SPEED CONTROL OF SINGLE AND THREE PHASE INDUCTION MOTOR USING FULL BRIDGE CYCLOCONVERTER

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ABSTRACT -This project proposes a full bridge cyclo-converter for three and single-phase induction motor speed control. The speed control of Induction Motor is simple and can be made efficient by using various methods to control the action of Cyclo-converter which will control the motor performance. There are two ways to control the speed of the motor, one method is by changing the frequency and the second method is by changing the number of poles. The speed control by the second method is uneconomical because under running conditions the number of poles can't be varied and the machine size becomes bulkier, but the problems can be overcome by the first method. In this scheme, the motor supply frequency can be varied in running conditions, so it will not change the motor size. In this scheme, the Cyclo-converter is a frequency changing device. It is a power electronic device used to convert constant frequency constant voltage AC power to adjustable frequency adjustable voltage. AC power is used without a DC link. Among all the schemes the frequency method is reliable, simple and economical. By using Cyclo converter the various speed of induction motor is obtained. The merits of proposed bridge type cyclo converter for speed control of single and three phase induction motor is verified by simulations in MATLAB/Simulink environment.

Key words - Cyclo converter, AC-AC frequency converter

1.INTRODUCTION

With the ever-increasing demand of power requirement in the present world, efficient energy conversion is the top priority. These high efficiency converter units are the power converters, where power electronics comes into action. Among the various converters, an AC-AC frequency converter is a single step converter. Speed control of Induction motor plays Important role in industries, there are various ways to control speed of motor but considering its efficiency, this paper proposed acyclo-convertor technique by thyristors to control the single-phaseand three-phase induction motor speed in three steps. AC Induction motors have the great benefits of being very reliable and relatively inexpensive. Induction motors are very robust in many domestic appliances such as vacuum cleaners, washing machines, water pumps, and also used in very large industries. It is also known as a constant-speed machine, one of its main disadvantagesis that the speed of the motor is difficult to vary and also it is very cost effective. Cyclo-converter have several important features, cyclo-converter frequency can be varied by conduction period for each MOSFET. However, control of induction motor is challenging task, many authors have suggested different techniques for speed control of induction of induction motor. These includes sliding mode control, fuzzy logic control and model predictive control and cyclo-converters etc. The advancement of standard field-oriented control could be viewed as a control methodology. It involves2 control loops, i.e. the speed control and the rotor flux loops, intended using the active control method, using disturbance rejection with the aim to cope with both endogenous and exogenous disturbances, which are projected by means of two extendedlinear state observers and then remunerated. Additionally, with the aim of total robustness.Uncertainties and disturbance estimation errors and in the knowledge of the control gains, for which the sliding mode-based control is designed. The Fuzzy controller algorithm is designed and carried out by fuzzy set theory inMATLAB/Simulink 2013a using T-S model (Takagi-Sugeno model). The output of both the controllers are examined by simulation and the results are compared. By the simulation result T-S model gives the better performance to control the speed of the motor with respect to load variations and control delay, when compared to the PI controller. The overall post and pre-analysis proves the proposed controller robustness with respect to all disturbances. The T-S model controller replaces the conventional PI controller in terms of dynamic performance of non-linear system. In some conditions such as interruption of power, the motor may be continuously rotating before the motor is powered by the inverter. Initial direction of rotation and speed is unknown for the speed less operation, so it will not achieve the smooth and fast resume of normal operation if the starting scheme is not well designed. In this methodology an adaptive full order observer (AFO) is designed to address the problems. Without a proper feedback gain matrix, the estimated speed cannot converge to the actual speed, if the speed is lower than the actual speed. By transfer function analysis of stator current error, the speed estimation is assumed. For improved restarting performance a feedback gain matrix condition is used for normal operation. The variable frequency has important usage in the industrial world. The electricity produced from the generating station are normally 50Hz and these frequency is not applicable for most of the application. The Speed Control of Induction Motor by Using Cyclo-converter. Some electrical devices which need variable frequency than the fixed supply frequency. The induction motors are one of the best example for variable frequency drives. The induction motors are used in traction system, mobile power supplies etc. The variable frequency drive has the great demand in industrial applications. The cyclo-converter is such a device which generates variable frequency. This project proposes the Cyclo-converter for induction motor application with neuro fuzzy controller. In this paper AC supply frequency cannot be changed, so this paper proposed a use of Cyclo-converter using thyristor which enables the speed control in steps for an induction motor. The controller used in this project is from PIC (Programmable interface Controller) family, a couple of switches is provided to select the set speed (F/3, F/2 and F) of the induction motor. These switches are implemented to the microcontroller. The switch status enables the microcontroller once it enabled the pulses and it will trigger the SCR's in a dual bridge. Thus, the speed control can be achieved in three steps i.e. (F/3, F/2 and F). The speed control of asynchronous motor (AM) or induction motor (IM) can be varied by varying the slip 'S' or number of poles 'p' or frequency fof the supply. The ability of varying any one of the above three quantities will provide methods of speed control of an induction motor. Constant V/F method is commonly used for constant and variable speed control of induction motor. The different methods of speed control of IM can be broadly classified into scalar and vector control methods. In this paper, scalar control methods are used. This transforms input AC power at one particular frequency into output AC at a completely different frequency avoiding a multiple step conversion thus reducing losses. These converters may be a step-up converter (cyclo-inverter) or a step-down converter (cyclo-converter) as per the requirement of the application. They are widely used in variable speed constant frequency systems (VSCF), large AC motor drives, arc welding, high frequency induction heating, plasma generation, industrial laser drives, power factor correction and so on. The output of these conventional converters is very rich in harmonics resulting in poor efficiency of the entire process. The normally used conventional technique of filtering can't be used in this case as it has problems related to design as well as in economic aspects when it is applied to a variable frequency system. In addition to this, use of tuned filters is not at all feasible to eliminate each of the harmonic component as the nature of the output frequency of the converter is varying. Hence the only way out of the problem is to use modulation techniques as they are feasible compared to use of tuned filters. Some of the modulation techniques that are in use are delta modulation,sinusoidal PWM,890 space vector PWM and staircase modulation. Some work on trapezoidal modulation technique has been done and comparison has been made among different PWM techniques. The various methods of implementation of frequency converters are also available in various literature.

2. Block Diagram

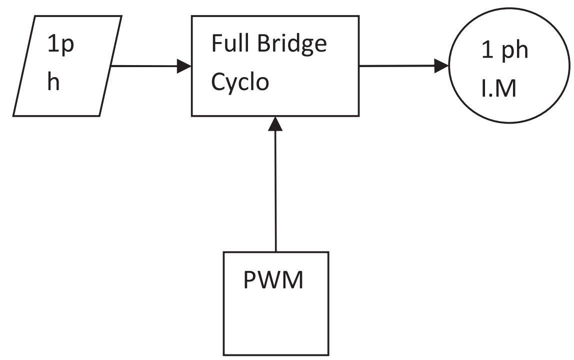


Fig1: Single phase Cyclo-Converter

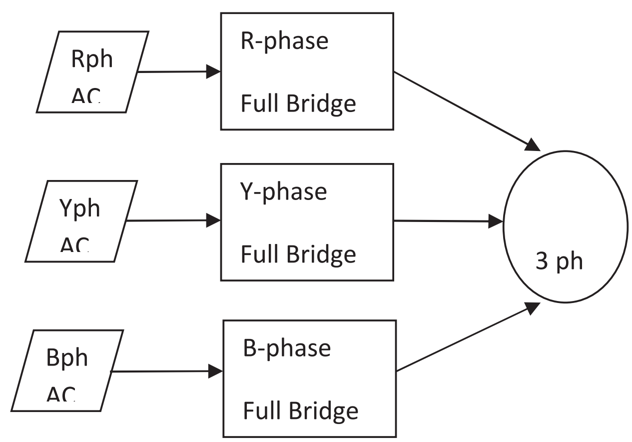


Fig 2: Three phase Cyclo-Converter

A. Single phase Cyclo-Converter Circuit Diagram

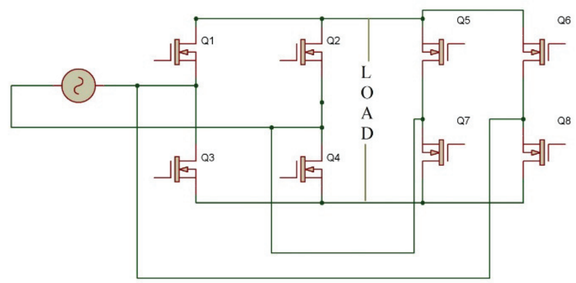


Fig3: Single phase Cyclo-Converter Circuit Diagram

B. phase Cyclo -Converter Circuit Diagram

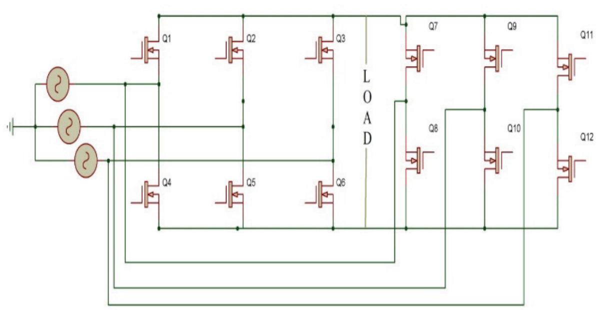


Fig4: 3- phase Cyclo-Converter Circuit Diagram

3. Theory of Operation of Cyclo-Converter

In very high-power drives usually above one megawatt,the Cyclo-converter has been traditionally used, where other type of drive cannot be used. Examples are the 13 MW German-Dutch wind tunnel fan drive,cement tube mill drives above 5 MW,ship propulsion drives, reversible rolling mill drives. The reasons for this a large number of thyristors is required for the traditional Cyclo-converter, it requiresat least 36for good motor performance, and with a very complex control circuit, but the frequency output limited to about one third the input frequency, and it is the main performance limitations.

The Cyclo-converter has 4 thyristors divided into a negative, positive and bank of 2 thyristors each. When the positive current flows through the load, two positive bank thyristors controlthe output voltage by phase control, while the bank of negative thyristors are kept off and vice versa when the negative current flows through the load. An idealized output waveform for a 45 degrees load phase angle and sinusoidal load current are shown in the simulation result. At all times always keep the non-conducting thyristor bank off, otherwise the mains would have been shorted via the two thyristor banks, resulting in possible device failure and waveform distortion from the shorting current. A cyclo-convertor has the major control problem is to swap between the banks in the shortest period of time to avoid distortion and also ensure that the two banks does not conduct at the same period of time. To overcome this problem center tapped inductor called a circulating current inductor between the outputs of the two banks in addition to the power circuit that removes the requirement of one bank off. Now the both banks can conduct together without short circuit in the mains. Also, the inductor keeps the circulating current in both banks operates at all the time, and this will improve the result of output waveforms. But this technique is not used often, because of the circulating current passed through the inductor tends to be bulky and expensive and this reduces the power factor of the input.

The mid-tap transformer type single-phase to single-phase Cyclo-converter with is shown in figure, to obtain variable voltage and variable frequency this type of arrangement midpoint tap transformer is used. The Waveforms are obtained by varying the number of cycle covered by negative and positive converters and firing angle. For each MOSFET the frequency can be varied by varying the period of conduction. The SCR gate pulse can be provided by using the firing circuit. T1 and T2 are forward biased for the positive half cycle of supply or input. T1 is given pulse. T2 is given pulse for negative half cycle. By using Cyclo-converter we can vary frequency and voltage. AC motor characteristics whenever the frequency is changed then the applied voltage will be proportionally adjusted in order to deliver the required torque this method is also called volts/hertz. For optimal performance, at low speeds, some additional voltage adjustment may be necessary by the general rule kept the constant volts per hertz. It can be changed the ratio in order to change the torque delivered by the Induction motor.

In a 1-φ Cyclo-converter, the output frequency is less than the supply frequency. These converters require natural commutation which is provided by AC supply. During the positive half cycle of supply, thyristors P1 and N2 are forward biased. First triggering pulse is applied to P1 and hence it starts conducting. As the supply goes negative, P1 gets off and in negative half cycle of supply, P2 and N1 are forward biased. P2 is triggered and hence it conducts. In the next cycle of supply, N2 in the positive half cycle andN1 in the negative half cycle are triggered. Thus, we can observe that here the output frequency is 1/2 times the supply frequency.

A. Types of Cyclo-converter

Based on the type of input ac supply applied to the circuit. The Cyclo-converter are divided into 3 types

- Single Φ to Single Φ Cyclo-converter
- Three Φ to Three Φ Cyclo-converter
- Single Φ to Three Φ Cyclo-converter

B. Single-phase to Single-phase (1 Φ-1 Φ) Cycloconverter

The single-phase to single-phase Cyclo-converter consists of back-to-back connection of 2 full-wave rectifier circuits. The frequency vs AC voltage as shown in the simulation result. Assume that all the thyristors are fired at α=0°firing angle, for the understanding purpose i.e. thyristors act like a diode. Note that the firing angles are named as αN for the Negative converter and αP for the Positive converter. Contemplate the operation of Cyclo-converter to get 1/4thof the input frequency at the output of the motor. For the first 2 cycles, the load current is supplied by the positive converter and it rectifies the input. In the next two cycles, the load current supplied in the reverse direction by the negative converter. The waveforms of the current are not shown in the figure because the voltage and current waveform will have the same resistive load current but only scaled by the resistance. Note that the other one is disabled when one of the converters operates, because there is no current circulating between the 2 rectifiers.

4. Three-Phase to Three-Phase (3Φ-3Φ) Cyclo-converter

If the output voltages are 2π/3 radians phase shifted from each other and also the outputs of 3Φ-1Φ converters of the same kind are connected in delta or wye and the resulting converter is a three phase to three-phase (3Φ-3Φ) Cyclo-converter. The resulting Cyclo-converter are shown in figure with wye connections. 3Φ-3Φhalf-wave Cyclo-converter is also called a 3-pulse Cyclo-converter or an 18-thyristor Cyclo-converter. Bridge converters are also used, then the result is the 3Φ-3Φbridge Cyclo-converter. On the other hand, the 3Φ-3Φbridge Cyclo-converter is also called a 36-Cyclo-converter or a 6 plus thyristor Cyclo-converter. The three-phase cyclo-converters are mainly used as a drive system to run the 3-phaseinduction and synchronous machines. It has more advantageous when used to run the synchronous machine due to their power factor characteristics. A Cyclo-converter can supply unity, lagging, or leading power factor loads while its input is always lagging in nature. This operation characteristic matches the Cyclo-converter to any synchronous machine. The Cyclo-converter does not have an edge compared to other converters in this aspect for running as an induction machine, on the other hand, induction machines can only draw lagging current, so cyclo-converters used for speed control purposes are used in Scherbius drives driving wound rotor induction motors. Equations (1) and (2) give the value of rotor and stator flux of induction motor.

$$\Psi_s = L_s I_s + L_m I_r \tag{1}$$

$$\Psi_r = L_r I_r + L_m I_s \tag{2}$$

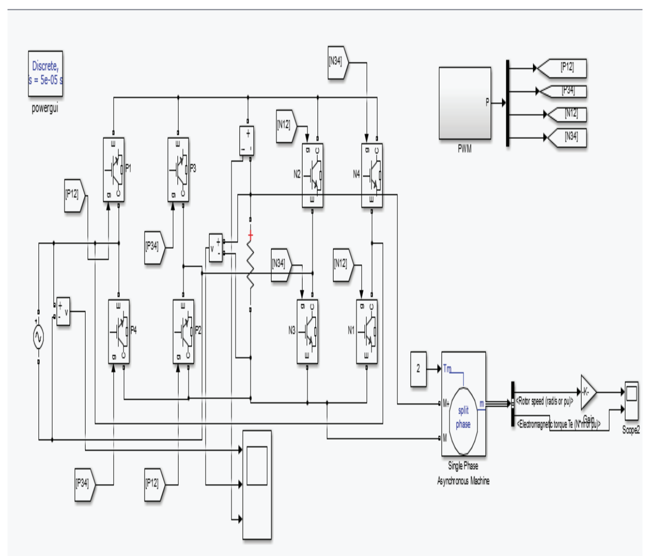
Electro-magnetic torque developed by 3-phase induction motor is given by equation-3

$$T_e = \frac{3}{2}\frac{p}{2}\Psi_s X I_s \tag{3}$$

Where $\Psi_s = \Psi_{qs} - j\Psi_{ds}$ (4)

$$I_s = I_{qs} - jI_{ds} \tag{5}$$

5. Simulation Results



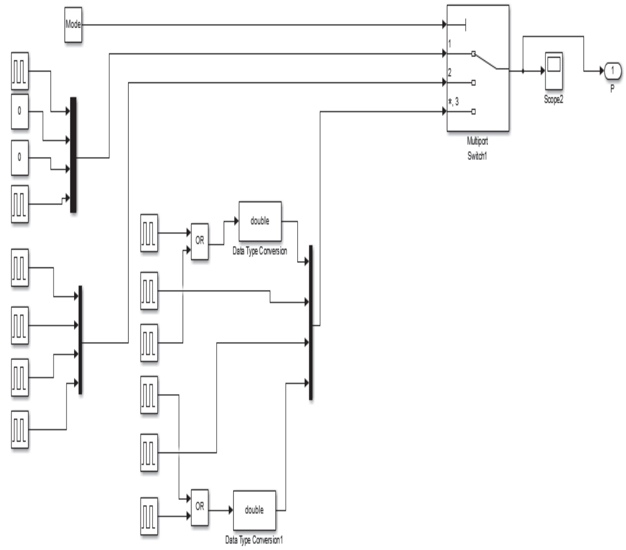


Fig 5: Simulink for Single Phase Cyclo-converter

Table1 Simulation parameters

Split phase Induction Motor Parameters	
Rated Voltage	110 v
Rated Power	0.25 hp
Stator Resistance Rs	2.02 ohms
Rotor resistance Rr	4.12 ohms
Stator Inductance Ls	0.0074 H
Rotor inductance Lr	0.00563 H
Mutual Inductance Lm	0.17722 H
Frequency	50 Hz
Inertia J	0.0146
Pole pairs	2

A. Mode=1 Fo=Fin

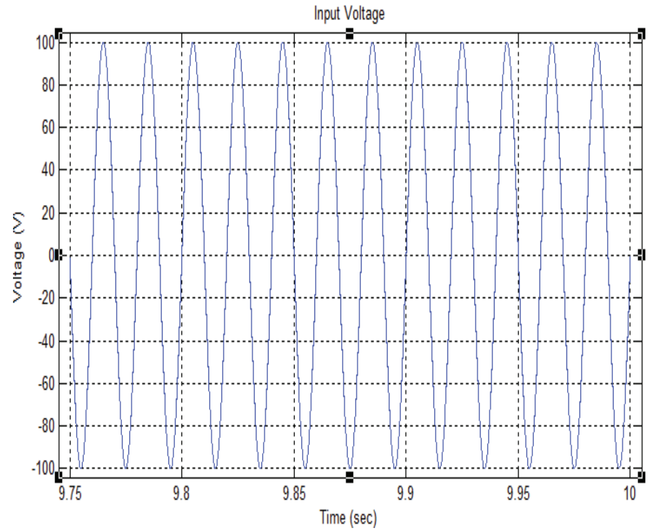


Fig 6: Input Voltage

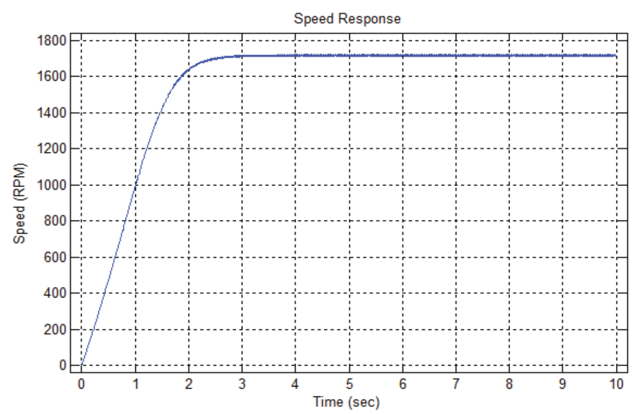


Fig 7: Speed response

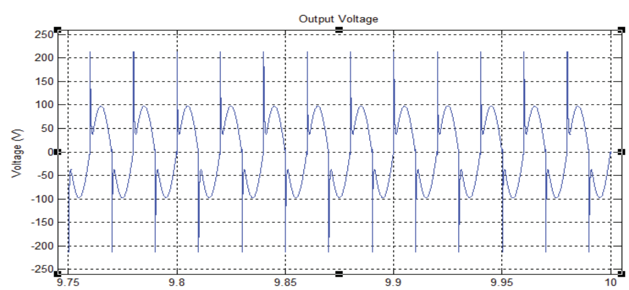


Fig 8: Output Voltage

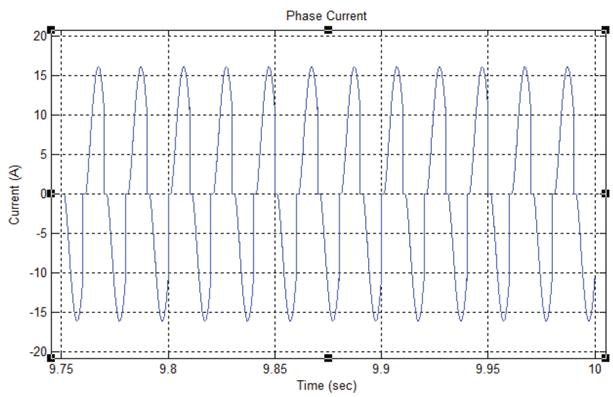


Fig 9: Phase Current

B. Mode 2 Fo=Fin/2

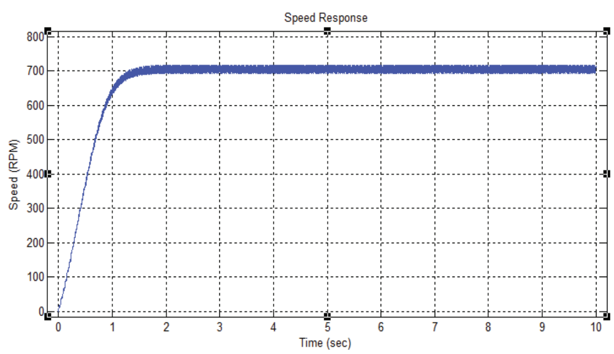


Fig 10: Speed Response

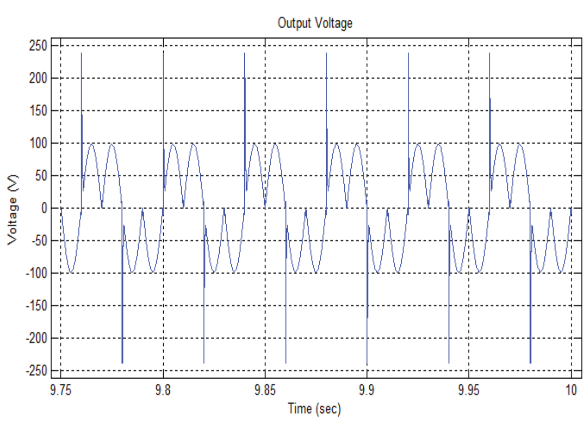


Fig 11: Output Voltage

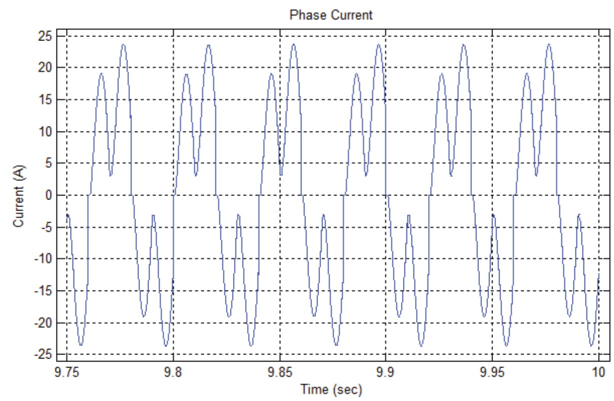


Fig 12: Phase Current

C. Mode 3 F0=Fin/3

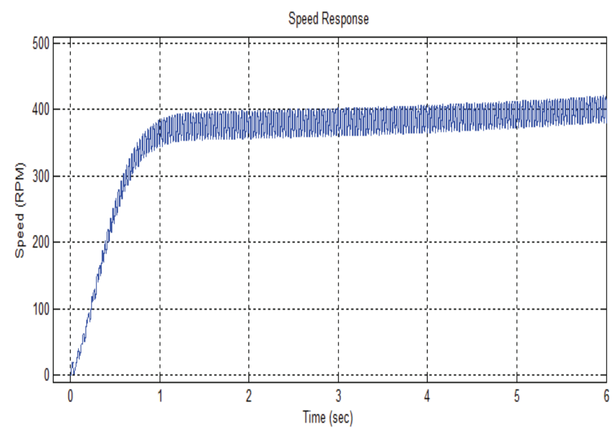


Fig 13: Speed Response

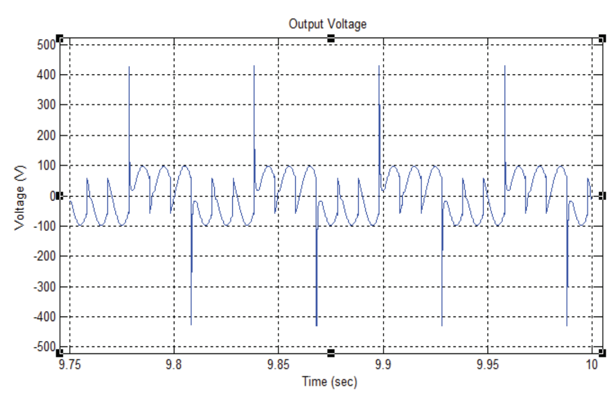


Fig 14: Output Voltage

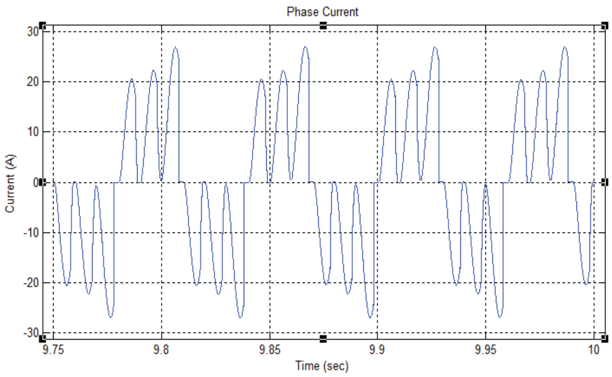


Fig 15: Phase Current

6. Three Phase Cyclo Converter

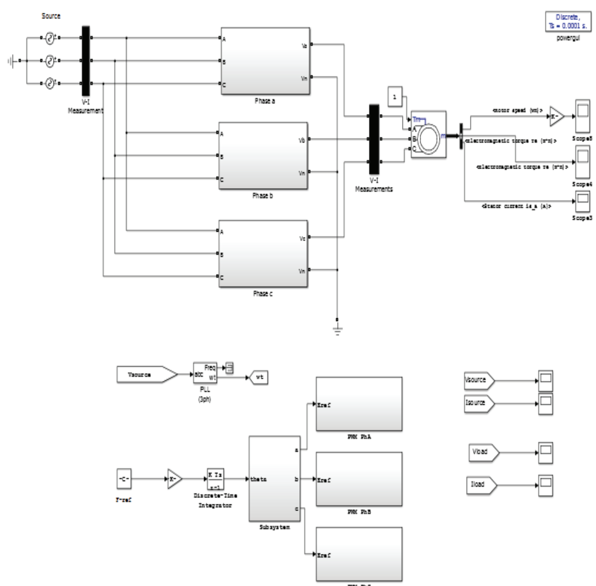


Fig 16: Simulink for Three Phase Cyclo-converter

Table 2. Simulation parameters

Three Phase I.M Parameters	
Rated Power	0.5 hp
Rated Voltage	460 v
Frequency	50 Hz
Stator Resistance Rs	0.435 ohms
Stator Inductance Ls	0.002 H
Rotor resistance Rr	0.816 ohms
Rotor inductance Lr	0.002 H
Mutual Inductance Lm	0.06931 H
Inertia J	0.0089
Pole pairs	2

A. Mode 1 Fo=Fin

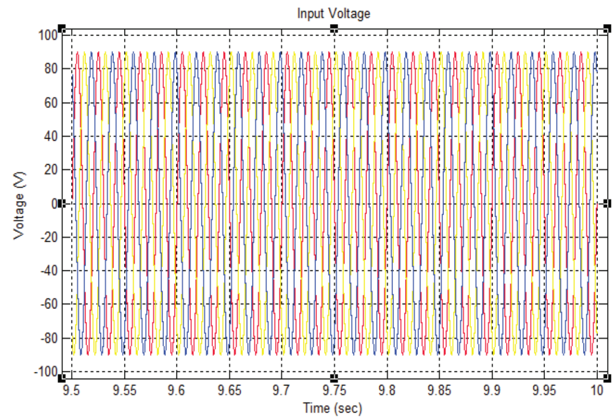


Fig 17: Input Voltage

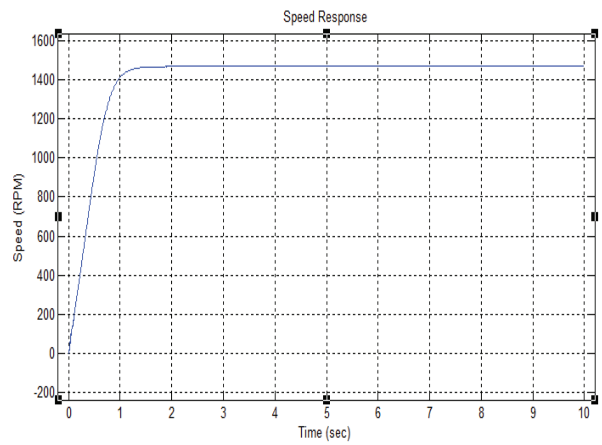


Fig 18: Speed Response

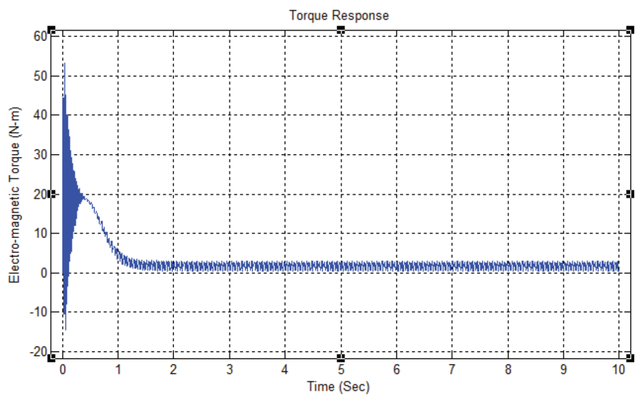


Fig 19: Torque Response

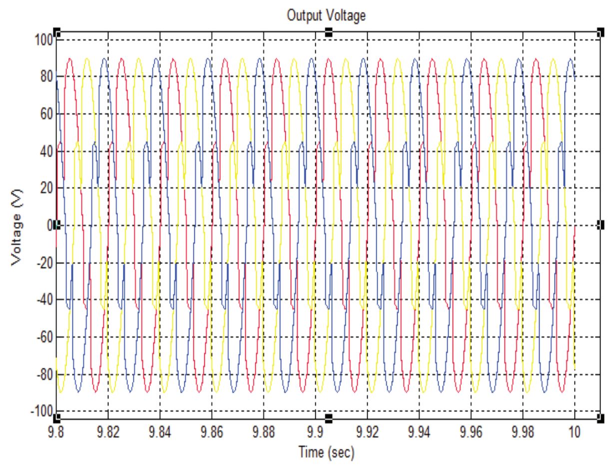


Fig 20: Output Voltage

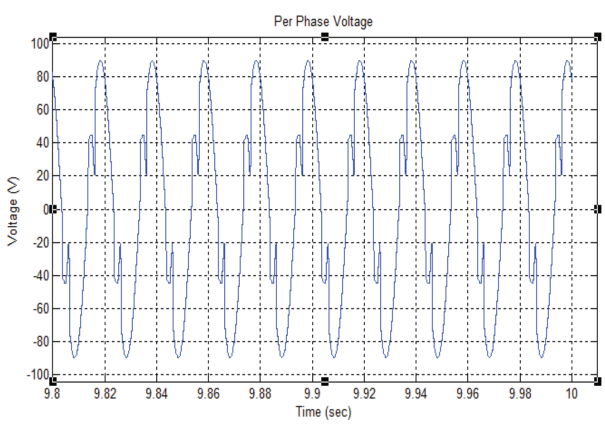


Fig 21: Per Phase Voltage

B. Mode 2 Fo=Fin/2

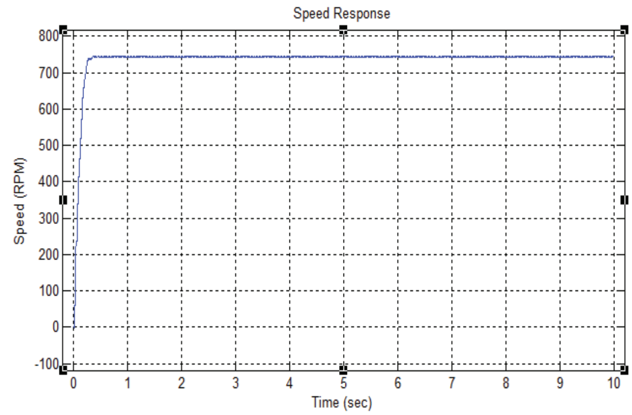


Fig 22: Speed Response

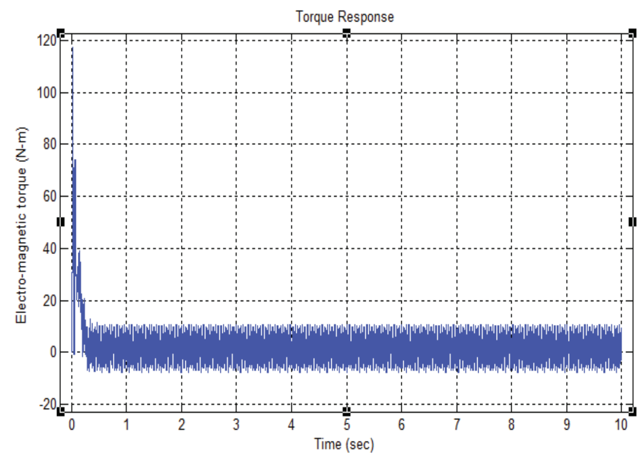


Fig 23: Torque Response

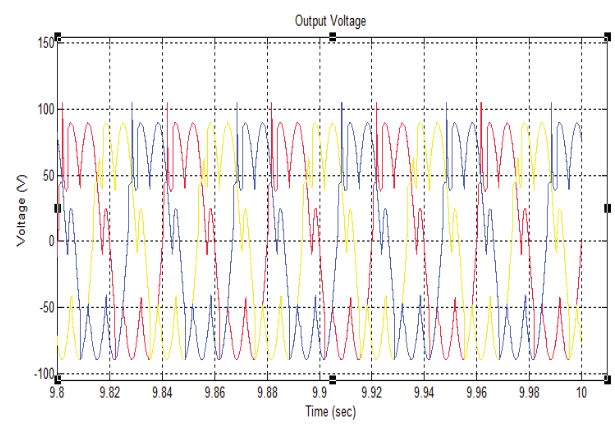


Fig 24: Output Voltage

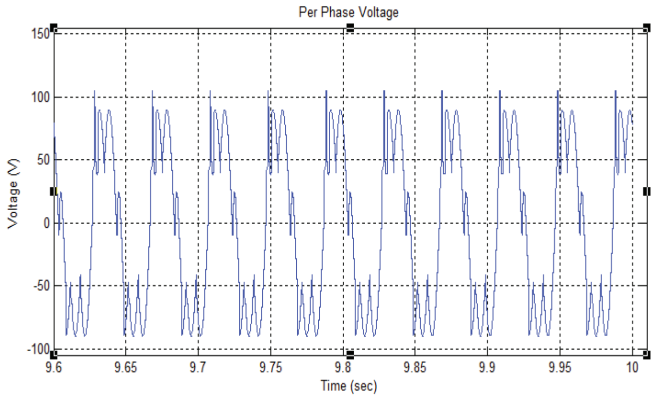


Fig 25: Per Phase Voltage

C. Mode 3 Fo=Fin/2.5

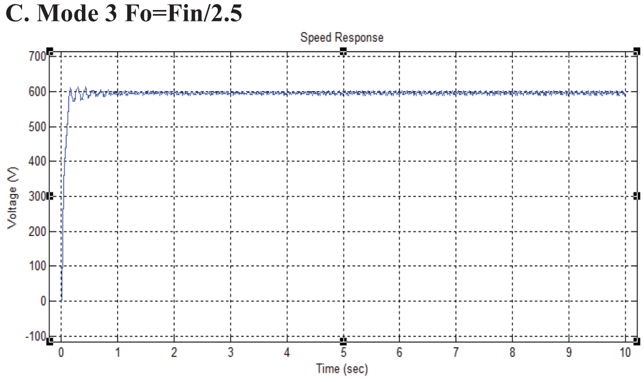


Fig 26: Speed Response

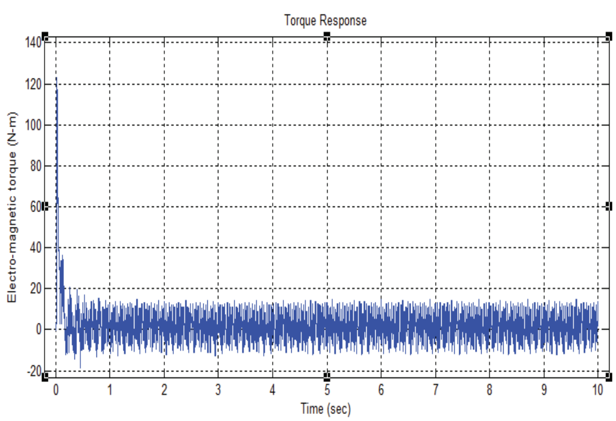


Fig 27: Torque Response

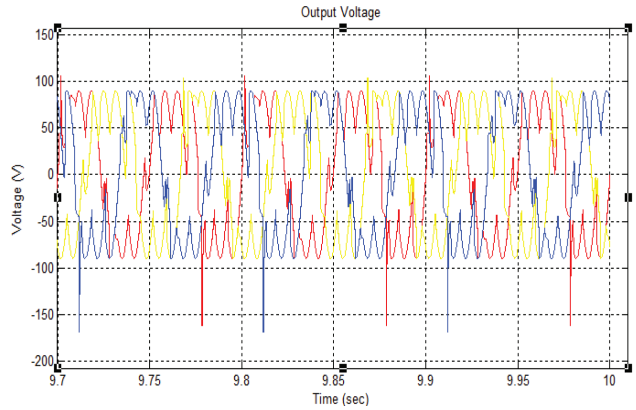


Fig 28: Output Voltage

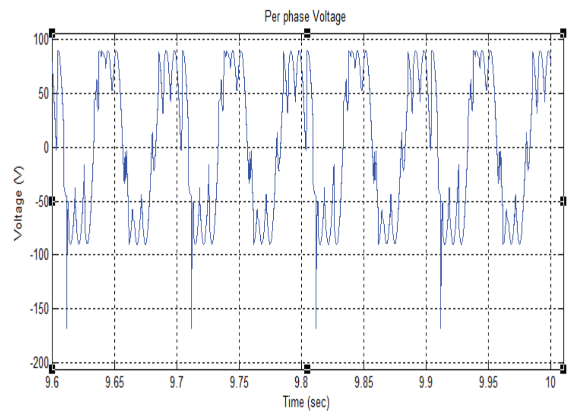


Fig 29: Per Phase Voltage

7. CONCLUSION

The single and three phase full bridge cyclo-converter circuit has been intended for speed control of induction motor with adjustable frequency. Single phase Cyclo-converter used to change the speed of induction motor with different desired frequency is obtained to equalize the desired speed. This different frequency of cyclo-converter is obtained in the manner of adjustable speed to F, F/2 & F/3.

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