Simulation of load & Electromagnetic Torque Controlled Single Phase asynchronous (induction) motor using Single phase Cyclo-converter

Javed Khan Bhutto[1], Pooja Sharma[2]
[1]Professor, Department of Electrical Engineering, Marudhar Engineering College, Bikaner, Rajasthan
[2]Research Scholar, Department of Electrical Engineering, Marudhar Engineering College, Bikaner, Rajasthan

Abstract- This paper is used to control the output parameters of load & Electromagnetic torque and speed of motor and also magnitude & phase difference of the motor. the Electromagnetic torque and speed of motor can be made economical by controlling the operation of cyclo-converter which in turns control the output parameters of single phase (split phase) asynchronous motor. When motor's Electromagnetic torque is controlled then motor speed is automatically constant and also nature of speed, torque, and voltage are inter-dependent of variegated load of motor. The speed of single phase asynchronous motor can be controlled by two methods, one method is by changing the number of poles & second method is by changing the frequency. The output parameter of the motor controlled through first method is not economical but under running condition number of poles can't be varied and size of the machine also get large. These problem can be solve by the second method. In the second method the frequency can be variegated under running condition & also no change in size of motor. In this method the frequency changing device is used as cyclo-converter. A Cyclo-converter is power electronics device that is used to convert constant voltage constant frequency. The various speed of the single phase asynchronous motor is obtained by varying the supply frequency by using cyclo-converter.The phase difference of an alternating waveform can vary from between 0 to its maximum time period, T of the waveform during one complete cycle. The formula for phase difference from between 0 to its maximum time period, T is inversely proportional to the frequency of firing pulses, T=1/F. The cyclo-converter is changing the input frequency, output frequency is less the input frequency. The cyclo-converter is controlled by its firing pulses.

Keywords- Single phase cyclo-converter, single phase(split phase) asynchronous motor , switches, logic gate NOT, Pulse generator, Matlab 2011a.

I. INTRODUCTION

The control of load & electromagnetic torque, speed of motor and voltage is needed to be done in industrial applications. There are various method to control the electromagnetic torque and speed of motor. The nature of speed, torque,and voltage are inter-dependent of variegated load of motor. The cyclo-converter frequency and depth of phase modulation of the firing angles of the converters, it is possible to control the frequency and amplitude of the output voltage. A cyclo-converter has the facility for continuous & independent control over both its output frequency & voltage. The quality of output voltage wave and its harmonic distortion also impose the restriction on this frequency. The distortion is very low at low output frequency. The cyclo-concerter used in very large variable frequency drives. Split phase asynchronous motor are widely used in many application due to their energy efficient characteristics. Improvements in its performance mean a great saving in electrical energy consumption.
The cyclo-converter is changing the input frequency, output frequency is less than the input frequency without any intermediate dc source. It can also be considered as frequency changer by controlling the input frequency. Cyclo-converter eliminates the use of flywheel because the presence of flywheel in machine increases torsional vibration and fatigue in the component of power transmission system. Therefore it is eliminated from the design of any machine. Hence variable voltage variable frequency (vvvf) method is chosen to design single phase cyclo-converter to drive single phase (split phase) asynchronous motor to get required frequency varying with different time interval that generates supply torque characteristics monitoring with demand torque. A variable-frequency drive (VFD) is a system for controlling the rotational speed of an alternating current (AC) electric motor by controlling the frequency of the electrical power supplied to the motor. A variable frequency drive is a specific type of adjustable-speed drive. Variable-frequency drives are also known as adjustable-frequency drives (AFD), variable-speed drives (VSD), AC drives, microdrives or inverter drives. Since the voltage is varied along with frequency, these are sometimes also called VVVF (variable voltage variable frequency) drives. Variable-frequency drives are widely used in ventilation systems for large buildings; variable-frequency motors on fans save energy by allowing the volume of air moved to match the system demand. They are also used on pumps, elevator, conveyor and machine tool drives. Drives can be classified as: Constant voltage , Constant current, Cycloconverter. A variable frequency drive system generally consists of an AC motor, a controller and an operator interface.

II.THE THYRISTOR CONTROLLED SINGLE PHASE TO SINGLE PHASE CYCLO-CONVERTER

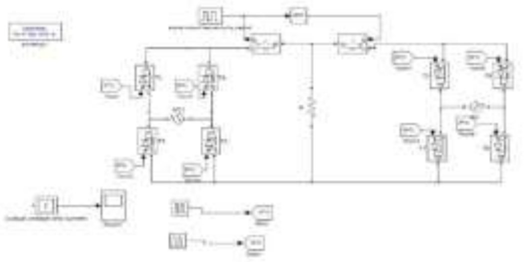


Fig 2: Single phase to single phase Cyclo-converter

All VFDs (variable-frequency drive) use their output devices (IGBTs, transistors, thyristors) only as switches, turning them only on or off. Using a linear device such as a transistor in its linear mode is impractical for a VFD drive, since the power dissipated in the drive devices would be about as much as the power delivered to the load. Because of upper frequency limitation of the output and power capability of the devices, it is possibility to use the thyristor controlled cyclo-converter to control low speed in very large motors.

There are two main works at present for the cyclo-converter. In first, the Cyclo-converter is used as a variable frequency variable speed drives for AC machines. The input of the cyclo-converter is connected to a power supply with fixed frequency and the machine to be driven is connected to the output of the cyclo-converter. In the second, the cyclo-converter is used to provide constant frequency power output from available frequency power source. The thyristor controlled single phase to single phase cyclo-converter is shown in Fig.1. As shown in Figure this type of arrangement is used to obtain variable voltage & variable frequency. Waveforms shown are obtained by varying the number of cycle covered by positive and the negative converters and firing angle

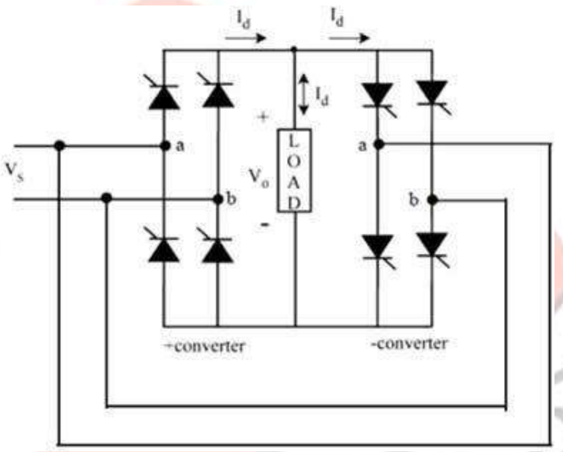
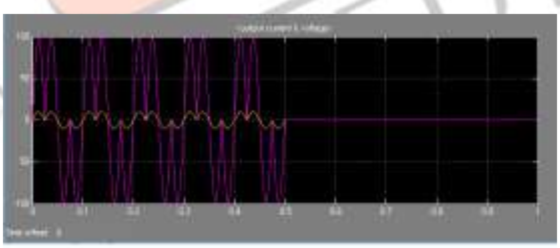
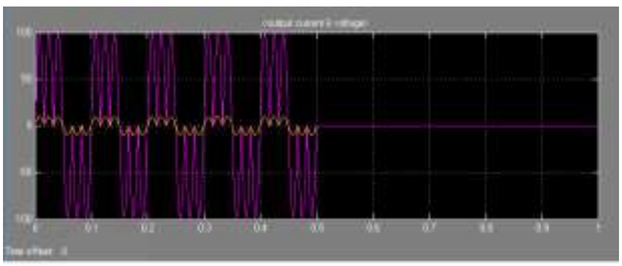


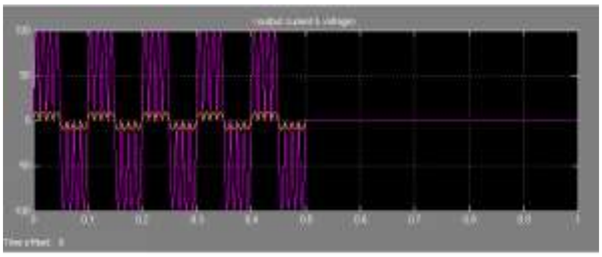
Fig 1 : Thyristor controlled single phase to single phase cyclo- converter



Waveform shows the output current & voltage, the input frequency is 2 times the output frequency



Waveform shows the output current & voltage, the input frequency is 3 times the output frequency



Waveform shows the output current & voltage, the input frequency is 4 times the output frequency

III.WORKING OF CYCLO-CONVERTER

The frequency can be varied by varying the conduction period for each Thyristor. The gate pulse for SCR can be provided by either by using firing circuit. Here for positive half cycle of input or supply. T1, T2" are forward biased, T1 is given pulse. For negative half cycle of input or supply T1", T2 are forward biased. T1" is given pulse. For another positive half cycle T2" is given pulse. For another negative half cycle T2 is given pulse. By using Cyclo-converter we can vary voltage and frequency. As AC motor characteristics require the applied voltage to be proportionally adjusted whenever the frequency is changed in order to deliver the rated torque this method is also called volts/hertz. For optimum performance, some further voltage adjustment may be necessary especially at low speeds, but constant volts per hertz are the general rule. This ratio can be changed in order to change the torque delivered by the motor.

IV. MODLING OF SINGLE PHASE (SPLIT PHASE) ASYNCHRONOUS MOTOR

The single coil of a single phase induction motor does not produce a rotating magnetic field, but a pulsating field reaching maximum intensity at 0^o and 180^o electrical.

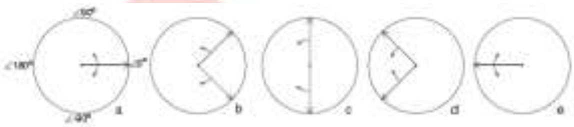


Fig.3 Single phase stator produces a nonrotating, pulsating magnetic field

Another view is that the single coil excited by a single phase current produces two counter rotating magnetic field phasors, coinciding twice per revolution at 0^o (Figure above-a) and 180^o (figure e). When the phasors rotate to 90^o and -90^o they cancel in figure b. At 45^o and -45^o (figure c) they are partially additive along the +x axis and cancel along the y axis. An analogous situation exists in figure d. The sum of these two phasors is a phasor stationary in space, but alternating polarity in time. Thus, no starting torque is developed. However, if the rotor is rotated forward at a bit less than the synchronous speed, It will develop maximum torque at 10% slip with respect to the forward rotating phasor. Less torque will be developed above or below 10% slip. The rotor will see 200% - 10% slip with respect to the counter rotating magnetic field phasor. Little torque other than a double freqency ripple is developed from the counter rotating phasor. Thus, the single phase coil will develop torque, once the rotor is started. If the rotor is started in the reverse direction, it will develop a similar large torque as it nears the speed of the backward rotating phasor. Single phase induction motors have a copper or aluminum squirrel cage embedded in a cylinder of steel laminations, typical of poly-phase induction motors.

The right control method for an application of the motor run most efficiently while maximizing torque and overall performance. Efficiently run motors also use less energy and experience less downtime for greater overall savings. For motors controlled by a variable frequency drive (VFD), the control method used in large part determines a motor's efficiency and performance in an application. There are four primary types of motor control methods for induction motors connected to VFDs: V/f (volts-per-hertz), V/f with encoder, open-loop vector, and closed-loop vector. VFDs control several different applications while maintaining optimal performance for each. The constant torque pattern is a straight line, which results in a constant V/f ratio that provides constant motor torque throughout the speed range. The variable-torque pattern has lower voltages at lower speeds to prevent motor saturation. Volts-per-hertz, commonly called V/f, is the simplest motor control method.

Single-Phase motors are not self-starting but Split-phase motors are self-starting motors. Split-phase motors are another common type of single-phase motor.

The split-phase asynchronous motor or induction motor are commonly used in major appliances such as air conditioners and clothes dryers ,washing machines, vacuum cleaners, water pumps, and used in industries as well. The split phase asynchronous motor has two windings main winding & starting winding. The starting winding is also known as auxiliary winding or running winding, which is used only for motor starting purpose. The main winding has characteristics of low resistance but high reactance. The starting winding has high resistance but low reactance.

The split phase asynchronous motor has difficulty of varying speed by a cost-effective device which is the main disadvantage of the motor.

The split phase (single phase) asynchronous motor is connected with single phase thyristor controlled cyclo-converter to control the electromagnetic torque of the motor & control the rotor speed and also consider the magnitude & phase difference of the two winding of the 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° electrical ahead of the main winding as shown in Fig.3.

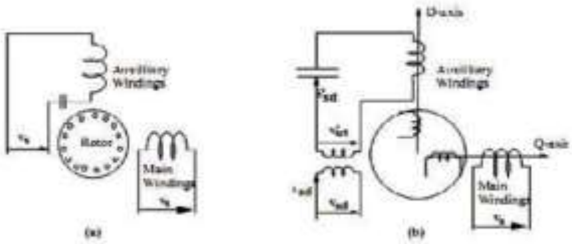


Fig 4 : D-Q transformation of the Split Phase asynchronous Motor

The simulation of the motor is presented in the stationary d-q frame to facilitate the application of the inverter. 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 physical windings. The squirrel cage rotor is represented by equivalent two coils transformed to the stationary d-q axis as shown in Fig.3. Stator windings covers two windings namely the main and auxiliary coils have different number of turns and different mutual reactance. Therefore, a transformation is made to transfer the auxiliary winding to an equivalent winding with the same number of turns as that of the main coil. The new variables referred to the equivalent coil are given as follows:-

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

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

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

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

The current equation of the motor can be written in the D-Q Stationary frame as follows:

$$i_{s\beta} = \frac{L_{r\beta}\psi_{s\beta} - L_{m\beta}\psi_{r\beta}}{L_{s\beta}L_{r\beta} - L^2_{m\beta}}$$

$$i_{r\alpha} = \frac{L_{s\alpha}\psi_{r\alpha} - L_{m\alpha}\psi_{s\alpha}}{L_{s\alpha}L_{r\alpha} - L^2_{m\alpha}}$$

$$i_{r\beta} = \frac{L_{s\beta}\psi_{r\beta} - L_{m\beta}\psi_{s\beta}}{L_{s\beta}L_{r\beta} - L^2_{m\beta}}$$

Where,

$\psi_{s\alpha}, \psi_{s\beta}, \psi_{r\alpha}, \psi_{r\beta}$ are the D-Q stator and rotor flux linkage , respectively $i_{s\alpha}, i_{s\beta}, i_{r\alpha}, i_{r\beta}$ are the stator & rotor current, $L_{s\alpha}, L_{s\beta}, L_{r\alpha}, L_{r\beta}$ are the stator and rotor inductance, $L_{m\alpha}, L_{m\beta}$ are the magnetizing inductances,

ω_r = Rotor speed, Electric radian/sec

Te = Developed torque

T_L = Load torque

J = Rotor moment of inertia

The equation of motion are given by:

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

$$J\frac{d}{dt}\omega_r = T_e - T_L$$

V.SIMULATION RESULT

Simulink model of Single Phase (Split Phase) asynchronous Motor and Single phase to Single phase Cyclo-converter is shown in figure.4. The objective of this paper is to study the load & Electromagnetic torque and motor speed and magnitude & phase difference of alternating source performance. For motors controlled by a variable frequency drive (VFD), the control method used in large part determines a motor's efficiency and performance in an application.The stator of a single phase(Split Phase) asynchronous motor has two winding , the main winding & auxiliary winding(Starting or Running winding) . since the D-Q axis model of an asynchronous motor is only valid for Sinusoidal input voltage .

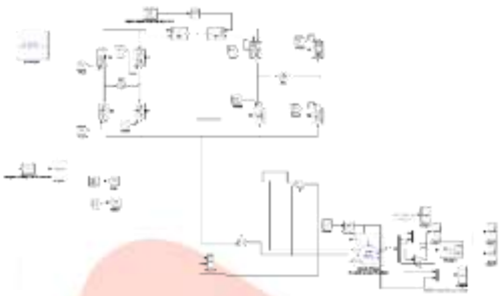
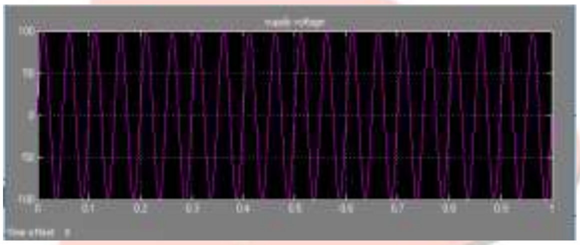
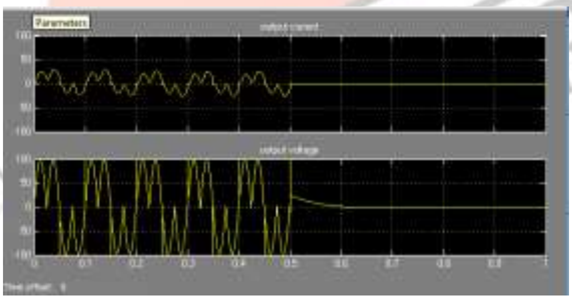


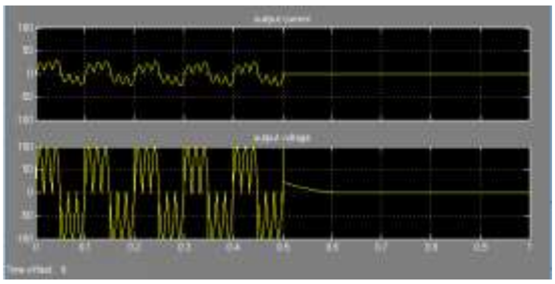
Fig.5 Single phase to Single phase Cyclo-converter connected with Single phase Motor



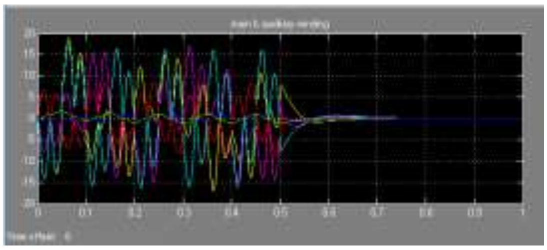
Waveform of Supply Voltage



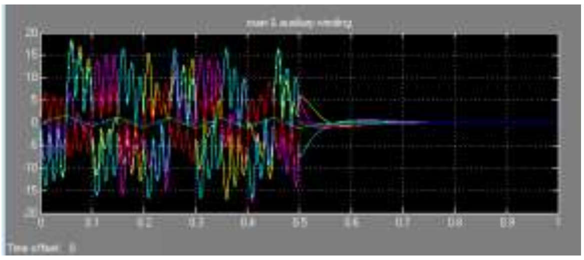
Waveform of Output Current & Voltage, input Frequency 2 times the output Frequency



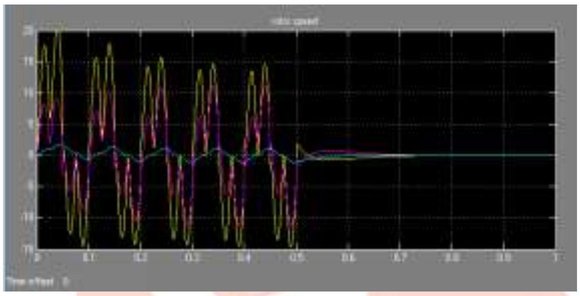
Waveform of output current & voltage, input frequency 3 times the output Frequency



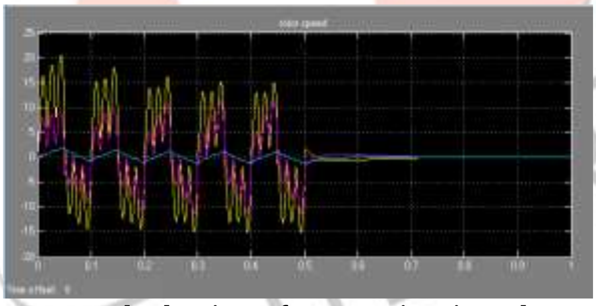
Waveform of main & auxiliary winding, when input frequency is 2 times the output frequency



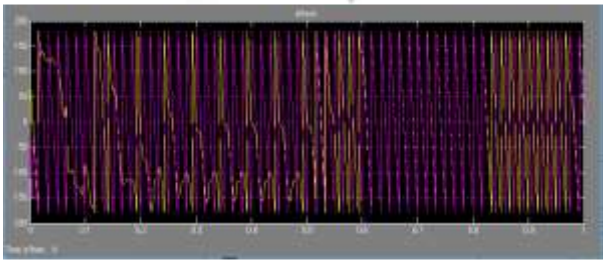
Waveform of main and auxiliary winding, when input frequency is 3 times the output frequency



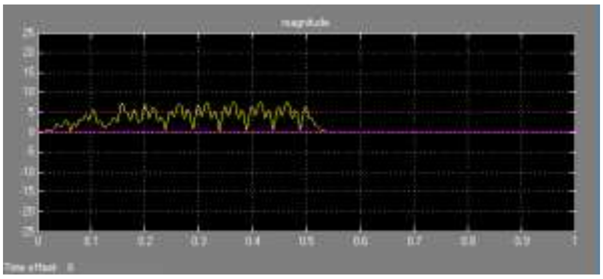
Waveform of rotor speed, when frequency is 2 times the output frequency



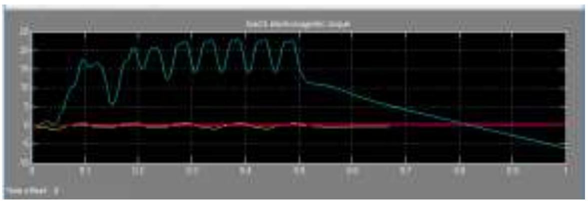
Waveform of rotor speed, when input frequency is 3 times the output frequency



Waveform of Phase difference of voltage and current



Waveform of magnitude of voltage & current



Waveform of Load & Electromagnetic torque

VII.CONCLUSION

The work and study of this result is achieved, it is noted that the Load & Electromagnetic torque and speed of the motor and magnitude & phase difference of the performance of the motor can be efficiently controlled by using Cyclo-converter as a Variable Frequency drive(VFD). The Cyclo-converter varying the supply frequency then change the speed of motor and control the electromagnetic torque. Cyclo-converter is also useful to replace the flywheel from the operating machine which reduces the cause of torsional vibration and fatigue damage of machine. In this paper the simulation of load & Electromagnetic control of motor at different frequencies by using Cyclo-converter is simulated and generated the output waveforms.

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