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SIMULATION AND ANALYSIS OF INDUCTION MOTOR USING CARRIER BASED SPACE VECTOR PULSE WIDTH MODULATION TECHNIQUE ENERGIZED FROM SOLAR CELLS

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ABSTRACT

Space vector pulse width modulation (SVPWM) method is advance and fast method among all the PWM techniques for variable frequency induction motor drives. The objective of this paper is to reduce the torque ripples, harmonic distortion with maintained constant switching frequency. This paper focuses on implementation of SVPWM on an induction motor. The model of a 3-phase VSI is discussed based on space vector theory and used to improve the torque performance and to obtain the voltage space vector required to compensate the flux and torque errors. The theoretical analysis, design, switching sequence and implementation of the SVPWM for three-phase induction motor is presented in this paper.

KEYWORDS— *SVPWM, total harmonic distortion (THD), variable frequency, induction motor drive, D.C link converter, SPWM.*

I. INTRODUCTION

Now a day's AC drives become a lot of widespread than the DC drives because of their advancement in coming up with and producing supported their potency and performance. The AC drives have a lot of benefits over DC drives attributable to their quicker dynamic response, constant and higher power issue (PF) and continuous torsion at zero speed (applicable to flux vector management technology). With the event in power physics and semiconductor technology lead improvement in power electronic system. Hence, investigator takes interest to analysis on this space. Electrical motors consumed sixty fifth of total voltage, so decrease within the energy input and increase within the potency of the mechanical transmission scale back the energy consumption. By the introduction of variable speed drive in situ of constant speed drive, the system potency is magnified from 15 August 1945 to terrorist organization.

The electrical machine may be a machine that converts voltage into energy and it's most generally use all the benefits offered by the voltage like low value, straightforward of provide and distribution. Induction motors square measure want to generate the torsion needed for Industries. The employment of squirrel-cage induction motors becomes larger because of its huskiness, low maintenance and high power rating [1].

However the induction motor works on the magnetic force principal and this create the look of speed and torsion controller additional complicated. Therefore, the induction motor should be modeled. For study of speed associate degreed torsion responses a steady-state equivalent circuit of an induction motor has been used, however during this model the impact of saturation that affects the performance of speed and torsion is negligible and can't be used for transient analysis. so to control and analysis of induction motor considering saturation impact and transient response, dynamic modeling of induction motor is needed [2]-[4]. Having the dynamic model subsequent step is to settle on the appropriate and effective management techniques so the speed and torsion of induction motor are often controlled no matter the changes within the system, as well as transient conditions [5].

Direct torque Control is without doubt one of the simplest process that's used however with torque and current ripple. The space vector modulation headquartered direct torque control (SVM-DTC) minimizes torque ripple through estimating a reference stator voltage, then making use of SVM to modulate it [7]. This approach creates pulse-width modulated indicators (PWMs) with constant switching frequency and are used to force the gates of the energy inverter that presents voltage to an induction motor. Right here three-section are converted into 2-section for simplification of the system and space vector are expressed as varying quantities sum of which perpetually equal to be zero and separated by means of 120° are expressed as space vectors. This gives greater output voltage for the same DC bus voltage, scale back switching losses and higher harmonic response as evaluation to different modulation. PWM inverters are most extensively used where a fixed dc input voltage is given to the inverter and controlled ac output is bought through adjusting the on and off intervals of the inverter element. Space vector modulation was 1st offered by using the German Researchers in the mid of Eighties. In this paper we are using carrier based space vector pulse width modulation for controlling the speed of three-phase Induction motor by adjusting frequency generated by multi-level inverter. Techniques used by multi-level inverter and space vector theory are briefly described in this paper.

II. Multi-Level Inverter

Inverter can be categorized on two types as single-phase inverter and three-phase inverter. Generally single-phase inverters are used for small power drives like domestic purpose or small industries where supply is needed as single-phase. But three-phase inverters are used for large power drives like large industrial purposes where power is needed to drive large drives. In this paper we are working with three-phase inverter which is also known as multi-level inverter. Here, induction motor is employed. To drive this induction motor we needed large power which can only be supplied by multi-level inverter. By adjusting the on/off switch of inverter pulses are generated and fed to the inverter to drive. A Fixed dc is applied in inverter and controlled ac output in the form of amplitude, phase and wave is obtained. The topology of three-phase inverter is as shown in Fig. 1. In this inverter can anticipate best eight states seeing that enter lines have got to by no means be shorted and the output current have got to at all times be steady. These states are as proven in Fig. 1 and switching period of inverter is shown in Table 1. Table 1 show 8 switching periods, in which 2 out of 8 are zero switching state also called as inactive state in which power doesn't flow from source to the motor so it becomes inactive during switching that's why it is referred as inactive states. Remaining 6 states are called non-zero states also known as active states, in which power flows from source to the motor so it becomes active during switching that's why it is referred as active states. In this circuitry the upper terminal of switch named as "1" ,which means conduction of upper switch and produce output +ve i.e. +Vdc and lower terminal of switch named as "0" ,which means conduction of lower switch as shown in Table 1.

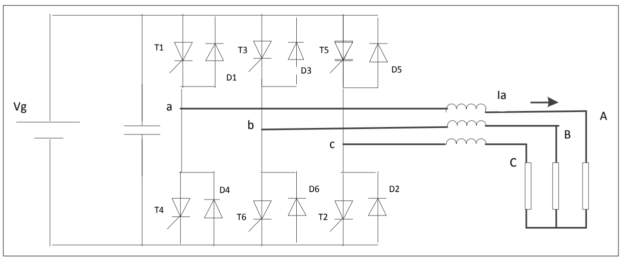

Fig. 1 Circuit diagram of Multi-phase inverter

Switching states (three-phases)	On-state switch
(000)	S_4, S_6, S_2
(100)	S_1, S_6, S_2
(110)	S_1, S_3, S_2
(010)	S_4, S_3, S_2
(011)	S_4, S_3, S_5
(001)	S_4, S_6, S_5
(101)	S_1, S_6, S_5
(111)	S_1, S_3, S_5

Table 1. Switching states of inverter

III. Pulse Width Modulation

To fulfill the partial energy specifications, variable resistance contraptions this sort of s rheostat were used to manipulate the present coming into a device (i.e. Stitching machines).These devices suffered from most important vigour losses from warmness within the resistor factors. So uses of these become necessity for low rate, effective and compact option for offering adjustable vigor for digital devices. However variable energy presents is being used by the army. One in all early software of pulse width modulation was once within the Sinclair X10s are available in Sixties as an audio amplifier. In 1976, Bob mammano (silicom basic) invented the SG1524 regulating pulse width modulator built-in circuit. Different corporations quickly followed leading to the evolution of PWM strategies.

The use of PWM inverter is increases steadily in industries because PWM inverter is a type of inverter that control output voltage by using itself. Based on pulses Pulse width modulation can be categorized in three types are below as

(a) Single pulse modulation

(b) Multiple pulse modulation

(c) Sinusoidal pulse modulation (carrier based PWM)

Duty cycle is determined by:

Duty cycle = $\frac{Ontime}{period} * 100$

In PWM, obligation cycle is modulated to deliver the information over a communique channel or manipulate the amount of energy sent to a load. PWM makes use of a square wave whose duty cycle is modulated ensuing within the variant of usual worth of the waveform. If we recall a rectangular waveform f(t) with a low price Ymin, a excessive worth Ymax and a duty cycle (Fig 2), the natural value of the waveform is given with the aid of

$$\bar{y} = \frac{1}{T}\int_0^T f(t)dt$$

For square wave the value of f(t) is Ymax for period 0<t<D.T and Ymin for D.T<t<T. Then the above expression become as

$$\bar{y} = \frac{1}{T}\left(\int_0^{DT} Ymax\ dt + \int_{DT}^{T} Ymin\ dt\right)$$

$$= \frac{D.T.Ymax + T(1-D)Ymin}{T}$$

$$= D.Ymax + (1\text{-}D)\ Ymin$$

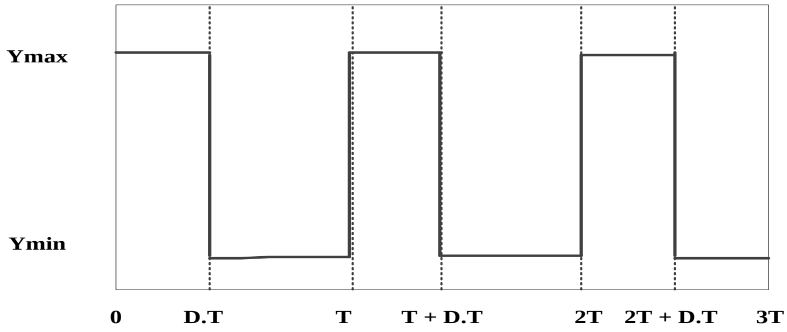

Fig. 2 square wave of Ymin, Ymax and D

IV. Types of Pulse Width Modulation

There square measure three usually used styles of PWM outlined by that fringe of analog signal is to be modulated.

- Lead edge modulation
- Trail edge modulation
- Pulse center 2 edge modulation/phase correct PWM

(a) Lead edge modulation

Lead fringe of trigger signal is fastened to the forefront of your time spectrum and also the edge is modulated as shown in Fig. 3.

(b) Trail edge modulation

The path fringe of the trigger signal is fastened to edge of the time spectrum and also the forefront is shown in Fig. 3.

(c) Center pulse 2 edge modulation

The pulse center is fastened within the middle of the time spectrum and each edges square measure modulated regarding the middle of trigger signal shown in Fig. 3.

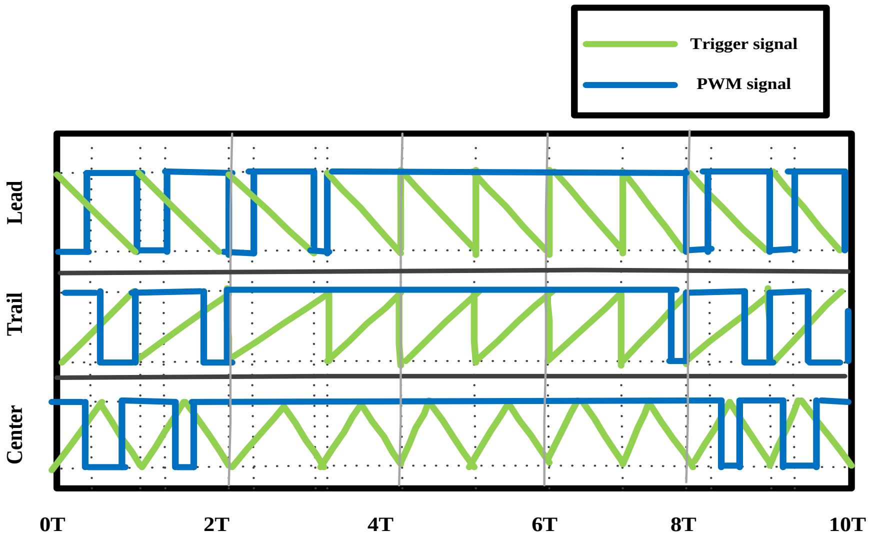

Fig. 3.Signal of lead, trail and center edges

V. Space Vector Pulse Width Modulation

1. Space Vector Modulation

The desired three-phase voltages at the output of the electrical converter will be described by constant vector V rotating within the counter dextrorotary direction. The magnitude of this vector is said to magnitude of the output voltage (Fig. 4) and also the time of this vector takes to complete one revolution is that the same because the basic fundamental measure of the output voltage.

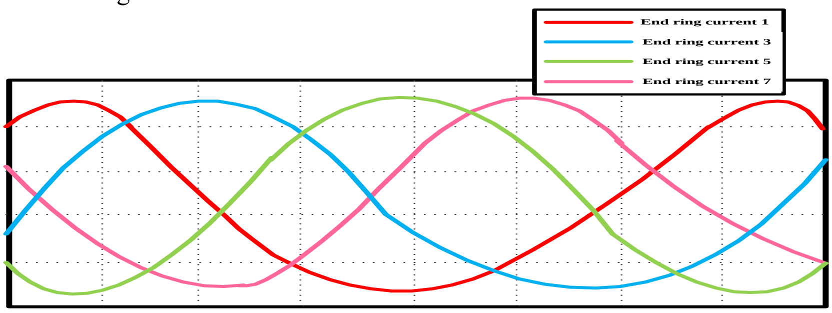

Fig. 4 Output line voltage in time domain

By means of considering the fact that the drawback when the desired line-to-line output voltage vector V is in sector 1 will also be synthesized via the heartbeat width modulation (PWM) of the two adjoining SSV's V1(pnn) and V2(ppn), the obligation cycle of every being d1 and d2 respectively and the zero vector (V7(nnn)/V8(ppp)) of responsibility cycle d0:

$d_1V_1 + d_2V_2$ = V = $mV_g e^{je}$……………………………….(3)

$d_1 + d_2 + d_0 = 1$ ………………………………………….....(4)

Where 0 ≤ m ≤ 0.866 is the modulation index. This would correspond to the maximum line voltage of 1.0 Vg, which is 15% more than conventional sinusoidal PWM as shown.

2. Implementing SVPWM

The space vector pulse width modulation (SVPWM) may also be carried out by means of utilizing both sector determination algorithm or by using utilizing a carrier situated space vector algorithm. There are different types of pulse width modulation. But in this paper we are using carrier based space vector pulse width modulation.

There are exclusive types of SVPWM implementation which can be:

a) Sector selection based space vector modulation
b) Reduced switching space vector modulation
c) Carrier based space vector modulation
d) Reduced switching carrier based space vector modulation

(a) Sector selection based SVPWM

The fig. 5 provides a proposal concerning the determination of sector and also via making use of the Simulink blocks and s-capabilities algorithm we are able to implant identical approach

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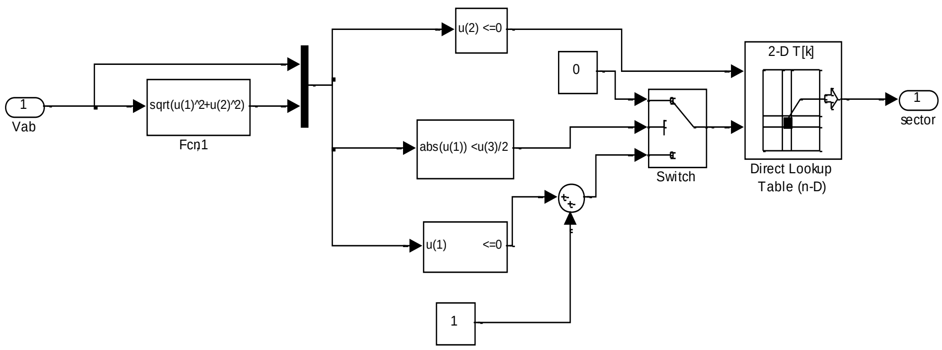

Fig. 5 Sector selection algorithm

(b) Reduced switching SVPWM

The switching of the IGBTs can also be lowered through 33% through selecting to probably the most zero vectors during each and every sector. The implementation is shown in Fig. 6 beneath.

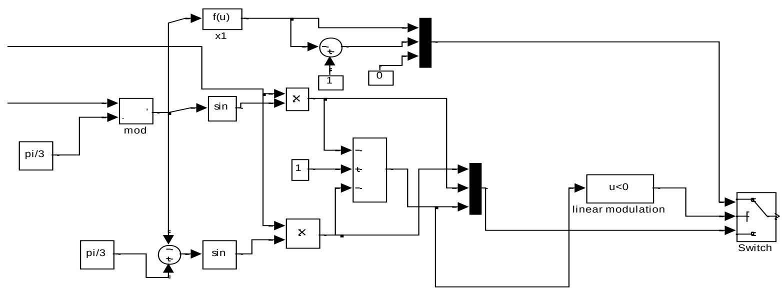

Fig. 6 Deriving the weights of the adjacent non-zero basic vector

(c) Carrier based SVPW

It permits quick and efficient implementation of SVPWM without sector determination. The strategies is situated on the obligation ratio profiles that SVPWM exhibits (as shown in Fig. 7 & Fig. 8).Through evaluating the obligation ratio profile with a greater frequency triangular carrier pulses may also be generated, established on the identical argument as the sinusoidal pulse width modulation.

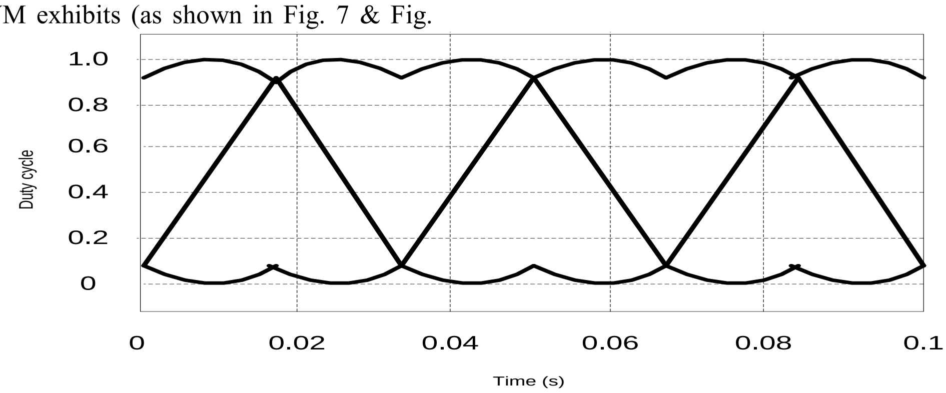

Fig. 7 Duty ratio profile with SVPWM

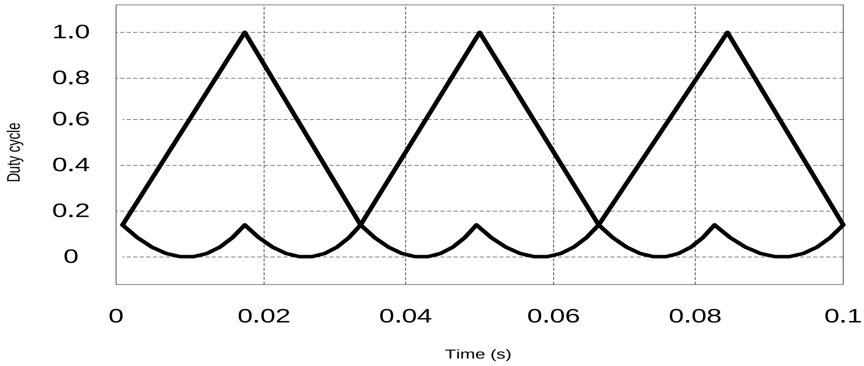

Fig. 8 Duty ratio profile with lesser switching SVPWM

3. *Block diagram of implementation of Carrier Based SVPWM*

Fig. 9 suggests the implementation of Carrier based SVPWM fed with three-phase induction motor by using multi-level inverter energized by solar cells without selecting sector number, only by comparing obligation ratio profile.

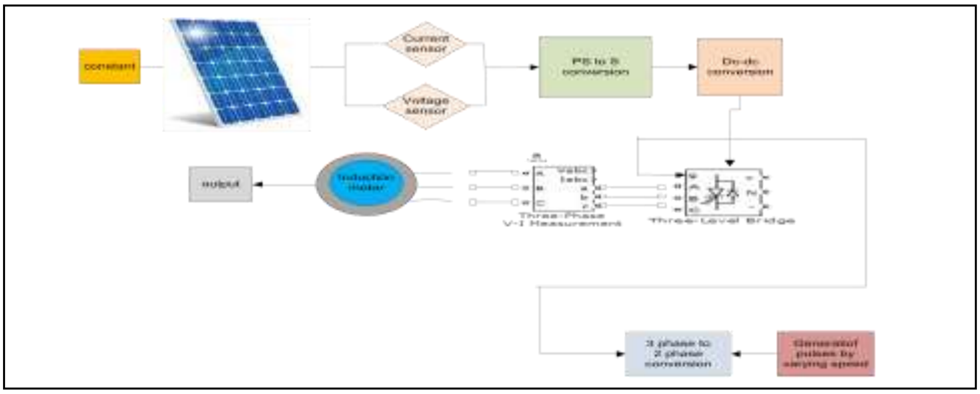

Fig. 9 Implementation of SVPWM

VI. Simulation and Results

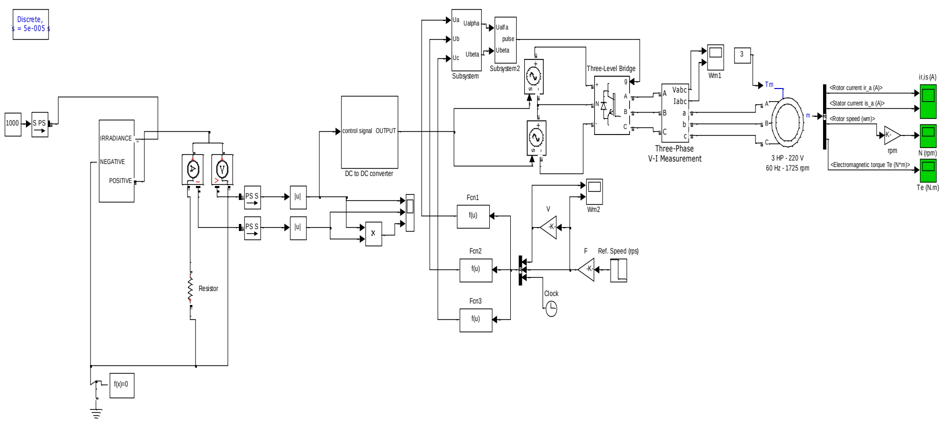

Fig. 10 Simulink model of Open loop speed control of an induction motor using SVPWM modulator

1. *Circuit description*

Fig. 10 show the open loop space control of an induction motor utilizing house vector PWM modulator.444A 3-segment squirrel cage induction motor rated 3 HP, 220 V,50 Hz, 1725 rpm is fed through a 3-phase MOSFET inverter linked to a dc voltage source of 325 V. The inverter is modeled utilizing the "common bridge" block and the motor by the "asynchronous computing device" block. Its stator leakage inductance Lls is ready twice to its genuine value to simulate the result of smoothing reactor positioned between the inverter and the machine's shaft is steady and set to its nominal worth of 11.9 N.M.

The firing pulses to the inverter are generated via the gap-vector modulation method. The reducing frequency is ready to 1980 Hz and the input reference vector to "magnitude angle". Speed control of the motor is performed with the aid of the "constant V/Hz" block. The magnitude and frequency of the stator voltages are set founded on the space set point and by using varying the stator voltages magnitude in proportion with frequency, the stator flux is kept consistent.

2. Simulation step and Results

Simulation steps

1) By run system model, system parameter initialized
2) Build Simulink model
3) Output of inverter generate voltages(Viab, Vibc, Vica) for control input (u)
4) Send this inverter output to motor
5) Send the output of the motor to workspace
6) Resultant of simulation can take by using Matlab

The simulation results are given for the induction motor with the following specifications:

VL = 300, f = 50, Rs = 0.000435, Rr' = 0.000816, Lls' = 0.000004, Llr'= 0.000002, Lm = $69.31*10^{-6}$

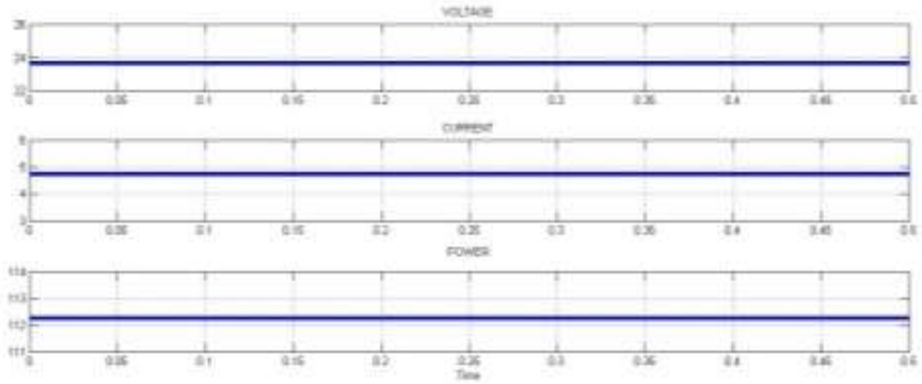

Fig. 11 Voltage, current and power of solar irradiance

Fig. 11 shows the output of solar panel in the form of voltage, current and power which is utilizing by inverter for conversion of energy from dc to ac.

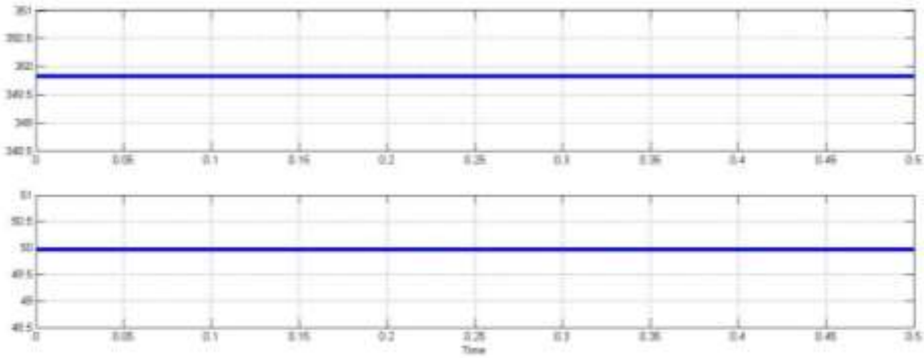

Fig. 12 Generation of pulses by multi-level inverter

Fig. 12 shows the pulses generated by the inverter to drive the induction motor by adjusting the on/off switch.

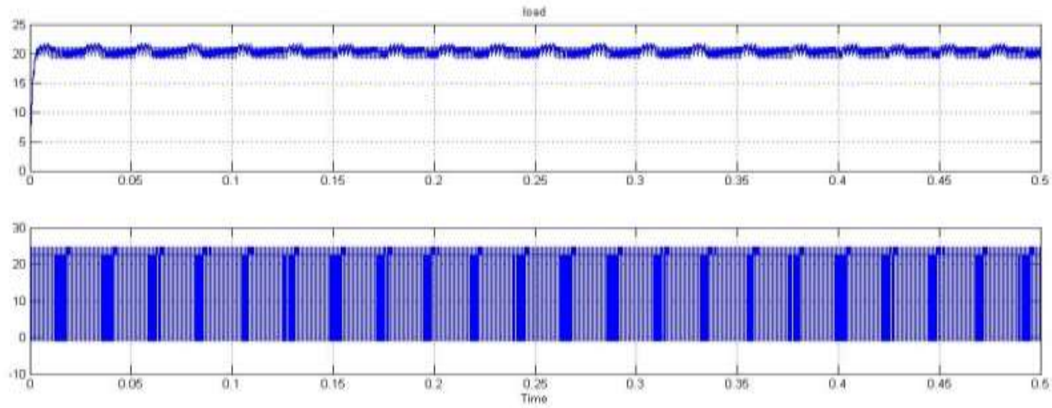

Fig. 13 Pulses show the DC-DC conversion

Fig. 13 shows the waveform which is sinusoidal in nature. The solar energy is coming from solar panel in form of voltage, current and power to fed back to the battery where instantaneous voltage, current and power is changed into sinusoidal form. To store the energy battery is use and utilizes this energy according to the load demand.

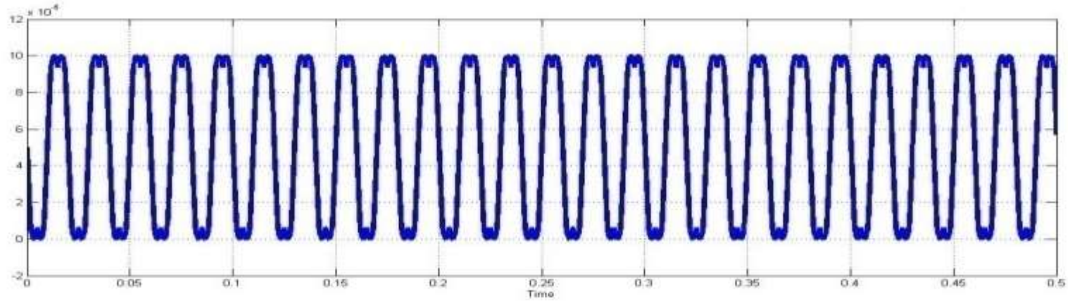

Fig. 14 Three-Phase to two-phase conversion for simlification 3 phase V-I measurement

Fig. 14 shows the output waveform of 3 phase V-I measurement where three-phase supply is converted into two-phase for simplicity of calculation.

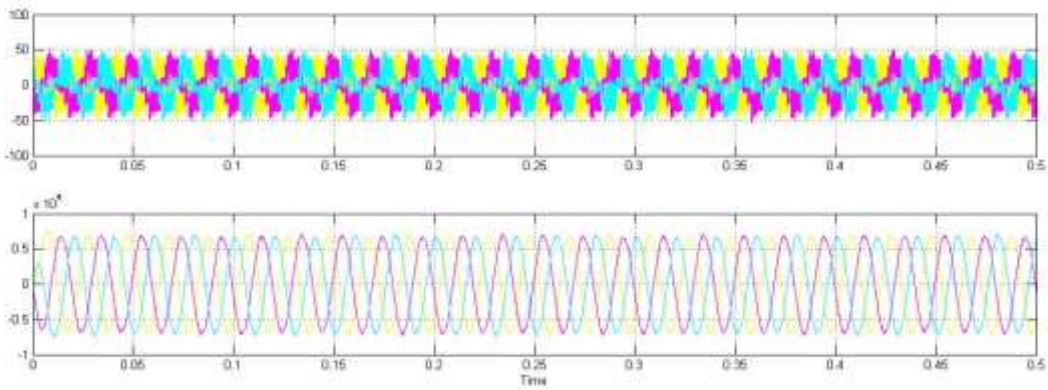

Fig. 15 Three-Phase voltage current measurement

Fig. 4.11 shows the waveform of V-I measurement which is connected to the drive to produce harmonic free output by using carrier based space vector pulse width modulation method. Through evaluating the obligation ratio profile with a greater frequency triangular carrier pulses are generated.

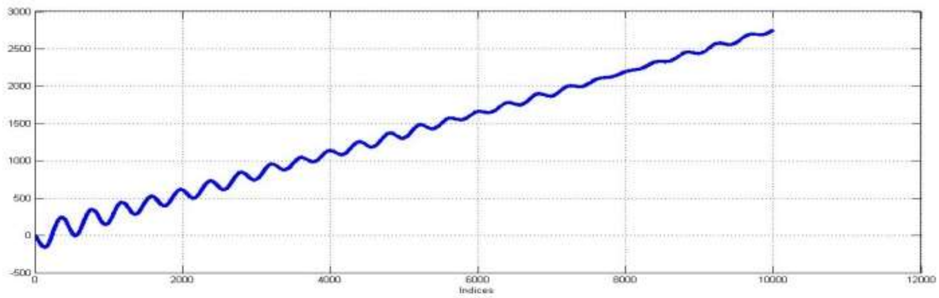

Fig. 16 Induction motor speed increases as frequency increases

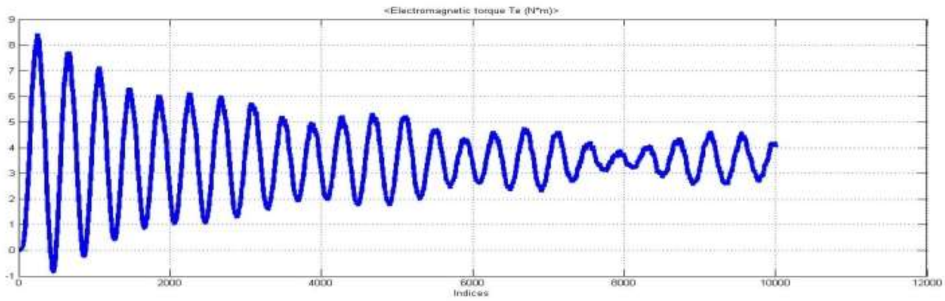

Fig. 17 Electromagnetic torque

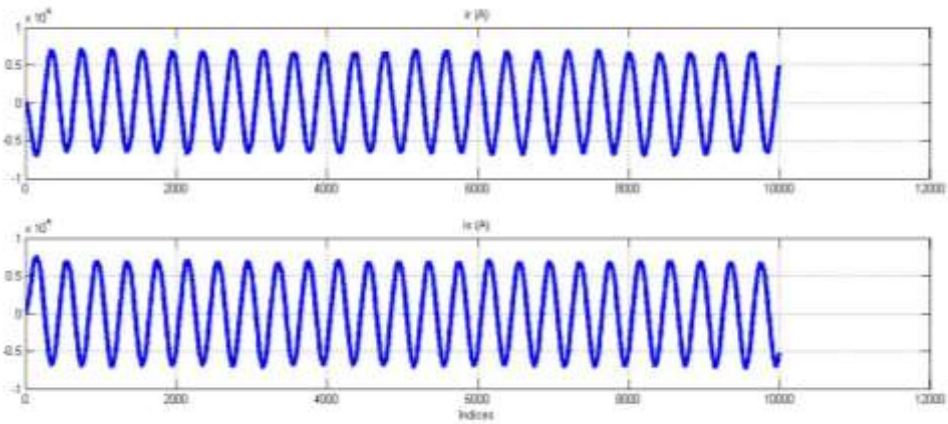

Fig. 18 Induction motor stator current and rotor current

Fig. 16 shows the increment in speed of induction motor from minimum to maximum i.e. 0 to 1725 rpm whereas Fig. 18 shows the constant electromagnetic torque obtain by induction motor. Since stator of drive is fed back to the multi-level inverter it produces ripple and noisy torque which cannot see because it is removed by using carrier based space vector pulse width modulation and produced noise free and harmonic free pure sinusoidal waveform. We can observe by Fig. 18, a pure sinusoidal ripple free waveform is produced by using this method.

VII. Conclusion

On this paper the distance vector pulse width modulation approach is used to derive the three-phase induction motor for controlling the velocity of the motor. Such technique is used to adjustable pace of three-phase induction motor drives. Among all procedures space vector pulse width modulation technique has emerge as most fashionable and major as a result of skills of this for control of AC induction, brushless DC, switched reluctance and permanent magnet synchronous motors. The potential of this technique is it will probably utilize one hundred % DC supply because there is no core tap from the Dc source, and enable index modulation better than 1(allow over modulation) and also have effective to eliminate using capacitor to run the motor.It gives a lot output as evaluate to different methods and makes use of DC bus voltage extra efficaciously and generate less harmonic distortion in three-section voltage supply inverter.

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