modulation (PWM) is to compare the required signal (modulating signal) with another higher frequency signal (carrier signal). The result of the comparison is a train of pulses with widths proportional to the amplitude of the modulating signal.

Conventionally, to generate a sinusoidal PWM signal [2,3], a sinusoidal modulating wave $f_m(t)$ is compared with a triangular carrier wave $f_c(t)$ as shown in Fig.(1). The frequency of inverter output is determined by frequency of the modulating wave, and its amplitude is determined by the ratio of $f_m(t)$ peak amplitude to the $f_c(t)$ peak amplitude. This ratio is called depth of modulation (M).

Fig.(1) represents a single-phase PWM. Three–phase PWM can be generated by direct comparison between the three phases of the modulating wave and a single carrier wave. However, the three–phase PWM can also be generated from single–phase PWM depending on the fact that the angle between each two phases is 120 electrical. This can be achieved simply by generating a single–phase PWM, then shifts the generated waveform by 120 and 240 electrical to produce the other two phases.

Frequency ratio (FR) is the ratio of the carrier frequency (f_c) to the modulating frequency (f_m). The high value of R (maximum switching frequency) reduces the effective low harmonics in the output and consequently, the output voltage waveform becomes closer to the sinusoidal shape. However, the highest value of R is restricted by the switching capability of the devices used and its switching losses [2,4,5].

Software Organization:

In this work the main program was used to achieve the required functions. All these programs are in the PC. The software programs that are executed in the PC are written in visual basic language. PC is used for monitoring and display wave forms and tables of trigger.

Fig.(2) shows the flowchart of generating PWM process. A simple sinusoidal pulse width modulation (SPWM) technique is used in the proposed system. Firstly the program gating signals produced by solving two equations. The first equation of the reference signal which is a sine wave and the second one is for the unipolar triangular carrier signal. The carrier signal is written by using Fourier series extension.

$$f(t) = \frac{K}{2} - \frac{16K}{\pi^2}\left[\frac{1}{4}\cos(\frac{2\pi t}{L}) + \frac{1}{36}\cos(\frac{6\pi t}{L}) + \frac{1}{100}\cos(\frac{10\pi t}{L}) + \frac{1}{196}\cos(\frac{14\pi t}{L}) + \frac{1}{324}\cos(\frac{18\pi t}{L}) + ...\right] \quad .... (1)$$

Where: $B = \frac{1}{4}\cos(\frac{2\pi t}{L}) + \frac{1}{36}\cos(\frac{6\pi t}{L}) + \frac{1}{100}\cos(\frac{10\pi t}{L}) + \frac{1}{196}\cos(\frac{14\pi t}{L}) + \frac{1}{324}\cos(\frac{18\pi t}{L}) + ...$

$L = \frac{\pi}{R_1.W}$, $R_1 =$ Frequency ratio (12).,$W =$Number of cycles (1).

Where: K= The amplitude of carrier (50).,*f*= Frequency ($f = N/30$).,*N*= The speed of motor., *V*= Line voltage ($V = 8f$).

The equation represents the wave form shown in Fig.(1). Each half cycle of the reference signal is divided by the program to 1024 sample i.e., resolution of 0.17578125°. The resulting gating signals are shown in Fig.(1).

For drawing sine wave and triangular wave and these are draw in by the PC.

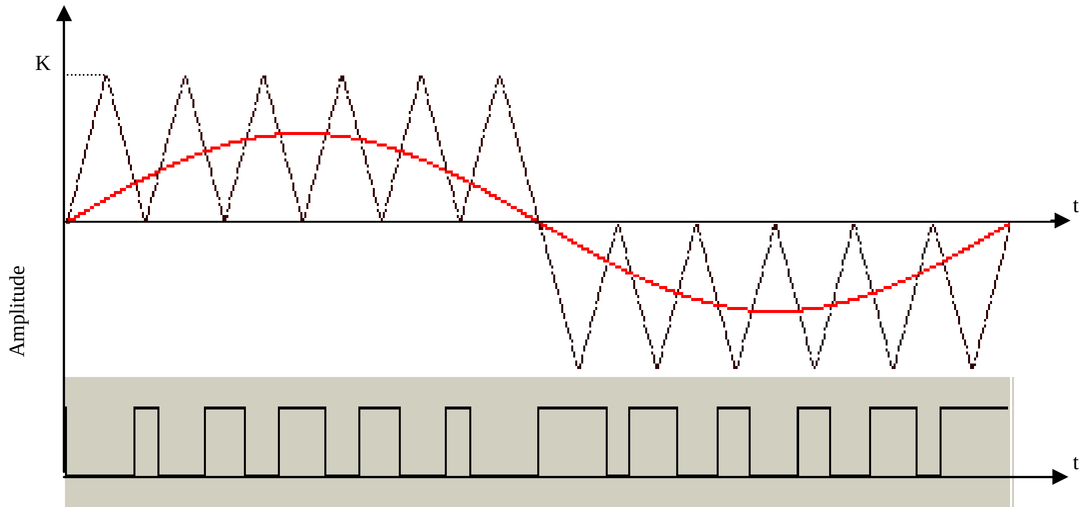


Fig.(1): Half voltage and half frequency with conventional PWM system

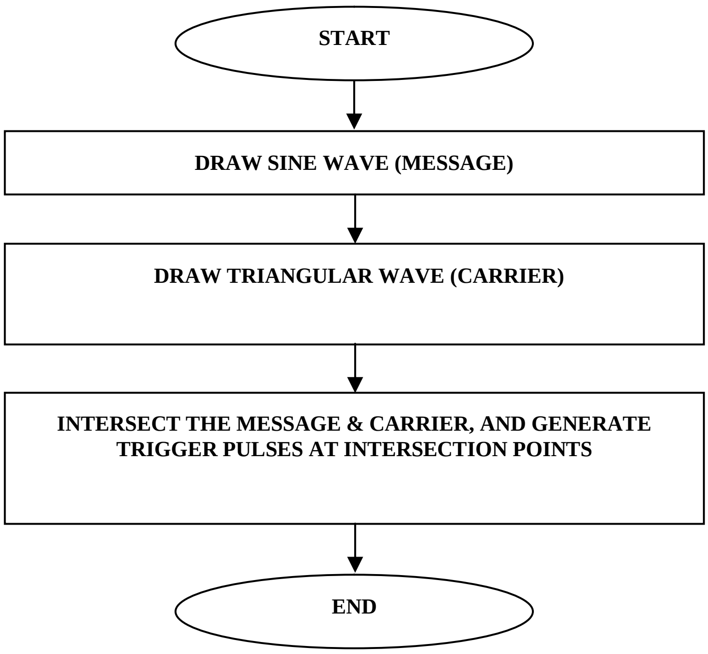
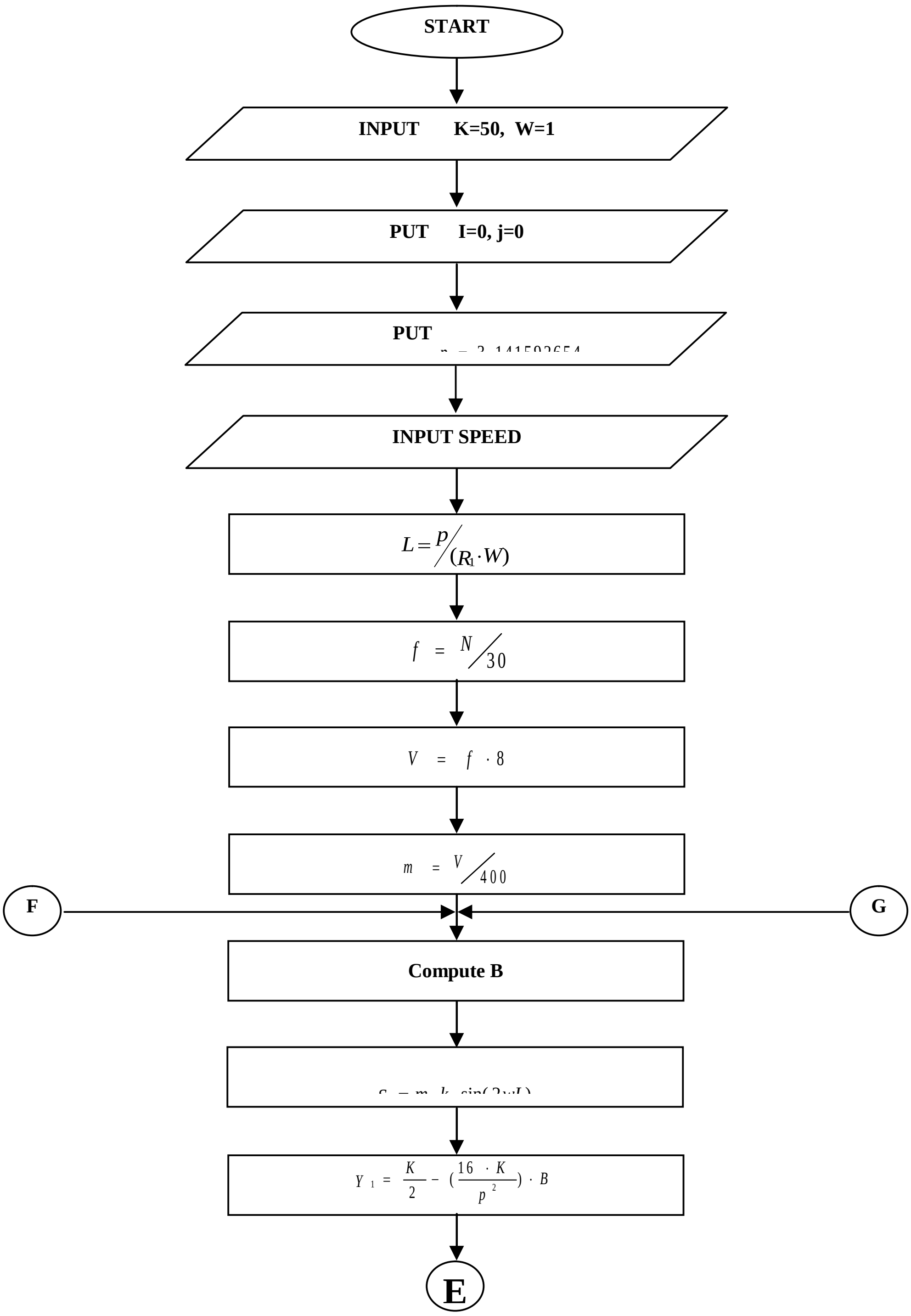


Fig.(2): Flowchart of generating PWM

Fig.(3) shows the flowchart of PWM generation, by intersecting sine wave and carrier (Triangular) wave, intersection points will set. From these intersection points, the appropriate pulses will be obtained. The widths of pulses depend upon the value of speed and the mathematic relationship that is shown in the Flowchart. The width of pulses is directly related with the value of speed and the number of pulses increased when the frequency ratio is increased.



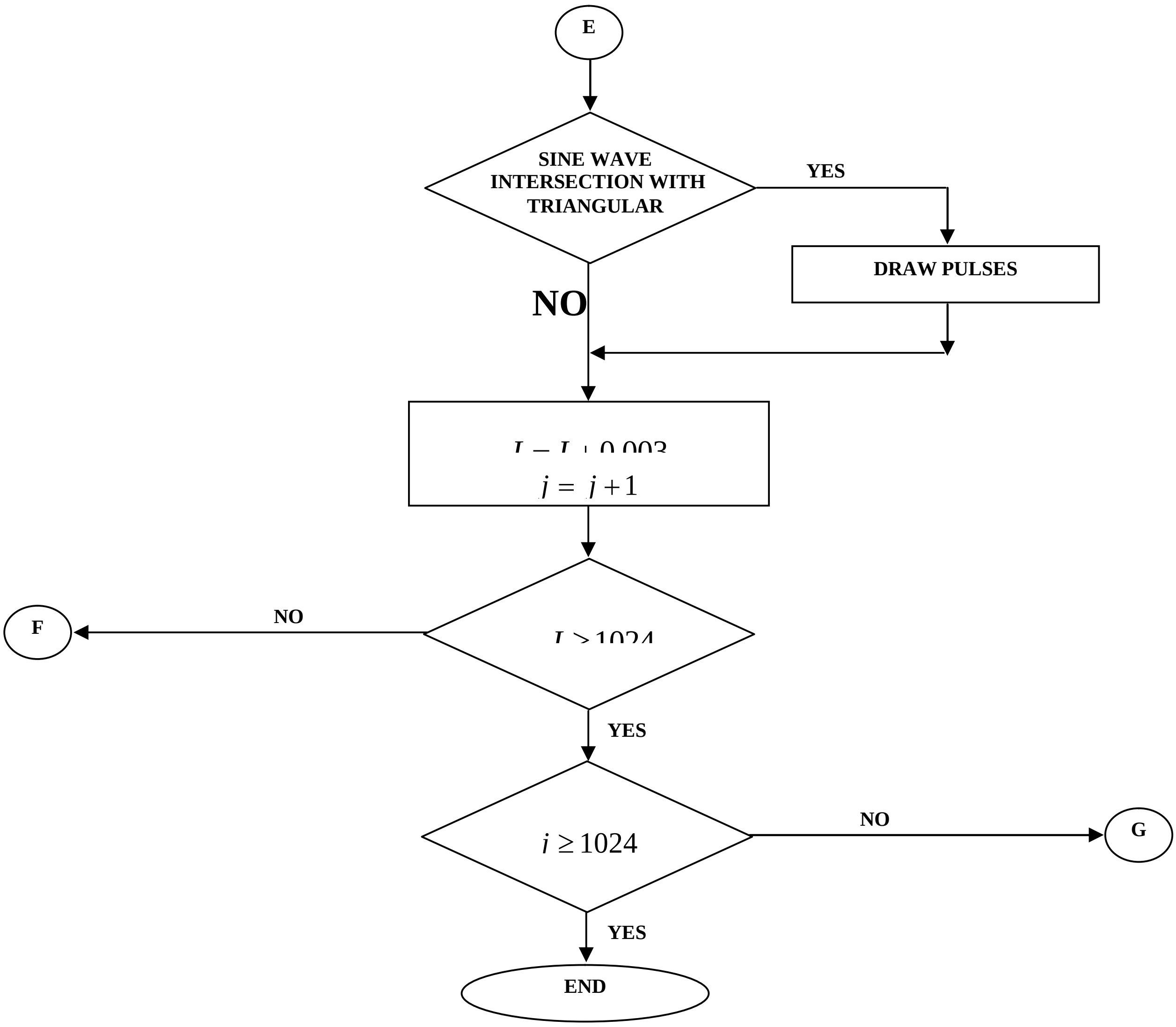


Fig.(3): Flowchart of PWM generation

Theoretical and Experimental Results:

Fig.(4),(5) are drawn according to tables (1),(2). The odd number of triggers represents the beginning of pulses and the even number of trigger represents the end of pulses, for instance the first pulse for phase R is T_1 it represents the begin of pulses and T_2 represent the end of pulses and thus, when the speed increases the width of pulse increases, for instants; the width of trigger pulses in Fig.(5) (at 1500rpm) is approximately twice the width of trigger pulses in Fig.(4) (at 700rpm).

Fig. (4),(5) shows the six trigger pulses of PWM that feeds to the six – MOSFET at speed 700 rpm, 1500 rpm respectively. These trigger pulses are obtained by simulation.

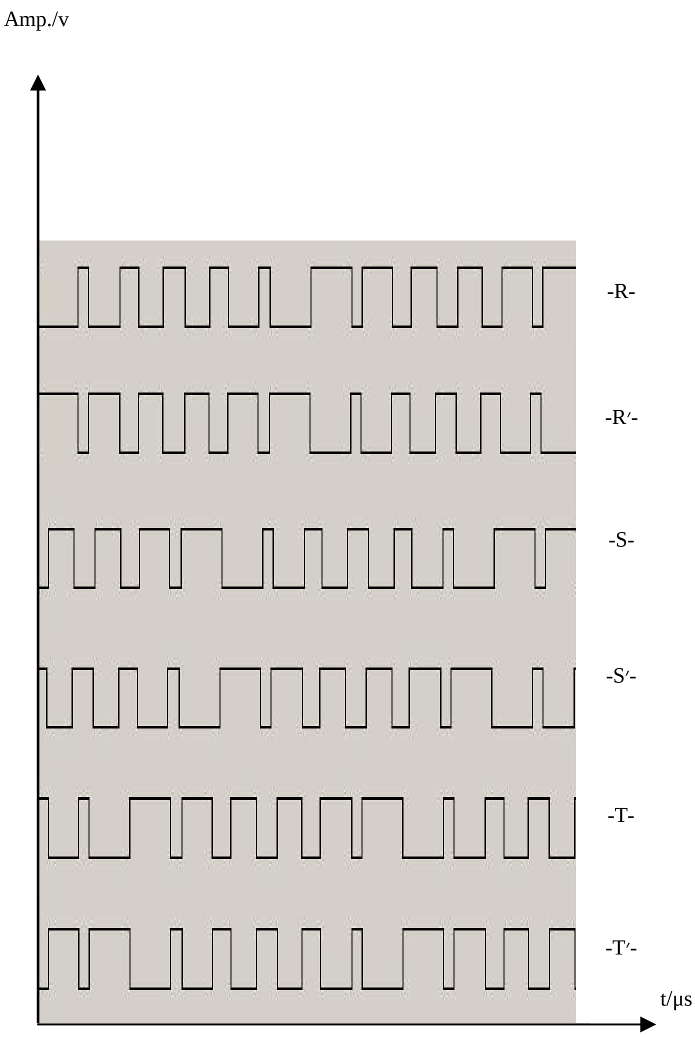


Fig.(4): Six trigger pulses at speed 700rpm

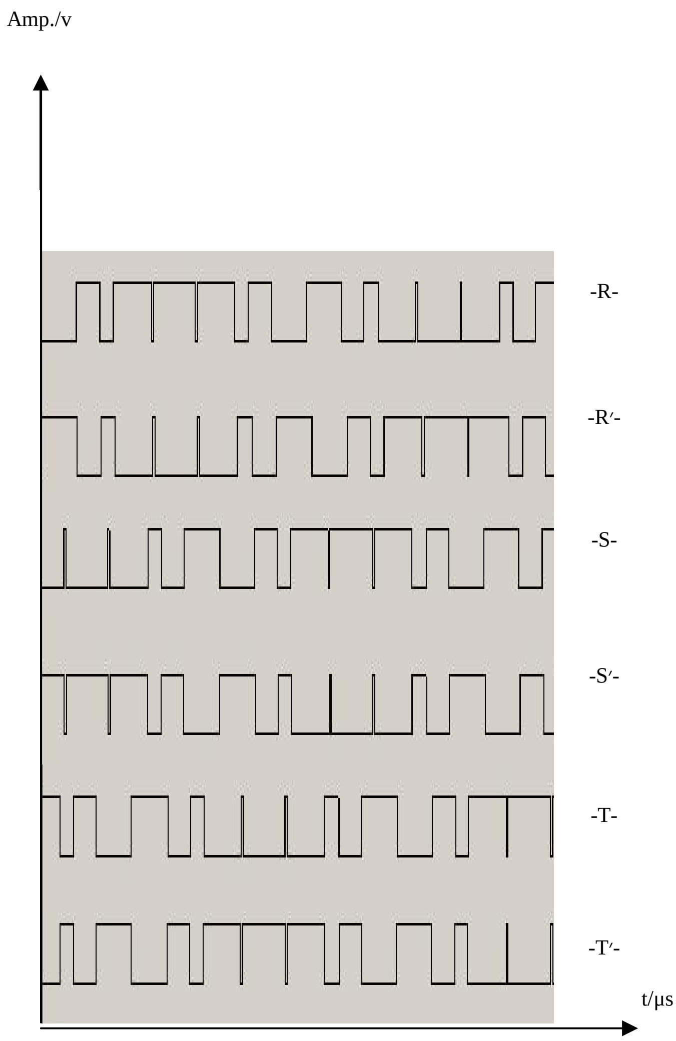
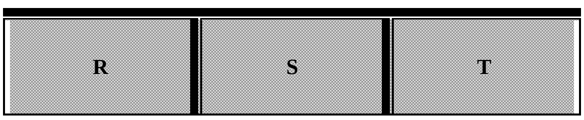


Fig.(5): Six trigger pulses at speed 1500rpm



32.840658:T_{22}	**772.195647:T_{15}**	**693.039499:T_{8}**
3233.118986:T_{1}	**2777.547929:T_{16}**	**3107.647350:T_{9}**
4051.630122:T_{2}	**4414.5702201:T_{17}**	**3967.084042:T_{10}**
6507.163530:T_{3}	**6378.996927:T_{18}**	**7159.277472:T_{11}**
7939.558017:T_{4}	**7852.316971:T_{19}**	**10351.470902:T_{12}**
9903.984743:T_{5}	**10266.924822:T_{20}**	**11210.907594:T_{13}**
11581.932571:T_{6}	**11126.361515:T_{21}**	**13625.515445:T_{14}**
13546.359297:T_{7}	**14318.554944:T_{22}**	**15057.909933:T_{15}**
14978.753785:T_{8}	**17518.833272:T_{1}**	**17063.262215:T_{16}**
17393.361636:T_{9}	**18337.344408:T_{2}**	**18700.284487:T_{17}**
18252.798328:T_{10}	**20792.877815:T_{3}**	**20664.711213:T_{18}**
21444.991758:T_{11}	**22225.272303:T_{4}**	**22138.031257:T_{19}**
24637.185187:T_{12}	**24189.699029:T_{5}**	**24552.639108:T_{20}**
25496.621880:T_{13}	**25867.646857:T_{6}**	**25412.075800:T_{21}**
27911.229731:T_{14}	**27832.073583:T_{7}**	**28604.269230:T_{22}**
29343.624218:T_{15}	**29264.468071:T_{8}**	**31804.547558:T_{1}**
31348.976501:T_{16}	**31679.075921:T_{9}**	**32623.058694:T_{2}**
32985.998773:T_{17}	**32538.512614:T_{10}**	**35078.592101:T_{3}**
34950.425498:T_{18}	**35730.706044:T_{11}**	**36510.986589:T_{4}**
36423.745543:T_{19}	**38922.899473:T_{12}**	**38475.413315:T_{5}**
38838.353393:T_{20}	**39782.336166:T_{13}**	**40153.361143:T_{6}**
39697.790086:T_{21}	**42196.944016:T_{14}**	**42117.787869:T_{7}**

Table(1): Trigger pulses for three-phases at speed

Tab
three

R	S	T
32.840658:T_{22}	**772.195647:T_{15}**	**693.039499:T_{8}**
3233.118986:T_{1}	**2777.547929:T_{16}**	**3107.647350:T_{9}**
4051.630122:T_{2}	**4414.5702201:T_{17}**	**3967.084042:T_{10}**
6507.163530:T_{3}	**6378.996927:T_{18}**	**7159.277472:T_{11}**
7939.558017:T_{4}	**7852.316971:T_{19}**	**10351.470902:T_{12}**
9903.984743:T_{5}	**10266.924822:T_{20}**	**11210.907594:T_{13}**
11581.932571:T_{6}	**11126.361515:T_{21}**	**13625.515445:T_{14}**
13546.359297:T_{7}	**14318.554944:T_{22}**	**15057.909933:T_{15}**
14978.753785:T_{8}	**17518.833272:T_{1}**	**17063.262215:T_{16}**
17393.361636:T_{9}	**18337.344408:T_{2}**	**18700.284487:T_{17}**
18252.798328:T_{10}	**20792.877815:T_{3}**	**20664.711213:T_{18}**
21444.991758:T_{11}	**22225.272303:T_{4}**	**22138.031257:T_{19}**
24637.185187:T_{12}	**24189.699029:T_{5}**	**24552.639108:T_{20}**
25496.621880:T_{13}	**25867.646857:T_{6}**	**25412.075800:T_{21}**
27911.229731:T_{14}	**27832.073583:T_{7}**	**28604.269230:T_{22}**
29343.624218:T_{15}	**29264.468071:T_{8}**	**31804.547558:T_{1}**
31348.976501:T_{16}	**31679.075921:T_{9}**	**32623.058694:T_{2}**
32985.998773:T_{17}	**32538.512614:T_{10}**	**35078.592101:T_{3}**
34950.425498:T_{18}	**35730.706044:T_{11}**	**36510.986589:T_{4}**
36423.745543:T_{19}	**38922.899473:T_{12}**	**38475.413315:T_{5}**
38838.353393:T_{20}	**39782.336166:T_{13}**	**40153.361143:T_{6}**
39697.790086:T_{21}	**42196.944016:T_{14}**	**42117.787869:T_{7}**

Conclusions:

The procedure used for calculating the changes according to the recommended strategy in pulses triggering showed an acceptable as results it requires small memory (ROM) size.

The PWM can be generated by many other methods as discrete cct's., but these methods which need complex electronic circuits and large size memory.

In this work the DC-link voltage is kept constant, while the modulation index is variable. The number of samples is chosen 1024 samples for each half cycle; to get a resolution is 0.17578125 degree in the width of each sample.

Future works:

At this stage of work, the module can be developed to include future facilities and capabilities, for future work.

- To use a microcontroller, to achieve flexibility, simplicity, develop programming and minimize.
- A new version of microcontroller 8051 such as effect of noise may be used to provide the control on a wide range of speed. So, to enhance the operation and time response of the system.

References

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