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Simulation and Analysis of PWM Controlled Cycloconverter Fed Split Phase Induction Motor

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ABSTRACT: The split phase induction motor are fixed speed motor used in most industrial processes due to their reliability, rugged nature, low maintenance and reduced cost. Induction motor use is limited in many industrial applications requiring variables speed due to high costs incurred in methods of speed control and efficiency of the methods used. This paper is implemented to control the speed of split phase induction motor using PWM technique based cycloconverter. The cycloconverter is built on with IGBT due to its improved dynamic performance, efficiency and reduction in the level of audible noise. With the help of PWM minimizes the lower order harmonics i.e. 1 and 3 order. In this paper simulink model of PWM based triggered cycloconverter is developed and the results shows that the output response is 2 & 4 times to input response. The output response of the cycloconverter is applied to the split phase induction motor and various output response of motor have obtained then observed the main & auxiliary winding current and speed-torque characteristics of the split phase induction motor.

KEYWORDS: 1-phase Cycloconverter,Split phase Induction Motor,PWM pulse generator.

I. INTRODUCTION

Power electronics converters, especially cycloconverter & IGBT have been extending their range of use in industry because they provide reduced energy consumption, better system, efficiency, improved quality of product and good maintenance. The split phase induction motors are fixed speed motors used in most industrial processes due to their reliability, rugged nature, low maintenance and reduced cost. The speed control of split phase induction motor is necessary in domestic and industrial application. There are number of method for the speed control of induction motor [1]. A split phase induction motor use is limited in many industrial applications requiring variable speed due to high costs incurred in methods of speed control. This controls speed of electric machine by converting frequency of grid to adjustable value on machine side hence allowing electrical motors to quickly and easily adjust its speed. The split phase induction motor is cheaper and easier to maintain as compared to other alternatives.There are several methods for the speed control of split phase induction motor but here PWM controlled cycloconverter is used to control the speed of motor. Cycloconverter are used in very large variable frequency drives with ratings from few megawatts up to many tens of megawatts[2].A cycloconverter is controlled through the timing of its firing pulses, so that it produces an alternating output voltage. In this paper PWM based triggered cycloconverter is used to control speed and improve torque response of split phase induction motor[3]. The single phase induction motor in its simplest form is structurally the same as a poly phase induction motor having a squirrel cage rotor, the only difference is that the split phase induction motor has single winding on the stator[4]. In this paper, simulink model PWM based triggered cycloconverter is developed and the results shows that the output response of cycloconverter is 2 & 4 times to input response of cycloconverter. Thus cycloconverter has the facility for continuous and independent control over both its output frequency and voltage. Cycloconverter eliminates the use of flywheel because the presence of flywheel in machine increases torsional vibration and fatigue in the component of power transmission. The output response of the

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cycloconverter is applied to the single split phase induction motor and various output response of motor are obtained. Therefore it's analyzed the main & auxiliary winding current and speed-torque characteristics of split phase induction motor. The results also shows that torque & rotor speed are varied and also increases after regular time interval. Here PWM Generator is used to generates a triggering waveform for cycloconverter and also used to minimizes the lower order harmonics i.e. 1 and 3 order in output voltage[8].

II. SINGLE PHASE CYCLOCONVERTER

A device which converts input at one frequency to output power at a different frequency with one-stage conversion is called a cycloconverter. A cycloconverter are two types –

***A. STEP UP CYCLOCONVERTER*:-** This types of cycloconverter increase the output frequency with respect to input frequency.

***B. STEP DOWN CYCLOCONVERTER*:-** This types of cycloconverter decrease the output frequency with respect to input frequency.
In this section basic principle of operation of step up as well as step down cycloconverter is presented. For understanding the principle of step down cycloconverter requires force commutation. It consists of eight thyristors P1 to P4 and N1 to N4, P for positive group and N for negative group as shown in fig. 1. During the positive half cycle of a supply voltage thyristors P1 & P2 and N1 & N2 are forward biased. The forward baisedthristors P1 & P2 are turned on together at wt = 0 and N1 & N2 are turned on together at 3π for 2 times output response to input response and 4π for 4 times output response to input response. During negative half cycle thyristors pair P3 & P4 and N3 & N4 are forward baised. The forward baisedthyristors P3 & P4 are turned on together at wt = π and N3 & N4 are turned on together at 4π for 2 times output response to input response and 5π for 4 times output response to input response as shown in fig. 3 & 4[6].

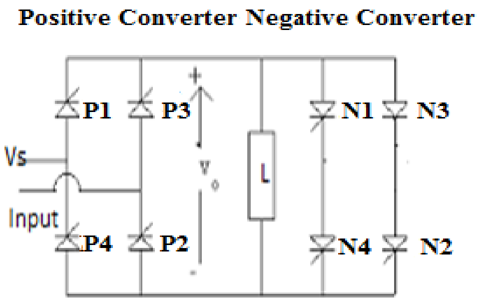

Fig. 1:Single phase bridge type of cycloconverter

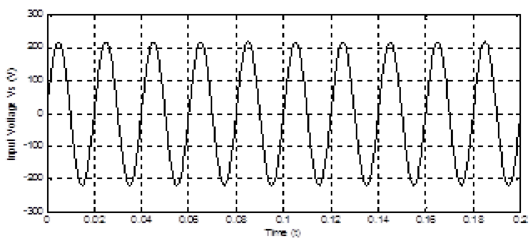

Fig. 2: Input voltage waveform of cycloconverter

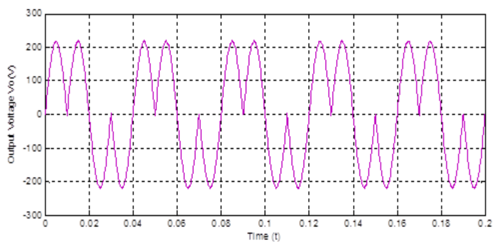

Fig.3: Output voltage waveform of cycloconverter when output response 2 times to input response

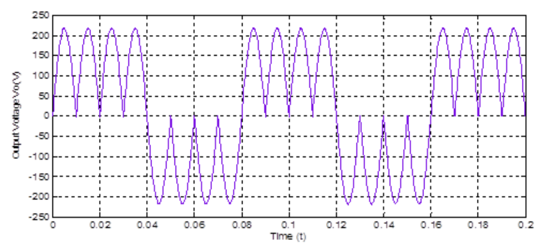

Fig. 4: Output voltage waveform of cycloconverter when output response 4 times to input response

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The rms value of output voltage of cycloconverter is given by:

$$V_{or} = \left[\frac{1}{\pi}\int_{\alpha}^{\pi} Vm^2 \sin^2 \acute{\omega} t\, d(\acute{\omega} t)\right]^{1/2}$$

α is s firing angle, V_m is a maximum voltage of input supply and here firing angle (α) is 0^o[6].

C. SIMULINK MODEL OF CYCLOCONVERTER

This is a simulink model of single phase bridge type cycloconverter at resistive load. IGBT used in behalf of the thyristors as shown in fig. 5 , IGBT will work when external pulse applied to the IGBT. The IGBT P1 & P2 are triggered by pulse generator 1, IGBT P3 & P4 are triggered by pulse generator 2, IGBT N1 & N2 are triggered by pulse generator 3, IGBT N3 & N4 are triggered by pulse generator 4. The P groups IGBT is used for positive waveform and N groups IGBT is used for negative waveform. By this simulink model, cycloconverter are developed 2 & 4 times output response to input response at resistive load as shown in fig. 3 & 4 according to time duration of pulse generator. Here all IGBT are fired at angle 0^o it means IGBT acts like a diode [3].In this simulink model 50 hz & 230 V is used as input signal, 8 IGBT and 4 different types pulse generator is used. In this paper these output waveform of cycloconverter are developed by two techniques i.e. simple pulse generator based and PWM generators. The cycloconverter are triggered by the pulse generator and PWM generator are developed same responses. This paper is analyzed that PWM controlled cycloconverter, output response of cycloconverter are applied to the split phase induction motor and various output response of motor have obtained. In this paper cycloconverter triggered by PWM generator and developed response are applied to the motor. After that response of motor i.e. main winding current, auxiliary winding current, rotor speed and torque characteristics have observed. Here simulink model of cycloconverter have simulated, designed and analyzed, after that modelling and simulated the single split phase induction motor in next portion [5].

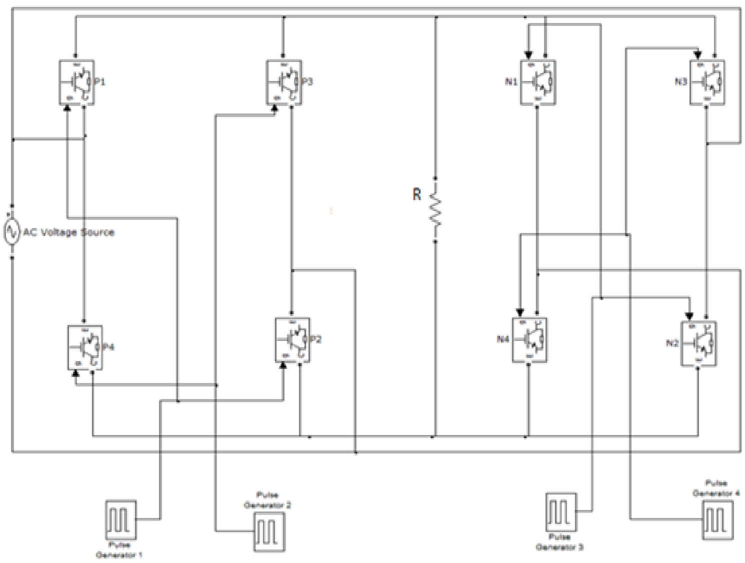

Fig. 5: Simulink Model of Single Phase Cycloconverter When Cycloconverter triggered by External Pulse Generator

III. MODELLING OF SPLIT PHASE INDUCTION MOTOR

Split phase induction motors are usually constructed with two windings on the stator side and squirrel cage winding in the rotor side. The auxiliary winding is used to produce a rotating field to start the motor. The axis of the auxiliary winding is placed 90 degree electrical ahead of the main winding as shown in fig. 6. Since the axis of the main and auxiliary windings are already orthogonal, the stationary d-q axes are chosen aligned with the orthogonal axes of the

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physical windings. The squirrel cage rotor is represented by equivalent two coils transformed to the stationary d-q axis as shown in fig 6.

$\Psi_{s\alpha}=L_s*i_{s\alpha}+L_{m\alpha}*i_{r\alpha}$

$\Psi_{s\beta}=L_{s\beta}*i_{s\beta}+L_{m\beta}*i_{r\beta}$

$\Psi_{r\alpha}=L_{m\alpha}*i_{s\alpha}+L_{r\alpha}*i_{r\alpha}$

$\Psi_{r\beta}=L_{m\beta}*i_{s\beta}+L_{r\beta}*i_{r\beta}$

The voltage equation of the motor can be written in the d-q stationary frame as follows:

$I_{s\alpha}= ((L_{r\alpha}*\psi_{s\alpha}-L_{m\alpha}*\psi_{r\alpha}) / (L_{s\alpha}*L_{r\alpha}-L^2_{m\alpha}))$

$I_{s\beta}= ((L_{r\beta}*\psi_{s\beta}-L_{m\beta}*\psi_{s\beta}) / (L_{s\beta}*L_{r\beta}-L^2_{m\beta}))$

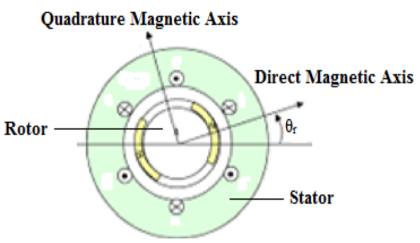

Fig.6: d-q Transformation of the split phase induction motor

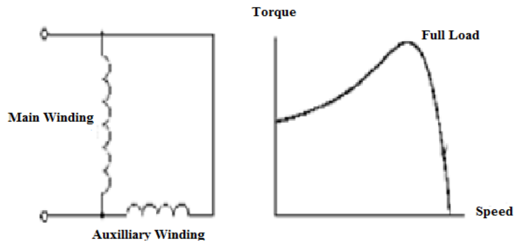

Fig.7: Torque speed characteristics of split phase induction motor

$I_{s\alpha}= ((L_{s\alpha}*\psi_{r\alpha}-L_{m\alpha}*\psi_{r\alpha}) / (L_{s\alpha}*L_{r\alpha}-L^2_{m\alpha}))$

$I_{s\beta}= ((L_{s\alpha}*\psi_{r\alpha}-L_{m\alpha}*\psi_{s\alpha}) / (L_{s\beta}*L_{r\beta}-L^2_{m\alpha}))$

The equations of motion are given by:

$T_e=p(L_{m\beta}*i_{s\beta}*i_{r\alpha} - L_{m\alpha}*i_{s\alpha}*i_{r\beta})$

$J\frac{d}{dt}w = T_e - T$

where $V_{s\alpha},V_{s\beta},V_{r\alpha},V_{r\beta}$ are the stator and rotor voltages $I_{s\alpha},I_{s\beta},I_{r\alpha},I_{r\beta}$ are the stator and rotor currents $\psi_{s\alpha},\psi_{s\beta},\psi_{r\alpha},\psi_{r\beta}$ are the stator and rotor flux linkages $R_{s\alpha},R_{s\beta},R_{r\alpha},R_{r\beta}$ are the stator and rotor resistances $L_{s\alpha},L_{s\beta},L_{r\alpha},L_{r\beta}$ are the stator and rotor inductances $L_{m\alpha},L_{m\beta}$ are the magnetizing inductances, ώr is the electrical rotor angular speed, T_e is the electromagnetic torque, T is the load torque, J is the rotor moment of inertia, $\frac{d}{dt}$ is the differential operator and α is the main per auxiliary winding turns ratio[8].

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A. SIMULINK MODEL OF SPLIT PHASE INDUCTION MOTOR

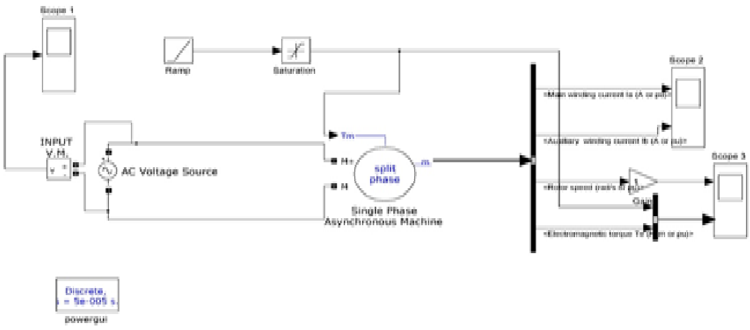
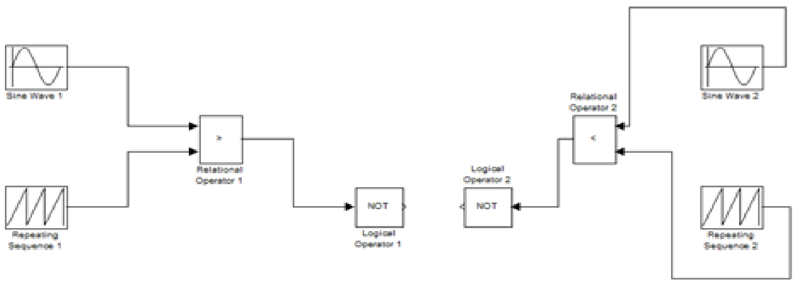


Fig. 8: Simulink model of split phase induction motor

This is a simulink model of split phase induction motor which developed in MATLAB 2011. In this model 230 V 50 hz AC voltage source is connected. Ramp & Saturation blocks is used for the motor saturation state and gain block is used to amplifies the rotor speed [7].

IV. PWM TECHNIQUES

In this type of modulation technique sine wave used as a reference signal and traingular signal used as a carrier signal. It can say that triangular signal travel with the reference of the sine wave. A high frequency triangular carrier wave is compared with a sinusoidal references wave of the desired frequency. The intersection of carrier wave and reference waves determines the switching instants and commutation of the modulated pulse. When sinusoidal wave magnitude higher than the triangular wave, the comparater output is high, otherwise it is low. When triangular carrier wave its peak coincident with zero of the reference sinusoid, there are $N = \frac{fc}{2f}$ pulses per half cycle. In case zero of the triangular wave coincides with zero of the references sinusoid, there are (N – 1) pulses per half cycle [6]. Here PWM generator are divided into the two portion as shown in fig. 9 (a) & (b). The portion (a) are generated a triggering pulse for P1,P2 & N1,N2 IGBT simuntaneously and portion (b) are generated a triggering pulse for P3,P4 & N3,N4. Both portion contain sine wave, repeating sequence, relational operator & not gate blocks and every blocks of both portion have different readings. In the both portion of PWM generator as shown in fig. 9, sine wave blocks generated sine wave and repeating sequence generated traingular wave then both signal applied simuntaneously to relational operator. The relational operator compared both signals and generates the square wave. The portion (a) & (b) both have signal generated blocks and every blocks have different parameters. Hence both portion have generated two square signal but different phase delay. By this simulink model different-different time delay square pulses are generated and applied as a triggering pulse for cycloconverter then the cycloconverter are developed 2 & 4 times output response to input response. The simulink model of PWM generator are shown in fig. 9 :



(a) Simlink Model of Pulse Generator for P1 P2 & N1 N2 IGBT

(b) Simlink Model of Pulse Generator for P3 P4 & N3 N4 IGBT

Fig. 9 : Simulink Model of PWM Generator

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V. SIMULATION RESULTS

This is a simulation model of PWM based cycloconverter fed single split phase induction motor as shown in fig. 10.In this model single phase cycloconverter triggered by PWM generator, then the cycloconverter developed 2 & 4 times output response to input response of voltage and current then developed waveform are applied to split phase induction motor.Therefore it's analyzed the main & auxiliary winding current and speed-torque characteristics of the split phase induction motor. Rotor speed and torque characteristics are varied and increases after regular interval of time. PWM based cycloconverter have also removes the lower order harmonics in output voltage waveform i.e. 1 and 3 order and its gives better response compare than the other techniques. The cycloconverter are triggered by two techniques i.e. pulse generator and PWM generator. The average output voltage waveform of cycloconverter is different from sinusoidal since the firing angle is held constant. The current waveform is not repeated after every cycle in main & auxiliary winding current and observed that some circulating current limit in reactor is connected between the positive and negative converter.The different frequency at cycloconverter is also useful flywheel from the operating machine which reduces the cause of torsional vibration and fatigue damage of the machine. The simulink model of PWM controlled cycloconverter fed split phase induction motor are shown in fig. below.

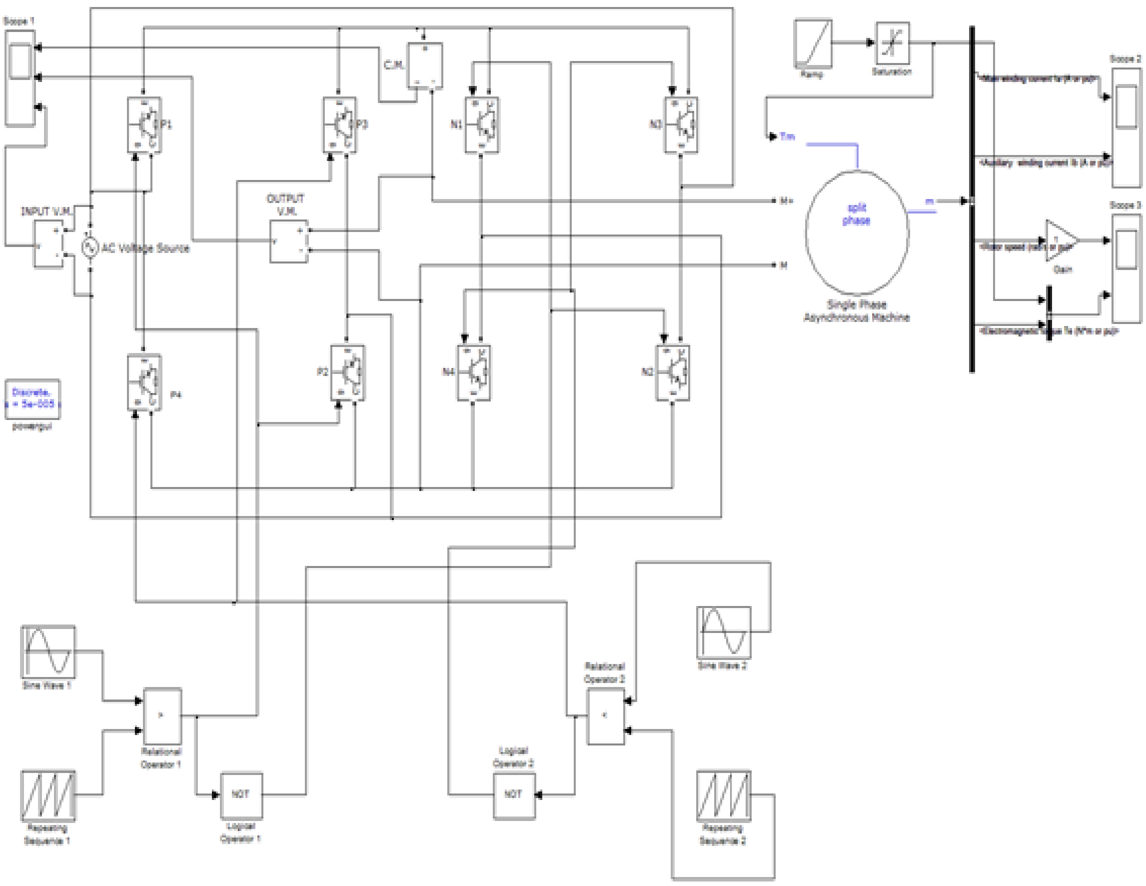

Fig. 10 :PWM Controlled Cycloconverter fed Split phase Induction Motor

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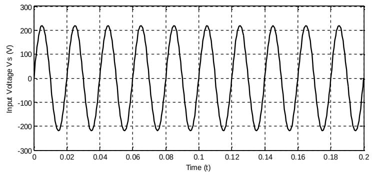
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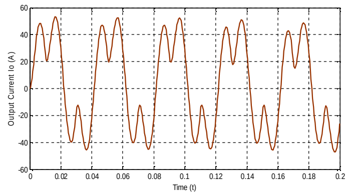
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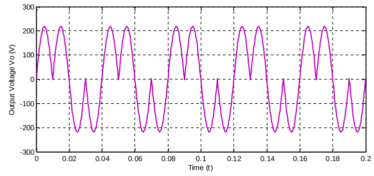
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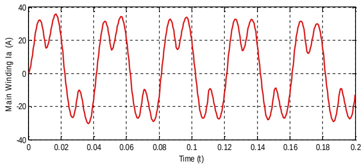
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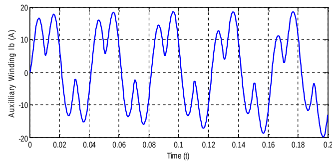
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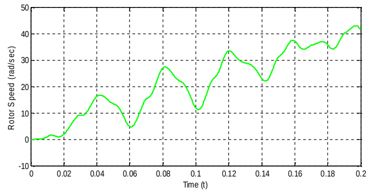
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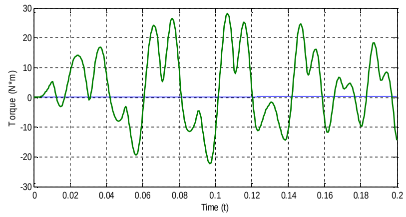
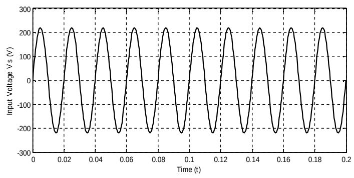

(g)

Fig. 11 : Output Response of Simulink Model(a)Input Supply Voltage Waveform of Cycloconverter (b) Output Current Waveform of Cycloconverter (c) Output Voltage Waveform of Cycloconverter (d) Main Winding Current Waveform of Motor(e) Auxiliary Winding Current Waveform of Motor (f) Rotor Speed of Motor (g) Torque characteristics of Motor, When Input Frequency is Two Times Output Frequency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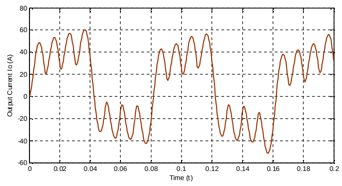
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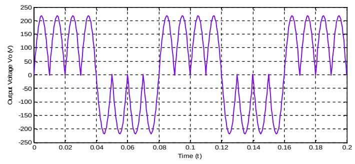
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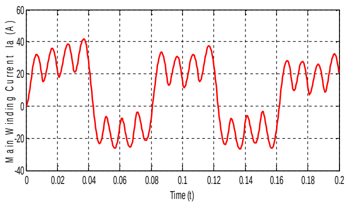
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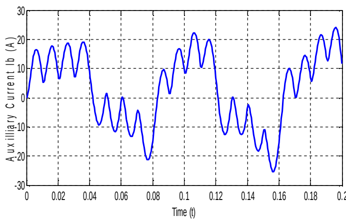
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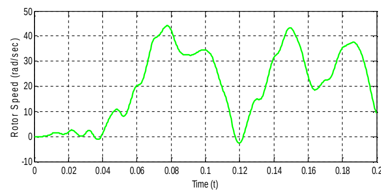
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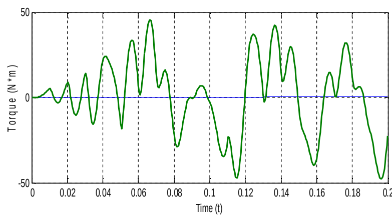
(g)

Fig. 12 : Output Response of Simulink Model (a) Input Supply Voltage Waveform of Cycloconverter (b) Output Current Waveform of Cycloconverter (c) Output Voltage Waveform of Cycloconverter (d) Main Winding Current Waveform of Motor (e) Auxiliary Winding Current Waveform of Motor (f) Rotor Speed of Motor (g) Torque characteristics of Motor, When Input Frequency is Four Times Output Frequency

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VI. CONCLUSION

The PWM controlled cycloconverter circuit is designed, simulated and desired above results are obtained. Single phase cycloconverter are developed output response 2 & 4 times to input response by two techniques : simple pulse generator and PWM generator and developed responses are applied to split phase induction motor. The output response of motor i.e. rotor speed and torque are varied and increases at various levels. Single phase cycloconverter used for split phase induction motor to generate supply torque characteristics that matches with demand torque characteristics of particular machine by the use of designing cycloconverter different desired frequency are obtained to equalize the torque demand of machine. This different frequency of cycloconverter is also useful to replace flywheel from the operating machine which reduces the cause of torsional vibration and fatigue damage of machine. The paper proposed a feedback control scheme of cycloconverter fed split phase induction motor. This means a reduction in the cycloconverter rating and better efficiency.

FUTURE APPLICATIONS

Cycloconverter have produced harmonics in output voltages, here only lower order have removed and higher order harmonics will removes from external aided cicuits. When cycloconverters are using for a running AC machine, the leakage inductance of the machine filters most of the high frequency harmonics and reducing voltage of the lower order harmonics. A speed controller of three phase motor on cycloconverter is proposed in future. It is very possible that there will soon be a possible combination of higher frequency generators and cycloconverter. The cycloconverter may be connected to differents motors and observed the output responses. In the future cycloconverter will perform with the higher frequency.

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BIOGRAPHY

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