Generation of PWM Inverter Based on a Microcontroller at Feeding Induction Motor

Mohammed Hussein Baqir

Abstract*—*The steps of process of generated PWM are implemented by using a microcontroller 89c51 and using personal computer (PC). In this project the unipolar modulation technique is presented to overcome many problems. The generated pulses are fed to six pulses at bridge inverter consist of six (MOSFET) transistors. The fundamental operation of PWM is depending upon mathematical relationships between the voltage and the frequency (V/ F) constant value, this relationship gives low harmonics that takes place the modulation process. The control signal of PWM inverters is generated by comparing a reference sinusoidal waveform and triangular waveform of modulating signal. The dc link is constant value, and modulation index is variable according to the varying output voltage of the inverter.

Keywords- PC, MOSFET, V/F.PWM

I. INTRODUCTION

The dc motor has satisfied these requirements satisfactorily in many applications, but it's not the ideal solution for variable speed operation. The commutator consists of a large number of copper segments separated by thin sheets of mica insulation; this elaborate construction increases the cost of the dc motor and reduces the power weight ratio. Brush and commutator wear by sparking, and the mica insulation limits the voltage between segments. The total armature voltage is then limited.

The magnitude of the armature current and its rate of change are restricted by commutation difficulties, and the speed of rotation of the dc motor is limited.

Ac motors such as the squirrel cage induction motor has a robust rotor construction, the simple rotor construction also results in cheaper motor and a higher power weight ratio.

A three phase induction motor consists of stator and rotor. By induction, the same number of phases and poles are produced by rotor as in the stator winding

When the stator is supplied by balanced 3-ph AC source of frequency ($f\,Hz$) a rotating field will move at a synchronous speed and expressed as:-

$$N_s = 120f/P \text{ ------- } (1)$$

Where N_S the synchronous speed in (r.p.m), P is the number of pole pairs and f is the stator frequency in Hz.

When the supply voltage is constant and the frequency is varied that the torque speeds.

Manuscript received March, 2014

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Efficient wide range speed control of the induction motor is possible when a variable frequency AC supply is available [1]. The inverter provides a controllable AC power supply over a wide range frequency. Figure (1) shows the diagram of 3 phase inverter. If the supply frequency is reduced from its rated value while the terminal voltage is kept constant, the motor flux will increase leading to excessive core losses and high magnetizing current. The function of AC drive power converter is to supply variable voltage and variable frequency to an AC motor. The output voltage must be varied linearly with the output frequency [2].

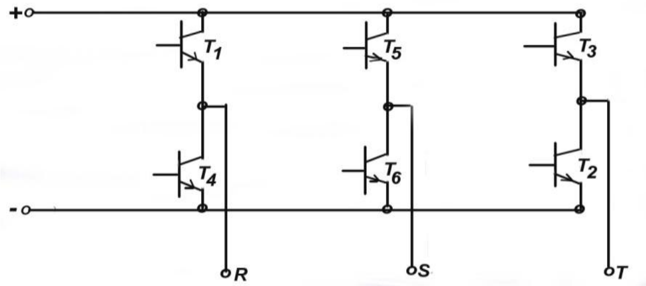

Fig.1.Three phase bridge inverter

II. PULSE WIDTH MODULATED (PWM) INVERTERS

The inverters control signals for six switches see figure (2), I_{C1} to I_{C6}.

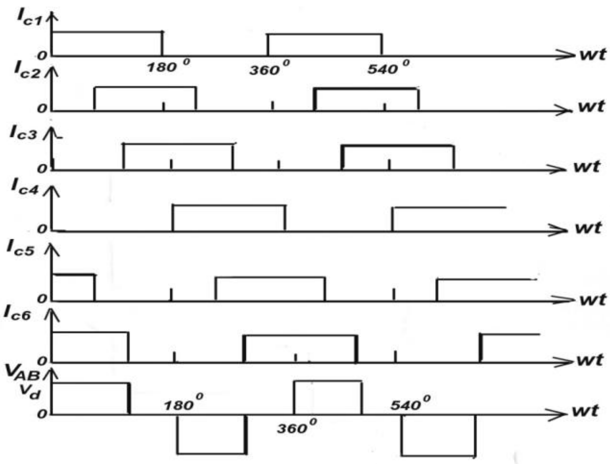

Fig.2.The control signals and quasi square waveform for 3 phase voltage source inverter (VSI) [2].

In inverter output voltage period of 2π radians (or Tsec) each control signal has duration of π radians or ((180^0), the control signals are applied to the switches in the sequence of their numbers.

With a phase difference of ($\pi/3$) radians, the period (T) has been divided into six equal intervals. The output voltage of a six step inverter can be controlled by either of the following methods:-

1-Control of the DC input voltage

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2-Control of the AC output voltage by use of multiple inverters [3].

The six step inverter suffers from disadvantages, so there other better inverters for AC motor drive used to overcome these disadvantages, these inverters are Pulse Width Modulation (PWM) inverters.

III. GENERATION OF PULSE WIDTH MODULATION (PWM) INVERTER

Three - phase variable frequency inverter, the 110 volts AC 3 phase power supply is converted to into fixed DC voltage by used three phase full bridge diode rectifier. The harmonics are filtered out by an LC filter to provide a smooth DC voltage, which is then applied to the inverter input. The inverter consists essentially of six powers (MOSFET), this inverter converts the DC linked voltage into an adjustable three phase AC voltage. The PWM control scheme used to control the inverter output voltage and frequency by modulating the ON and OFF times of power switches, see figure (3).

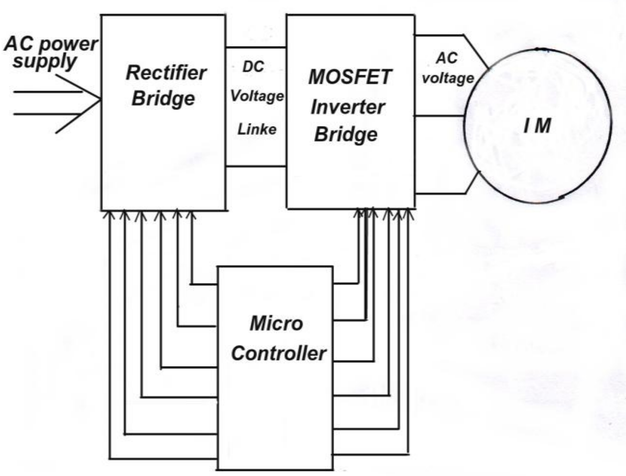

Fig.3. Block diagram of system generation PWM

IV. SWITCHING TECHNIQUES

The heart of any PWM inverter is the switching strategy used to generate the switching edges of the PWM voltage waveforms [4].

The main switching strategies can be categorized as:

* Optimized PWM techniques.
* Regular sampling techniques.
* Natural sampling techniques.

V. SWITCHING AID NETWORK

The switching loss of transistors increases at higher frequencies and increase the power dissipation around the transistor. Hence it is necessary to the switching losses of the transistor to this network and correspondingly reduces the losses in the device. In addition, the current spikes during turn on voltage spike at turn off of the device can be almost eliminated using suitable values of this network [5]. During transistor work sudden changes of the load current generate high voltage spikes, which could damage the transistors.

Hence it is necessary to have an anti parallel connected diode across each transistor to provide a path for maintaining the current flow in the same direction [6]. The switching power loss can be reduced, if the rise in voltage across the device is slowed down until the current through it falls to zero, this is achieved by connecting a capacitor (C_S) of suitable value across the device. The discharging of (C_S) through the transistor must be limited to prevent the damage of MOSFET the resistor (R_S) is connected in series with (C_S) in order to limit this. The diode (D_S) as shown in figure (4) provides low impedance only for the charging path for the capacitor.

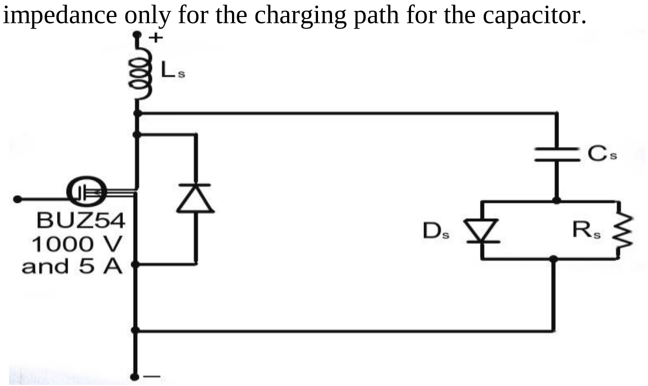

Fig.4. Diagram of MOSFET with using switching aid network

The addition of an inductance (Ls) in series with the transistors to limit $\left(\frac{dI}{dt}\right)$ at turn on of the transistor, the voltage a cross capacitor at any time is calculated from the following equation:

$$V_{C_s} = \frac{1}{C_s}\int_0^t I_L\,dt ----------(2)$$

$$V_{C_s} = \frac{1}{C_s}\int_0^t \frac{I_L}{t_f}t\,dt ---------- (3)$$

Where I_L is the load current?

If C_s is chosen such that the capacitor voltage attains a suitable chosen design value V_{CD} at time $t = t_f$, then

$$V_{CD} = 0.5\left(\frac{I_L t_f}{C_s}\right) -----------(4)$$

The design criterion for the choice of capacitor C_s can now be calculated as:

$$C_s \geq \frac{I_L t_f}{2V_{CD}} -------------(5)$$

A suitable design value for V_{CD} is a fraction of V_{DC}; where V_{DC} is the D.C link voltage. The maximum value of R_s is decided by minimum on time ((T_{ON}(min)) of the transistor. The minimum on time can be designed to be at least three constants $R_s C_s$:

$$T_{on}(\min) \geq 3R_s C_s ---------- (6)$$

or

$$\frac{R_s(T_{on}min)}{3C_s} --------------(7)$$

The power dissipation in the resistor R_s is:

$$P_{R_s} = 0.5 C_s V_{DC}^2 f --------- (8)$$

Where f is the operating frequency of the transistor.

The value of the inductance is selected such that the transistor current does not rise above the allowable value, I_M during its current rise time t_r.

Assuming identical element values for the switching aid network inductance, the voltage across the transistor is given by

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$$V_{Ds} = V_{DC} - 2L_s \frac{d_i T_1}{dt} - - - - - - - - - (9)$$

Where V_{Ds} is drain source voltage, at instant $t = t_r$ the drain voltage becomes practically zero, the value of inductance L_s can then be calculated from equation (9),

$$L_s = \frac{V_{DC} t_r}{2I_M} - - - - - - - - - - - - - (10)$$

The practical designed values of C_s , R_s and L_s are $7\ nF, 100\ \Omega/15\ W$, and $3\ \mu H$ respectively.

VI. CHARACTERISTIC OF MICROCONTROLLER 89C51

The 89c51 is a low power, high performance CMOS 8-bit microcontroller see figure (5), and the device is manufactured using Atmel's high density nonvolatile memory technology. In addition, the 89c51 is designed with static logic for operation down to zero frequency and supports two software selectable power saving modes. The idle mode stops the CPU while allowing the RAM, timer/counters, serial ports and interrupt system to continue functioning. The power down mode saves the RAM contents as data but freezes the oscillator disabling other chip function until the next hardware reset [6].

The 89c51 can address 64kbytes of external data memory and 64kbytes of external program memory (separate blocks of code and data memory are referred to as the Harvard architecture). It has two modes of operation, microcontroller mode or microprocessor mode, with microcontroller mode the internal nonvolatile 4kbytes EEPROM (Electrically Erasable Programmable Read Only Memory) is used as program memory and 60kbytes as separate 64kbytes as external program memory and 64kbytes external data memory.

The design of the entire feature found in a microprocessor CPU:

Arithmetic logic unit ALU, program counter PC stacks pointer SP and registers, and added the other of ROM, RAM, parallel I/O ports, serial I/O ports, counters, and a clock circuit.

The 89c51 architecture consists of the following specific features. Eight bit CPU with registers A (the accumulator) and B, sixteen bit program counter (PC) and data pointer (DPTR), eight bit program status word (PSW), eight bit stack pointer (SP), internal ROM or EEPROM (8751) of (0 use (8031) to 4k (8951), (four register banks, each containing eight registers, sixteen bytes which may be addressed at the bit level, eighty bytes of general purpose data memory), thirty two input/output pins arranged as four 8 bit ports (P0-P3), two 16 bit timer/counter (T0-T1), full duplex serial data receiver /transmitter (SBUF), control register (TCON, TMOD, SCON, PCON, IP, and IE), two external and three internal interrupt sources, oscillator and clock circuits.

The heart of the 8951 is the circuitry that generates the clock pulses by which all internal operations are synchronized.

Pin XTAL1 and XTAL2 are provided for connecting a resonant network to form an oscillator. Quartz crystal and capacitor are employed as shown in figure (5) and (6), the crystal frequency of the microcontroller.

The manufactures make available 8051 designs that can run at specified maximum and minimum frequencies, typically (1 MHz – 60 MHz). The time required to execute any particular instruction, is calculated as following [7].

$$T_{total} = \frac{C \times 12}{f} - (2)$$

Where

C = Number of required cycles for the instruction

f = Crystal frequency

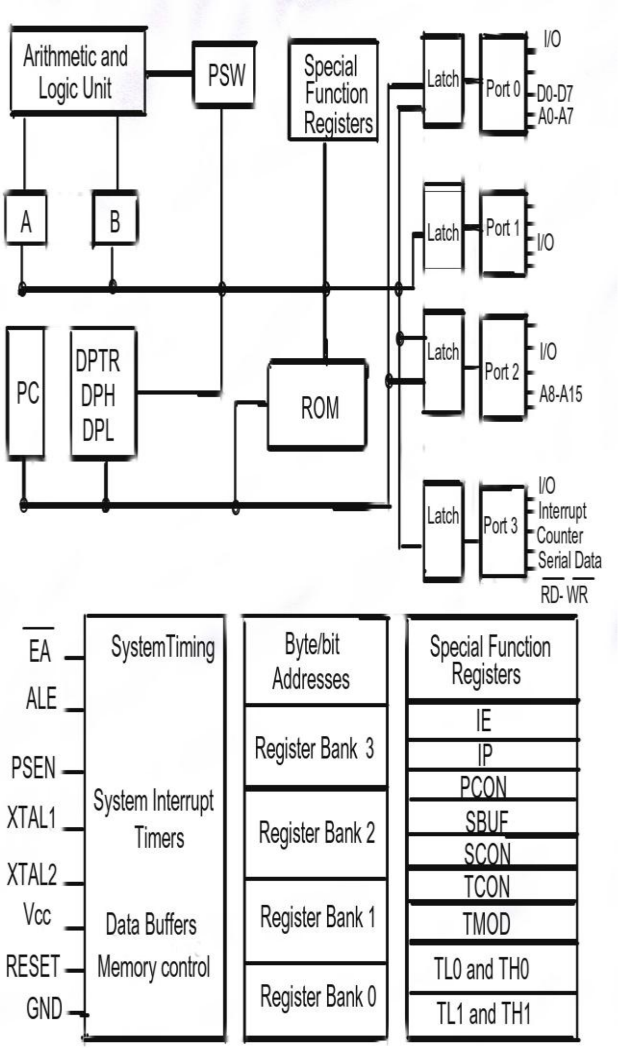

Fig.5 Block diagram of microcontroller 89c51

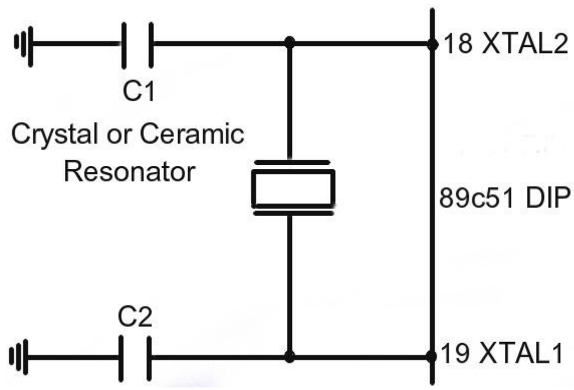

Fig. 6 Crystal or ceramic resonator oscillator circuit

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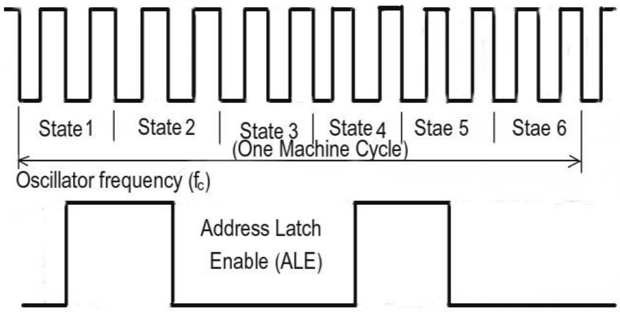

Fig.7 Oscillator circuit and Timing

VII. OPEARTING COUNSEL BY (PC)

The operating is used to control the speed of motor using personal computer (PC) , this technique offers flexibility and easy in operation and monitoring the calculation and results and change the set point by entering it via keyboard of PC[6]. For a certain condition the set point speed is choose in the rang from 100 to $1500\,rpm$, with step size ($\pm 10\ rpm$). The PC is monitoring the local controller and offers a report consisting the following:

1. Trigger pulses for three phases at the demanded speed as table.
2. Draw the trigger pulses.
3. The statues of local controller.
4. The PC is connected with local controller via serial link by using RS 232. The baud rate is used in this work is 1200 bps.

VIII. SOFTWAR ORGANIZATION

The personal computer (PC) and microcontroller are connected via serial port. The software packages that are executed in the PC are written in visual basic language and the executed by the micronroller are written in assembly language. Personal computer is used for monitoring and display wave forms and of trigger pulses show figure 8, main flowchart. The microcontroller checks $P_{1.5}$ stop/start button, if $P_{1.5}$ is set to zero the system start operation, $P_{1.3}$ and $P_{1.4}$ are set to zero, because these pins are used in the self test package.

This self test package is executed by microcontroller this package consist many tests for parts and devices that used in the system such as RAM, EEPROM and serial Porte. Microcontroller is started with initial speed of ($100\ rpm$), then the personal computer (PC) will generate PWM. The PWM is generated by an intersection between sine wave and triangular wave and then generate samples coincident with intersection points. These samples are send to microcontroller the later is compare the time of each sample with the data of look up table 1,to generate trigger pulses and feed to the driver via port.1($P_{1.0}, P_{1.2}$), these data are stored in the external EEPROM to cover the whole speed range values. The microcontroller test is $P_{1.5}$, again if $P_{1.5}$ is changed, the operation of system is stopped.

If $P_{1.5}$ is unchanged the new speed is entered through the key board of the PC, this speed value is sent to the microcontroller to the checked with previous value, to reach to set new speed value where the previous value is must be increased or decreased by step size of $\pm 10\ rpm$.

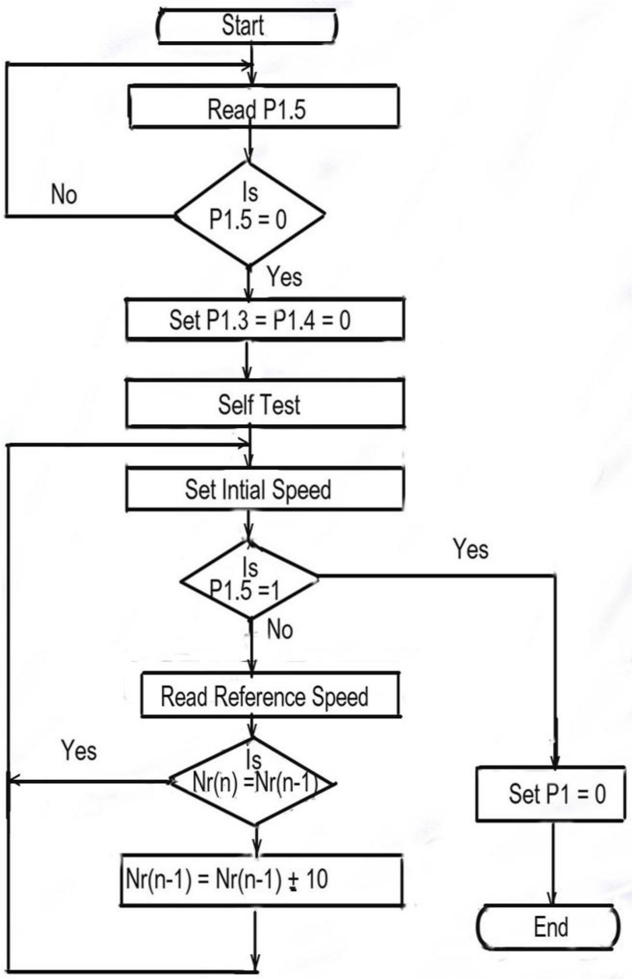

Fig. 8 Flowchart of main program to generated PWM

The carrier signal can be written by using Fourier series extension.

$$f(t) = \frac{K}{2} - \frac{16K}{\pi^2}\left[\frac{1}{4}\cos\left(\frac{2\pi t}{L}\right) + \frac{1}{36}\cos\left(\frac{6\pi t}{L}\right) + \frac{1}{100}\cos\left(\frac{10\pi t}{L}\right) + \frac{1}{196}\cos\left(\frac{14\pi t}{L}\right) + \frac{1}{324}\cos\left(\frac{18\pi t}{L}\right) + \right] --(3)$$

The equation represents the waveform of PWM; each half cycle of the reference signal is divided by the program to 1024 sample, i.e.; resolution of 0.17578125^0. The resulting dating signals are shown in figure 9, [8].

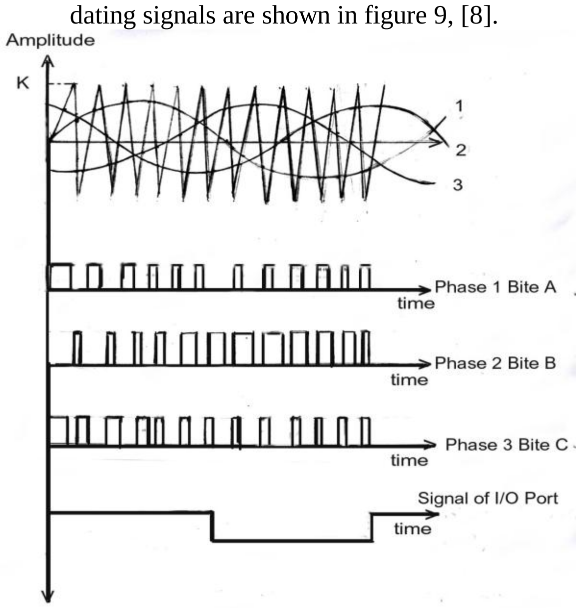

Fig.9 Sinusoidal pulse with modulation Ram 12cycle/ half cycle.

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IX. MOTOR EFFINIENCY

Choice of models**:** The two principal contenders for modeling the induction motor are the two-axis (or crossed field) method and the equivalent circuit (or rotating field) method, both of which have been used for modeling inverter fed machines, as described in the literature.

The tow axis method [7], [8], enables mechanical as well as electrical transients to be modeled, but it cannot easily accommodate space harmonic fields, and the representation of deep-bar effects presents some difficulty.

The equivalent circuit method, is essentially a steady-state analysis for constant speed and sinusoidal excitation, pulse width modulated terminal voltages must first be Fourier analyzed into a sum of time-harmonic excitations each of which is applied to its own version of the equivalent circuit, in which reactance components and slip are appropriately scaled for frequency.

Space harmonic fields may be included if required, and the deep-bar effect is readily modeled on a harmonic by harmonic basis.

Magnetic saturation may be represented in both methods by making adjustments to reactance in response to changing conditions within the machine. This process is somewhat facilitated in the equivalent circuit method by the division of the input current into magnetizing and load current.

The magnetizing reactance may then be expressed as a function of the magnetizing current, whereas stator and rotor leakage reactance are functions of the stator load current and rotor current. In the study described in this paper, the object is to differences of system efficiencies under various switching strategies, and for this purpose constant speed operation has been assumed Furthermore in an attempt to prevent the results from being too specifies in a particular motor design, space harmonic effects in the motor are ignored, except in so far as the contribution they make to stator and rotor leakage reactance.

These two restrictions mean that either method could be used. The authors however that the equivalent circuit method represented are better option, because of the ease with which deep bar differences can be made to each time harmonic equivalent circuit using well known techniques, and because the presentation of magnetic saturation is more straightforward.

X. THEORETICAL CALCULATION

TThe columns in table 1 represent the change in speed from $100\ rpm$ to $1500\ rpm$ with step size $10\ rpm$

For each speed value appropriate frequency is getting voltage and modulation index and the time related to theses speed values.

The input or required speed is used to find the appropriate frfrequency according to equation (1). Where Poles (P) =4 and N = required speed, the voltage to frequency ratio is calculated according to equation,

$$\frac{V}{f} = \frac{V_{rated}}{f_{rated}} ------------- (11$$

Where:

$V_{rated} = 400\ Volts$ and $f_{rated} = 50\ Hz$ then

$$V = f \times 8 ------------- (12)$$

And modulation index (m) be calculating by equation,

$$m = \frac{V}{V_{rated}} ------------- (13)$$

The theoretical calculations can be calculated by frequency ratio 12.

Table.1 Trigger pulses for three phases at speed $100rpm$

R	S	T
229.884609	821.70716	840.56193
4637.185187	24312.9767	24618.32042
25496.621880	26031.85015	25477.75711
49274.370375	49236.6408	50114.9423
50993.243760	50955.51423	74752.12749
74198.034460	74733.26272	75611.56418
75916.907845	75592.69942	99389.31267

Tabble.2 Trigger pulses for three phases at speed $1500rpm$

R	S	T
15.325641	799.625611	628.995924
1336.901522	867.019984	1144.657939
2215.436808	2480.301810	2023.193225
2712.000230	2537.597590	3340.996154
4144.394718	3969.992077	4677.897675
4201.690497	4485.654093	5537.334368
5805. 972323	5345.090785	6052.996384

From the trigger pulses in one cycle, the time is in μsec. The number of trigger is put to know the number and time of trigger together because the phase S is shifted from phase R by 120^0, and phase T is shifted from phase R by 240^0.

The trigger pulses are for one cycle for the required speed [6]. The number of triggers is proportional directly with frequency ratio.

The width of pulse increases when speed value increases. As the reference speed increases the modulation index increases, this leads to increase the width of pulse this concept in table.1 and 2.

XI. EXPERIMENTAL RESULTS

From the six trigger pulses of PWM that feeds to six MOSFET at speed of $100\ rpm$. these trigger pulses are obtained by simulation. This trigger pulses are closely to the experimental trigger pulses that shown in figure (10), and (11). The time base of experimental trigger pulses is $50\ msec$ and $20 msec$, but the amplitude is $5\ Volt$ in both figures. Theoretical and experimental results for different values of speed, the output frequency at different speed is shown in table.3.

Table.3 Output frequencies for different speeds

Speed (rpm)	Frequency (Hz)
100 rpm	3.333
300 rpm	10.0
500 rpm	16.666
700 rpm	23.333
900 rpm	30.333
1100 rpm	36.666
1300 rpm	43.333
1500 rpm	50.0

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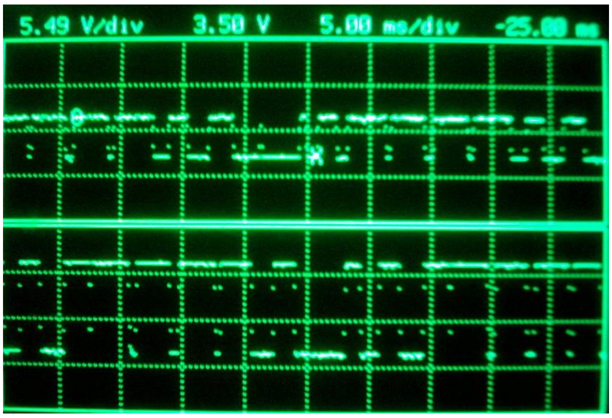

Fig. 10 Three phase bridge inverter (SPWM) at voltage $5\ Volte$ and time $50\ msec$.

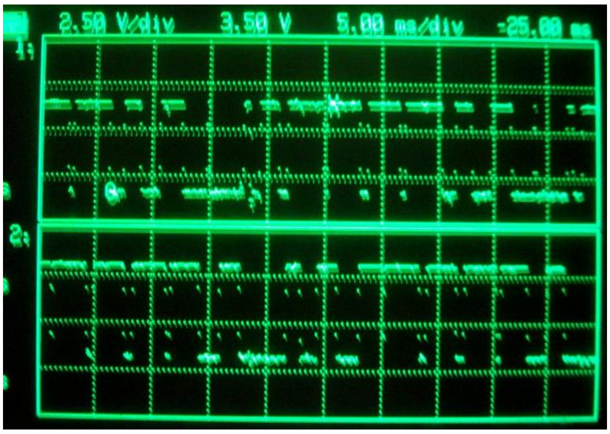

Fig.11 Three phase bridge inverter (SPWM) at voltage $5\ Volt$ and time $20\ msec$

XII. CONCLUSION

PWM generated by complexity circuits and use SPWM method to reducing the harmonics. The used technique with low cost and easily to maintain and at the same time gives fast response and efficient using microcontroller from using modulation index is variable. The samples are chose 1024 for each half cycle to get the resolution very accuracy from the width of each sample.

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ACKNOWLEDGWENT

In this research has been the light of careful analysis and practical experience of which has been obtained on the exact results and those described in the results listed in the search process.

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