MODELING OF SPLIT PHASE INDUCTON MOTOR WITH SINGLE PHASE CYCLOCONVERTER

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ABSTRACT: *The cycloconverter is a power electronic device used to convert constant voltage constant frequency AC power to adjustable voltage adjustable frequency AC power without a DC link. Single-phase induction motors are widely used in many applications due to their energy efficient characteristics. Improvements in its performance mean a great saving in electrical energy consumption. A cycloconverter fed variable frequency motor is a typical example of such improvement.* In this regard, the paper presents an analysis of the performance and speed control of the split phase induction motor when it is fed with cycloconverter. *The various speed of induction motor is obtained by varying the supply frequency by using cycloconverter.*

Keywords—Cycloconverter, Split Phase Induction Motor

I: INTRODUCTION

During Analysis of induction motors controlled with cycloconverter has been investigated extensively. 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 [1]. The split phase induction motor is the most commonly used motor in the utility network. Split phase induction motors are usually built with small power, they are widely used in domestic and commercial applications [2]. A cycloconverter is a naturally commutated converter capable of bidirectional power flow. Its size is only limited by the availability of the rating of thyristors. Compared with rotary frequency changers, its losses are considerably lower. Cycloconverters can deliver a nearly sinusoidal waveform resulting in minimum torque pulsations for the case of rotating loads [5]. This paper shown a speed control scheme for a split phase induction motor fed with cycloconverter. Cycloconverters are used in very large variable frequency drives with ratings from few megawatts up to many tens of megawatts. The following sections will describe the operation principles of the cycloconverter starting from the simplest one, single phase to single-phase (1Φ-1Φ) cycloconverter. A single-phase input to single-phase output cycloconverter is shown in Fig.1, the simplest cycloconverter circuit. A cycloconverter is a type of power controlled in which an alternating voltage at supply frequency is converted directly to an alternating voltage at load frequency without any intermediate d.c stage [3]. A cycloconverter is controlled through the timing of its firing pulses, so that it produces an alternating output voltage [4]. By controlling the 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. Thus, a cycloconverter has the facility for continuous and independent control over both its output frequency and voltage [7]. The distortion is very low at low output frequency. Cycloconverter eliminates the use of flywheel because the presence of flywheel in machine increases torsional vibration and fatigue in the component of power transmission system.

II: MID-TAP TRANSFORMER TYPE CYCLOCONVERTER

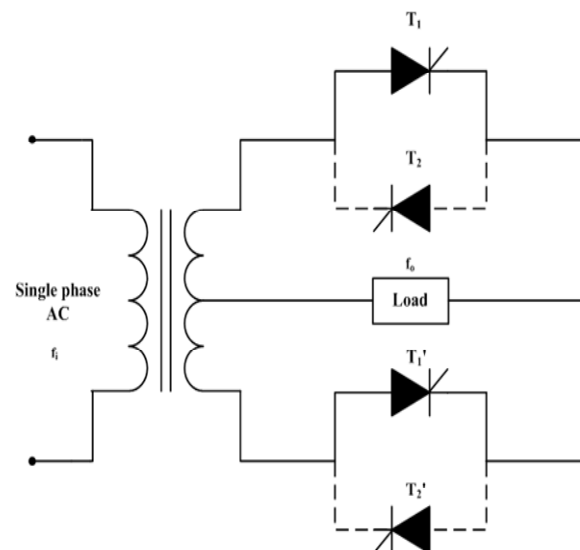The single-phase to single-phase cycloconverter with mid-tap transformer type converter is shown in Fig. 2.

Fig.1 Single Phase Mid-tap Transformer Type Cycloconverter[5]

As shown in fig in this type of arrangement midpoint tap transformer is use to obtain variable voltage and variable frequency [2]. Waveforms shown in fig.3 are obtained by varying the number of cycle covered by positive and the negative converters and firing angle.

III: BRIDGE TYPE CYCLOCONVERTER

The single-phase to single-phase cycloconverter consists of back-to-back connection of two full-wave rectifier circuits as shown in Fig.2 [3]. Fig.3 shows the operating waveforms for this converter with a resistive load.
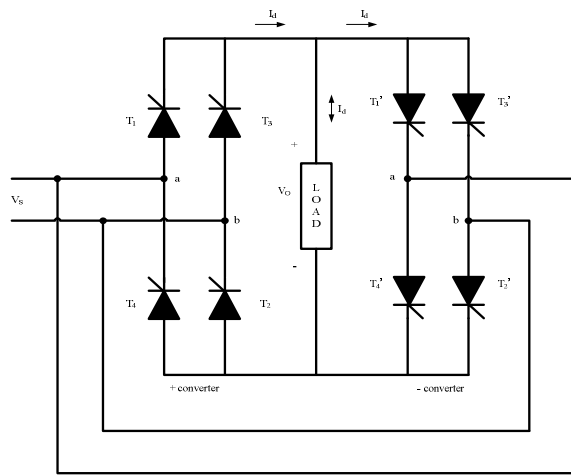

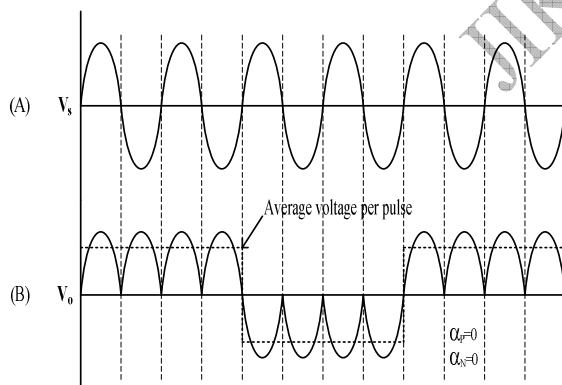Fig.2 Single Phase Bridge Type Cycloconverter[3]

Fig.3 (A) Input Voltage Waveform of Single Phase to Single Phase Cycloconverter

Fig.3 (B) Output Voltage Waveform for Zero Firing Angle of Single Phase to Single Phase Cycloconver--ter (Input Frequency is Four Times Output Frequency)

The input voltage, Vs is an ac voltage at a frequency, fi as shown in Fig.3 (A). All the thyristors are fired at α=0° firing angle, i.e. thyristors act like diodes. Note that the firing angles are named as α_P for the positive converter and α_N for the negative converter. The frequency of Vo can be changed by varying the number of cycles the positive and the negative

converters work [3]. It can only change as integer multiples of input frequency in Single Phase to Single Phase Cycloconverter. For example, to obtain the input frequency four times the output frequency as shown in fig.3 (B) fired positive group and negative group converter alternately.

IV: MODELING 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 [5]. The axis of the auxiliary winding is placed 90° electrical ahead of the main winding as shown in Fig.4. 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.4.
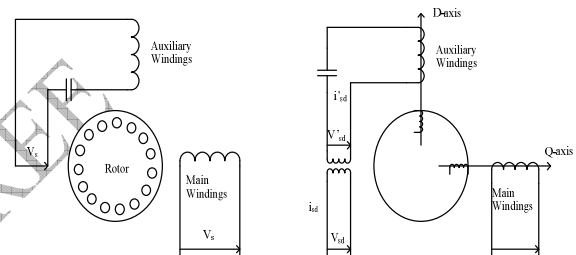

Fig.4 Modeling of Split Phase Induction Motor[5]

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 [5]:

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

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

$$i_{s\alpha} = \frac{L_{r\alpha}\Psi_{s\alpha} - L_{m\alpha}\Psi_{r\alpha}}{L_{s\alpha}L_{r\alpha} - L_{m\alpha}^2}$$

$$i_{s\beta} = \frac{L_{r\beta}\Psi_{s\beta} - L_{m\beta}\Psi_{r\beta}}{L_{s\beta}L_{r\beta} - L_{m\beta}^2}$$

$$i_{r\alpha} = \frac{L_{s\alpha}\Psi_{r\alpha} - L_{m\alpha}\Psi_{s\alpha}}{L_{s\alpha}L_{r\alpha} - L_{m\alpha}^2}$$

$$i_{r\beta} = \frac{L_{s\beta}\Psi_{r\beta} - L_{m\beta}\Psi_{s\beta}}{L_{s\beta}L_{r\beta} - L_{m\beta}^2}$$

The equations of motion are given by:

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

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

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 and rotor currents, $L_{s\alpha}, L_{s\beta}, L_{r\alpha}, L_{r\beta}$ are the stator and rotor inductances, $L_{m\alpha}, L_{m\beta}$ are the magnetizing inductances,

ω_r = Rotor speed, electric rad/sec,

T_e = Developed torque,

T_L = Load torque,

J = Rotor moment of inertia,

V: SIMULATION RESULT

Simulink model of split phase induction motor and single phase to single phase cycloconverter is shown in Fig.5. The objective of this paper is to analyze the speed of induction motor performance. The stator of a split phase induction motor has two windings, the main winding and auxiliary winding. Since, the d-q axis model of an induction motor is only valid for sinusoidal input voltage. Fig.6 and Fig.8 shows output phase voltages and currents for input frequency is 2 and 3 times the output frequency of the single-phase Cycloconverter.
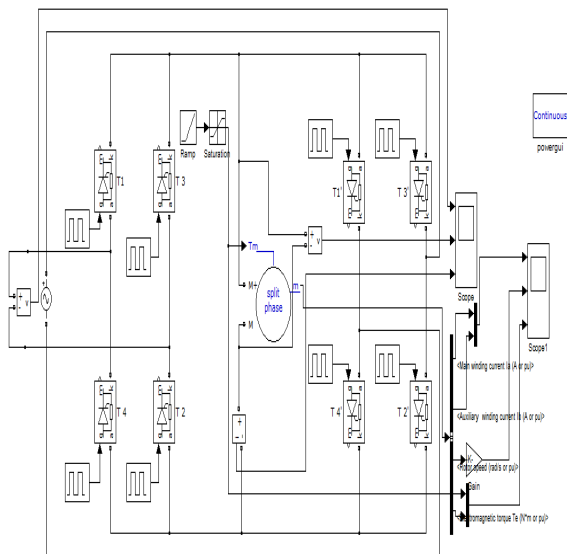

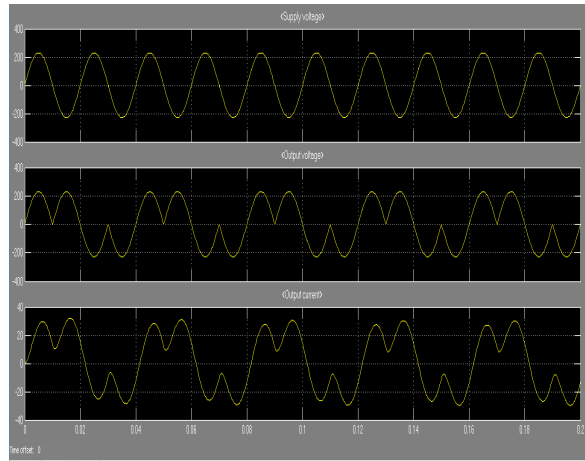Fig.5. Cycloconverter Fed Split Phase Induction Motor

Fig.6 (a) Source Voltage (b) Output Voltage (c) Output current Waveform of Single Phase to Single Phase Cycloconverter When Input Frequency is Two Times Output Frequency
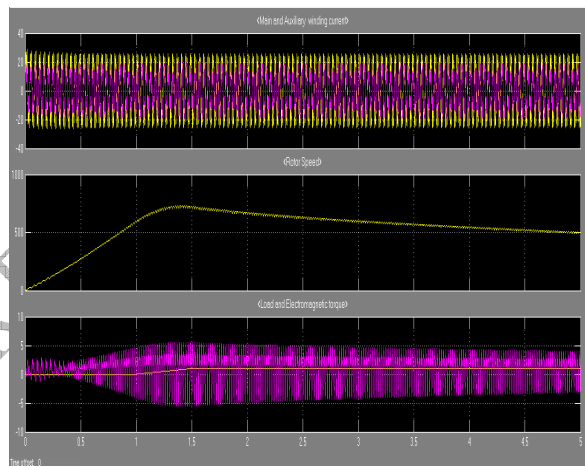

Fig.7 (a) Main winding and auxiliary winding current (b) Rotor Speed (c)Load and Electromagnetic Torque Waveform of Single Phase Induction Motor, When Input Frequency to the Cycloconverter is Two Times Output Frequency
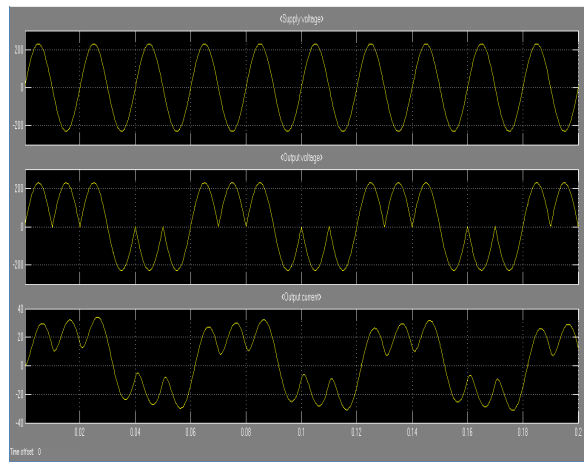

Fig.8 (a) Source Voltage (b) Output Voltage (c) Output current Waveform of Single Phase to Single Phase Cycloconverter When Input Frequency is Three Times Output Frequency
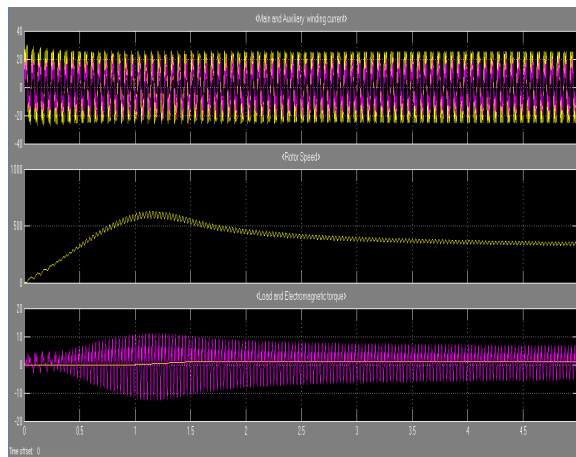
Fig.9 (a) Main winding and auxiliary winding current (b) Rotor Speed (c)Load and Electromagnetic Torque Waveform of Single Phase Induction Motor, When Input Frequency to the Cycloconverter is Three Times Output Frequency

VI: CONCLUSION

From this work and result analysis, it is observed that speed of an induction motor can be efficiently controlled by using cycloconverter. The role of cycloconverter in speed control of induction motor is to vary the supply frequency which in turn, changes the speed of motor. In the present work, the simulation of speed control of motor at different frequencies by using cycloconverter is simulated and waveforms are discussed.

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