Efficiency and Power factor Improvement of Three phase Induction motor Using just one IGBT switch

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Abstract- With the help of proposed scheme the chopped and modulated three phase AC voltages appears across the stator terminals . The Three phase induction motor makes use of single controllabled IGBT switch connected across the three phase diode bridge rectifier forming A.C. switch for chopping three phase A.C. voltage. With the help of given technique .the chopped and modulated three phase A.C. voltages appear across stator voltage terminals of three phase induction motor .The of A.C. voltage magnitude is controlled with the help of high frequency PWM controlled switch . The peculiar feature of this scheme with high frequency controlling the speed and power factor of induction motor with single semiconductor switch .The speed of the three phase induction motor with fan load will be controllable within around 50% of the rated motor speed. This induction motor drive find utility in Industrial high power cooling fans, blowers and pumps. This drive will provide higher efficiency, improved power factor and required speed control over wide range for above applications with simple design and control feature and good economical advantage.

Keywords- Three phase Induction motor, PWM techinique. IGBT , power factor , VVVF drive.

1. INTRODUCTION

The main limitation of firing angle control technique using SCR bridge is very poor power factor at low speed control range and thereby increase in source current requirement for a required power output. Another technique of speed control which is most common and widely popular is voltage variable frequency drive with PWM technique the speed is controllable in wide range but it requires one additional power factor more improve stage by using additional bridge rectifier and IGBT switch in boost converter topology, the efficiency of the converter reduced due to additional stage and difficulty andcost of the circuit is also increase .

The inverter is construct with the help of six controllable switches operated consequent manner. The control techniques required exact sequential control of six switches using SPWM or SVPWM. In current situation power conservation is an main issue across the world. This project mostly deals with the minimum power utilization by enhancing

the output efficiency and providing capacitor as a freewheeling element of three phase squirrel cage Induction motor, it requires less maintenance and rugged in construction .For industrial application induction motors are most favoured and widely used drive in pumps, fans and blower. Speed control techniques of these machines can be achieved by various methods [1].

2. PROPOSED TECHNIQUE

Phase angle control (PAC) technique was used earlier for this purpose but it has some disadvantages such as lagging power factor at the input supply side especially at low speeds due to increased firing angle.

To get rid of above disadvantages, the said research work focuses on reduce in power consumption and enhancing power factor of induction motor drives. A variable voltage control scheme is suggested using diode bridge by varying duty ratio of the bridge for said induction motor drives. A 3 KHz high frequency PWM controlled direct AC to AC voltage controlled converter is suggested for three phase induction motor to enhance the efficiency and improve input power factor and speed control along with fan using three phase induction motor . In this advanced technique only one active switch and six diodes are connected to form a bridge . The current continuity in the stator winding of the motor is maintained using parallely connected low value capacitors causing free wheeling action in both quarters of AC voltages. The three phase balanced voltage fed to stator the motor is controlled simply by varying duty ratio of diode bridge. Motor current control is not allowed to lag much more as in the technique using firing angle control. The main features of the scheme are high frequency of 3Kz PWM switching and by eliminating additional three A.C. switches that is SCR , in place of it we are using here three parallel connected low value capacitors, which gives high power factor and high efficiency and one more thing is minimum number of controlled power semiconductor switches are required . One more dominant feature is that in the proposed scheme here we are using single active IGBT switch instead of using six or four A.C. switches topology. In this scheme the induction motor drive can operate in entire complete range of speed and torque which is not possible in conventional phase angle control scheme. The supply current from AC

source can be made leading. The triggering pulse technique used for power electronics switch is different to that of firing angle control.

The switching devices are turned on in every half cycle at zero crossing and turned off at desired instant where we wish in every half cycle. The motor stator voltage is controllable in the entire range from zero to full rated voltage. In this case the supply current becomes leading.

A. POWER CIRCUIT:

This scheme is used to modify Induction motor drive with the help of single controllable switch and six power diodes operated in high frequency PWM manner. The AC supply which is three phase is fed to the induction motor will be controllable by single power IGBT by duty ratio control. .The three phase induction motor is connected between AC source and AC input terminals of three phase bridge rectifier .The controllable switch that is power IGBT switch is placed across the output terminals that is at open star point after three phase bridge rectifier. The controllable switch therefore always get the DC voltage and remain in forward bias condition. After giving gate pulse to the IGBT switch the motor terminals at the input bridge rectifier get short circuited and motor draws current from supply side the path of which is completed through diode bridge rectifier and the IGBT switch. Therefore the motor is connected in star mode.

When IGBT switch is turn off by removing gate pulse, the current through the motor is reduced but now circulated in same direction through parallel connected high voltage and low value capacitors for short time interval called free wheeling period.This repeated turning OFF and ON of the IGBT switch is continued by the help of high frequency PWM pulses which are generated by control circuit.IC 555 is used for pulse generation in gate driver. The cost of IC 555 is less so gate driver circuit cost is reduced considerably. As the current is not drawn from source in OFF period but continuity of current in the stator winding is maintained by free wheeling action caused by parallel connected low value capacitors. These capacitors causes free wheeling action in both positive and negative half of AC cycle. The current is drawn from the source by the motor during short time interval where as the current is not drawn by the motor during turn OFF period of the power semiconductor switch. By varying ON and OFF period of diode bridge duty ratio is varied and therefore r.m.s. voltage drawn by motor is controllable. The input current is not allowed to lag voltage by large angle therefore they are approximately in phase. This becomes possible due to high frequency PWM operation. The main task for smooth operation and control is to provide variable three phase input voltage to motor and at the same time proper DC voltage to the IGBT switch and this is exactly achieved in this novel technique.

B. CONTROL CIRCUIT

IC 555 is generating equal magnitude ON-OFF pulses of 3Kz frequency. Also it is generating triangular pulse of equal rise and fall time which are available at pin 2 of IC555 .This triangular wave is given to comparator so comparator has two inputs one triangular and another is variable DC available from POT. The output of the comparator will be PWM signal with variable duty ratio and constant frequency. This frequency depend on the RC parameters used in IC555 which is now acting as astable multivibrator. The output of the comparator is fed to input to the IC555 at pin no.2 and output of this IC which is available at pin 3 will be used to trigger the IGBT switch in the power circuit. The second IC555 is used as inverting driver for driving IGBT used in power circuit.

$$Vm = Vs * \sqrt{k}$$
$$= Vs * \sqrt{(Ton/T)}$$

Where T=Ton+Toff
Vm=voltage applies to motor winding
Vs= supply voltage
K=Duty ratio

C. C. M0DE OF OPERATION:

Mode 1: Conduction mode

When the switch S1 is made ON at the moment t=0 the current flows through all the stator windings a-a', b-b' and c-c' during time interval between t=0 to t1 and polarity of the induced voltage in stator winding is positive rising at entering terminal and negative at leaving terminal as shown in fig.1 . Therefore the voltage applied to stator windings is instantaneous value of respective source voltage.

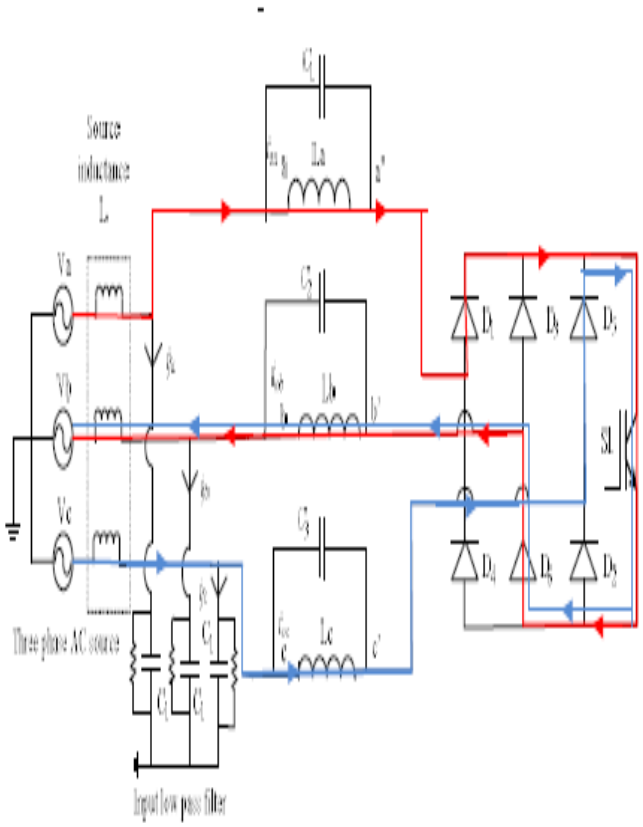


Figure 1. conduction mode (0 -60)

Mode 2: freewheeling mode

In the next time interval that is from t1-t2 named freewheeling mode current starts decreasing in motor windings and the polarity of induced voltage in stator windings reverses and current therefore freewheels in the same direction as in mode-1 through parallel connected capacitors across the stator windings as shown in fig. 2. No current is drawn from supply in this mode of operation .The voltage applied across the coil of stator winding is zero during this mode. The mode-1 and mode-2 operation repeats n-times during each 60 degree interval of 50Hz voltage cycle .The direction of one of the phase currents will be changing cyclically interval, 50times during interval 0-60 for switching frequency equal to 3KHz.

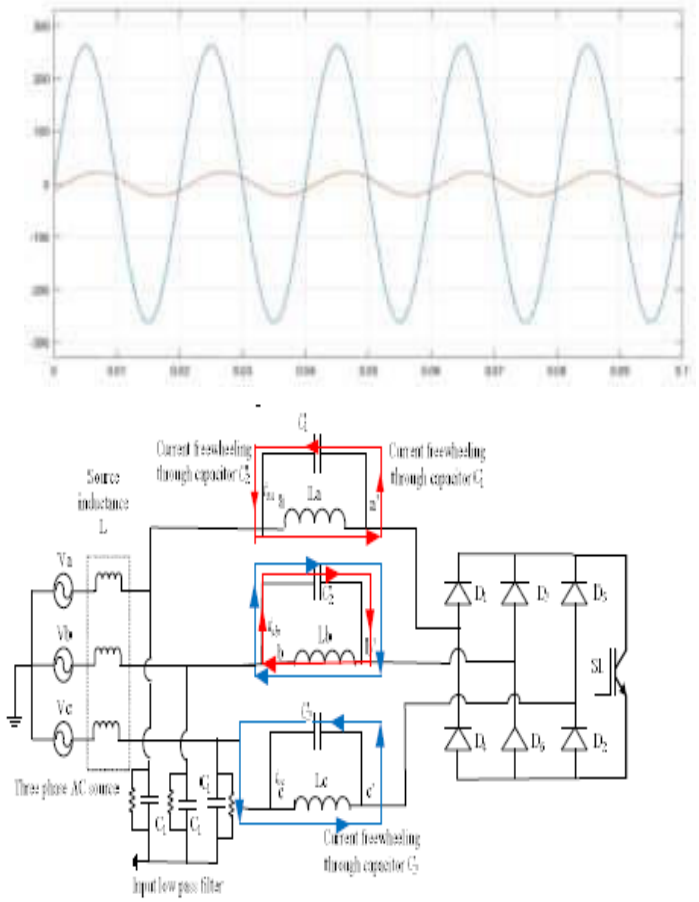
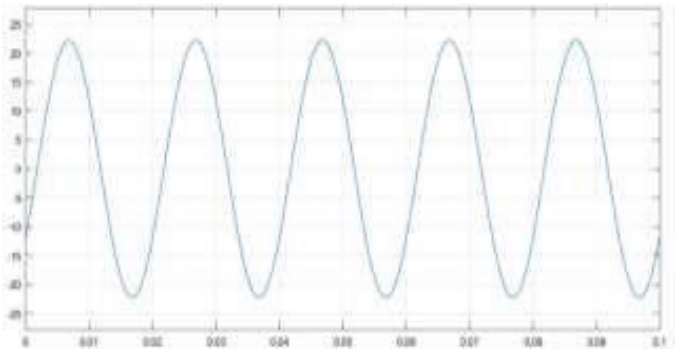


Figure 2. freewheeling mode (0 -60)

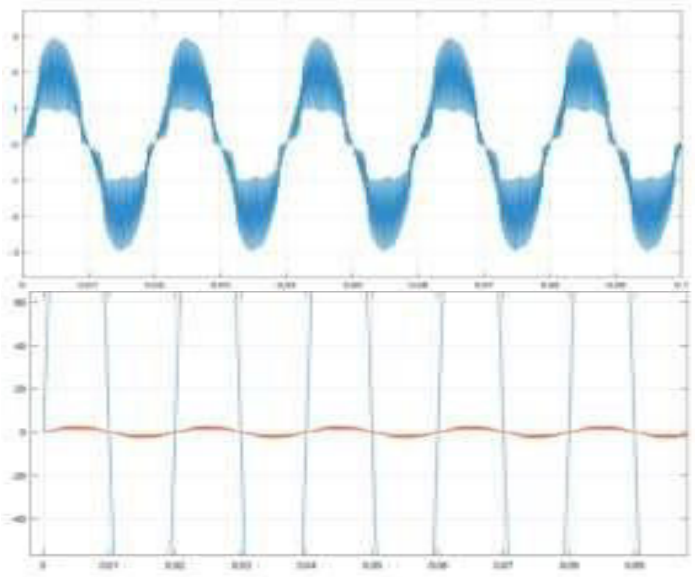
3. SIMULATION RESULTS

MAGNITUDE OF PHASE CURRENT WITH IGBT



MAGNITUDE OF PHASE CURRENT WITHOUT IGBT

Instead of using four or six AC switches in this paper we are using six diodes in bridge and and IGBT switch and low value capacitors which are in parallel with stator windings of induction motor drive. The PWM pulses generated by comparing with triangular carrier frequency wave with variable controlled DC reference voltage whose range is 0-10V and the speed of motor is varied by duty ratio of diode bridge.



Vph AND Iph IN PHASE

Analysis on per phase basis

(i) Output voltage across windings induction motor is

$V0rms = VS/(л)1/2*[л-α+(sin2α)/2]1/2$ ----------(1)

Where, Vs = RMS value of the AC source voltage

V0rms= RMS value of the output voltage

α= firing angle

$V0ang = 2Vm \cos(α)/л$ ----------(2)

Vm= Peak value of the AC source voltage Vs

From Eq.(2) we conclude that

Power factor (pf) Proportional to cos(α) as the firing angle (α) increases power factor deceases

Mechanical power of fan motor

$Pm=TL*ω$----------(3)

$TL \alpha N2$

therefore, Pm Proportional to N3

Electrical power of motor = VsIscosø----------(4)

As cosø=cosα

Is αPm/(Vscosα)

Is αN3/(Vscosα)

Power loss in induction motor is $\alpha Is^2 Rs$

Where, Is source current,

Rs is stator winding of motor

current increase therefore Is2Rs is also increases.

pf=(Is/I0)*cosα----------(5)

Where, I0 is RMS load current,

Is/I0 is distortion factor and

cosα is displacement factor.
We know the distortion factor is unity for sine wave and is less than one for distorted waveform

(ii) PWM controlled voltage controller
output voltage root mean square value is given by
V0rms= VS*(2d/л)1/2----------(6)
d - the width of single pulse

To get the unity power factor displacement and distortion factor should be unity . As we know unity power factor reduces the current drawn from source by motor and therefore copper losses are reduced and also heat produced by stator winding is reduced and ultimately motor performance is improved.

IV. Phase angle control regulator hardware results:-

The hardware results are as given below:

At firing angle α = 0 degree

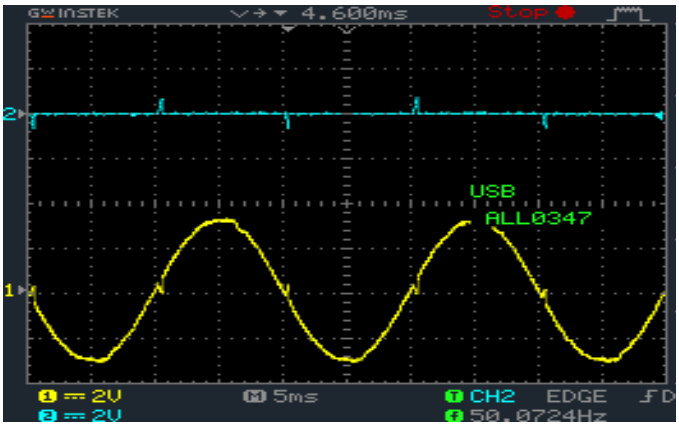


Fig.4. Voltage across switch (Vsw) shown by Blue waveform
Voltage across load is shown by Yellow waveform

Vsw = V0 = 200 volts per division
Time T = 5 millisecond per division

At firing angle α = 15degree

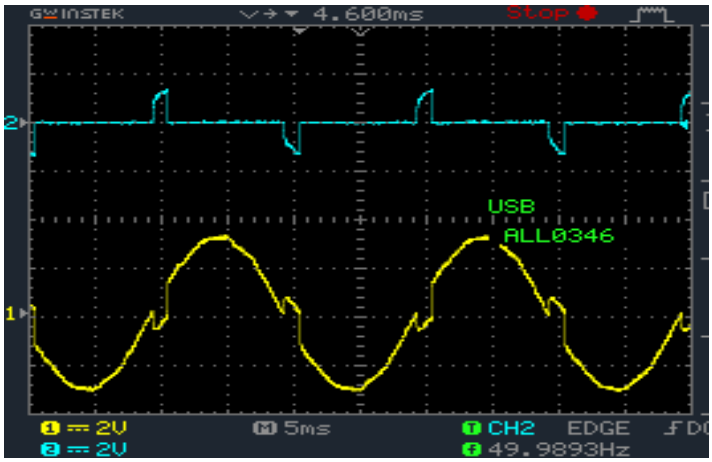


Fig.6 Voltage across load is shown by Yellow waveform and voltage across switch is shown by Blue waveform.

Vsw = V0 = 200 volts/division
Time T = 5 millisecond/division

At firing angle α = 40degree

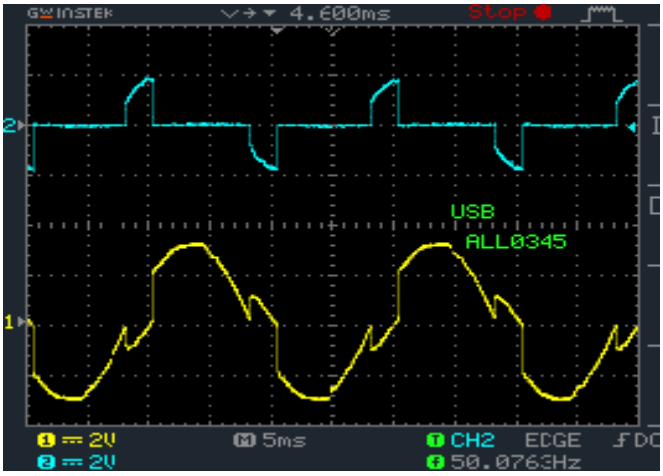


Fig. 5 Voltage across switch (Vsw) shown by Blue waveform
Voltage across load (V0) by Yellow waveform

Vsw = V0 = 200 volts per division
Time T = 5 millisecond per division

At firing angle α = 60 degree

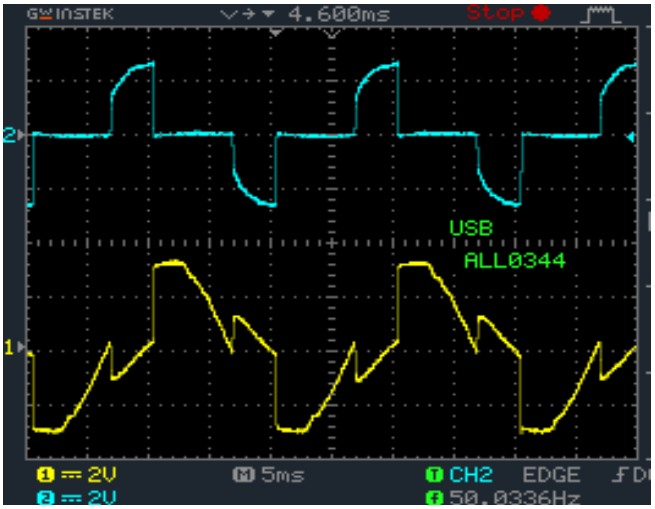


Fig.7 Blue waveform shows voltage across switch (Vsw)
Yellow waveform shows voltage across load (V0)

Vsw = V0 = 200 volts per division
Time T = 5 millisecond per division

At firing angle α = 120 degree

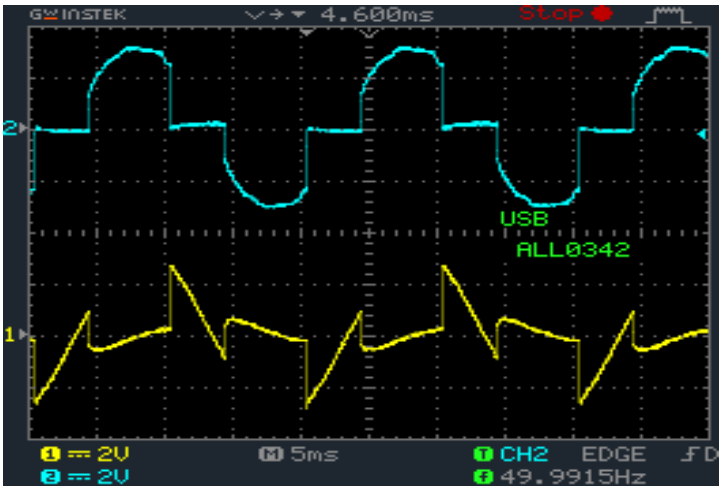


Fig8. Blue waveform shows voltage across switch (Vsw)
Yellow waveform shows voltage across load (V0)

Vsw = VO = 200 volts/division
Time T = 5 millisecond/division

It is observed from above waveforms that when firing angle is more voltage across load is not a sine wave. When the switch turns OFF then voltage does not falls to zero , it falls up to some negative value because of reverse recovery process.

V. CONCLUSION

AC voltage across the windings of three phase induction motor is thus varied and AC current magnitude and phase is controlled. Due to high frequency IGBT switch noiseless operation is achieved. This technique is used for energy saving , energy efficient giving economic operation which is achieved by improved power factor and reduced input current from source. Also reduced number of semiconductor switches , simplicity of control ,reduced initial cost , lower size and space occupied also less weight and soft start and high efficiency.

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