

SIMULATION OF CYCLOCONVERTER BASED THREE PHASE INDUCTION MOTOR

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ABSTRACT

The process machine including provision for variation in load and this is achieved by using three phase cycloconverter based variable voltage variable frequency (VVVF) method. To realize this, a demand torque characteristics of a specific process machine is studied. The cycle duration of demand torque characteristics is divided into suitable number of time intervals. The subdivisions of time intervals in form of frequencies are tabulated to simplify design procedure. Change in frequency on particular subdivision results in demand torque of the induction motor. To meet this new frequency hence voltage, three phase cycloconverter is designed. This contribution describes a method used to simulate an induction motor drive using MATLAB software.

KEYWORDS

Cycloconverter, Induction motor, MATLAB.

1. INTRODUCTION

This work addresses with the continuous improvement of technology in power electronics and micro-electronics, variable voltage and variable frequency ac motor drives have come to increased use in various industrial applications. These new approaches need a simple method of control for ac motors. Control of ac motors become very popular because it is possible to obtain the characteristics of dc motors by improving control techniques. It is well-known that the control method of an ac motor is comparatively more difficult to realize because of involvement of various controllable parameters like voltage, current, frequency, torque, flux and so on. Though it is possible to achieve almost the same characteristics of dc motor using induction motor, it is very complicated to realize because of need for on line co-ordinate transformation and continuous need of either speed or position signal.

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. A cycloconverter is controlled through the timing of its firing pulses, so that it produces an alternating output voltage. 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. This frequency is normally less than 1/3 of the input frequency. 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.

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. Therefore it is eliminated from the design of any machine. Hence variable voltage variable frequency (vvvf)

method is chosen to design three phase cycloconverter to drive three phase induction motor to get required frequency varying with different time interval that generates supply torque characteristics monitoring with demand torque.

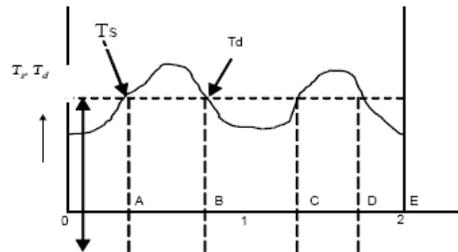


Figure 1. Arbitrary demand torque characteristic

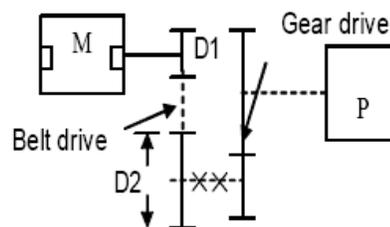


Figure 2. An arbitrary process unit

Figure 1 describes arbitrary demand torque characteristics of any machine this can be estimated based on cycle time of operation process resistance and inertia resistance. It shows that demand torque varies with time which motor unable to generate similar supply torque characteristics. Hence flywheel is used to makeup the difference but it will deaccelerate during interval AB and CD where it will gain speed during interval OA, BC, DE sections of time axis.

Figure 2 shows an arbitrary process unit along with usual mechanical power transmission system for amplification and reduction of torque and speed respectively. D2 and D1 are flywheel pulley and driving pulley respectively, where M is induction motor.

2. APPLICATIONS OF THYRISTOR CYCLOCONVERTERS

Due to the power capability of the devices and the upper frequency limitation of the output, it is possible to use the thyristor line-commutated cycloconverters to control low speed but very large horsepower motors. There are presently two main applications for the cycloconverter. In first application area, the Cycloconverter is used as a variable frequency variable speed drives for AC machines. The input of the cycloconverter is connected to a power supply with fixed frequency and the machine to be driven is connected to the output of the cycloconverter. In the second application area, in contrast, the cycloconverter is used to provide constant frequency power output from a variable frequency power source.

2.1 The Basic Principle of the Cycloconverter

The line-commutated cycloconverter consists of a number of phase-controlled converter circuits connected to a poly-phase AC supply system that provides the voltages necessary for natural

commutation. The individual circuits are controlled so that a low-frequency output voltage waveform is fabricated from segments of the polyphase input voltages.

2.2 Single-Phase Input to Single-Phase Output Cycloconverter

A single-phase input to single-phase output cycloconverter is shown in Fig 3, the simplest cycloconverter circuit. The secondary transformer of the power supply for the cycloconverter consists of two separate windings, which can provide 180° displaced input voltages to each of the two thyristor half bridges. As there are two controlled timing pulses for each thyristor half bridge, this topology is referred as a 2-pulse (or 4-pulse in circulating current mode) cycloconverter.

The cycloconverter is connected as shown in Figure 3, which is operating without circulating current; the non-conducting thyristors should always be kept off otherwise the input power supply could be shorted via the positive and negative thyristor half bridges. When the load current is positive, the output voltage is only controlled by phase control of thyristors T1 and T3 whilst the other two negative thyristors T2 and T4 are kept off and vice versa when the load current is negative. When the load current changes direction whilst ensuring that the two thyristor half bridges do not conduct at the same time.

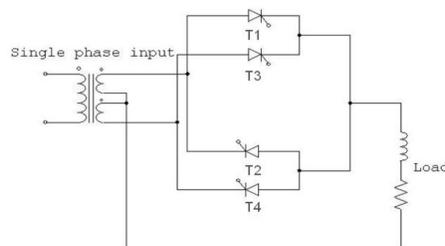


Figure 3. Single-phase input cycloconverter

If the cycloconverter is operating in circulating current mode, both thyristor half bridges are continuously conducting, eliminating the output voltage distortion during load current zero crossing but additional coupled reactors are required between the two thyristor half bridges to limit the circulating current. Although the output voltage of the cycloconverter can be improved in circulating current mode, the circulating current reactor tends to be bulky and more expensive and the presence of the circulating current will degrade the input power factor.

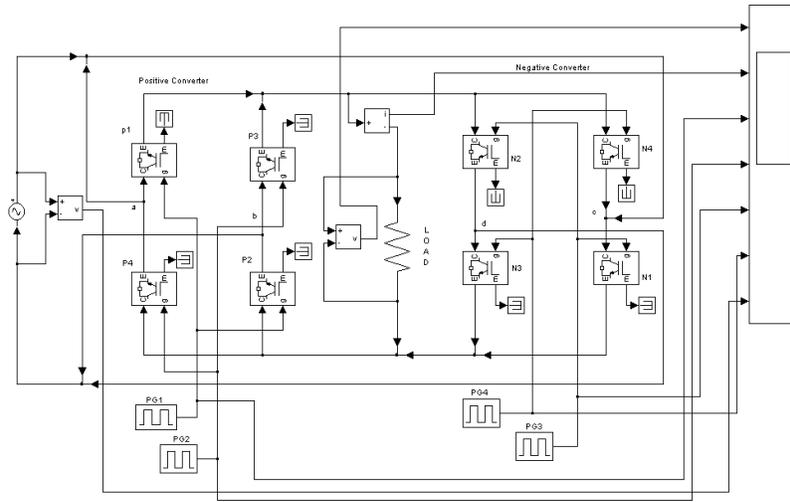
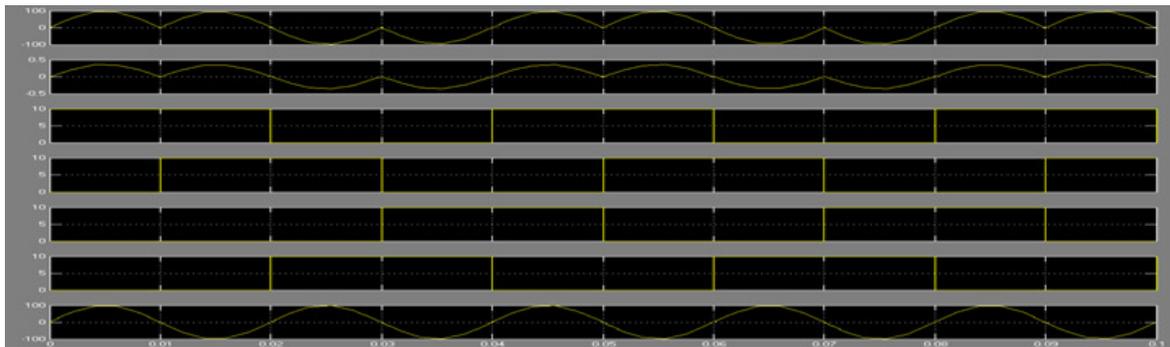
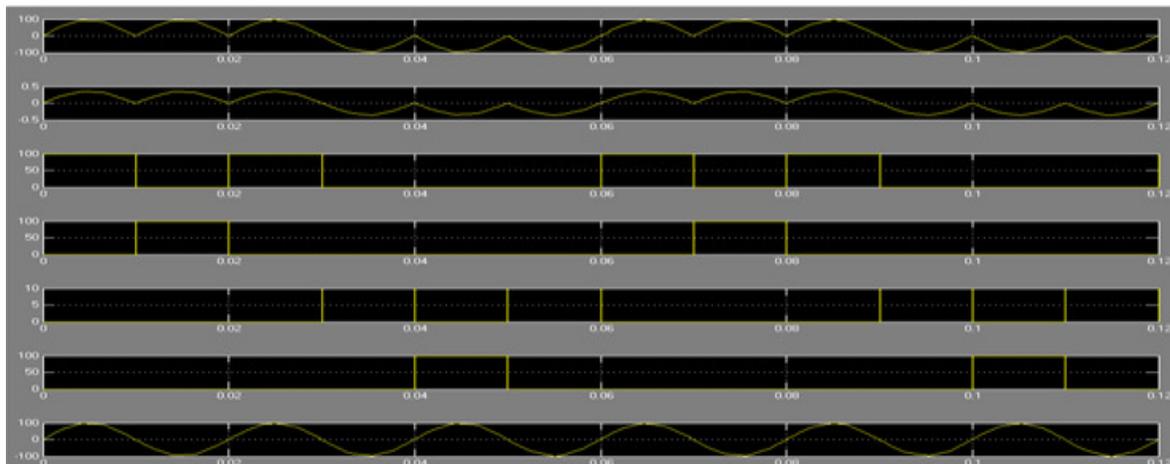


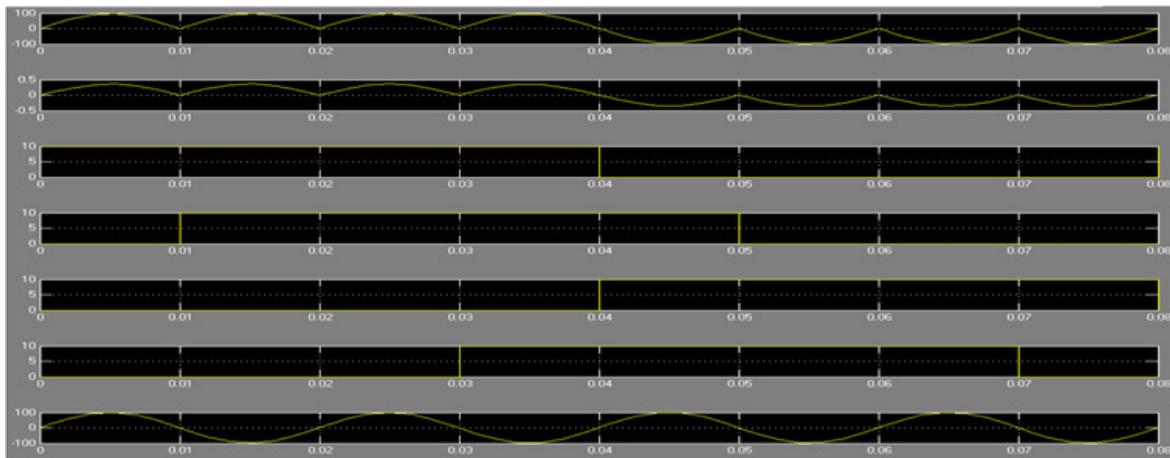
Figure 4. Single phase to single phase cycloconverter



Waveform shows the input frequency is 2 times the output frequency.



Waveform shows the input frequency is 3 times the output frequency.



Waveform shows the input frequency is 4 times the output frequency

From the above discussion and from the waveform shown in fig following point may be noted.

1. The average output voltage waveform is far from sinusoidal since the firing angle is held constant.
2. The current waveform not repeated after every cycle.
3. Some circulating current is allowed to flow from the positive converter to the negative converter. In this case a circulating current limit in reactor is connected between the positive and negative converter.
4. In order to obtain reasonably good sinusoidal or square output voltage waveform using line commutated two quadrant converter and eliminating the possibility of short circuit of the supply voltage, the output frequency is limited to a value much lower than supply frequency.

2.3 Three phase to single phase cycloconverter

The principle of the three-phase input cycloconverter is identical to that of the single phase input cycloconverter except that there are three input voltages which have 120° shift between each other instead of 180° . From the point of view of reducing the output voltage and current harmonics to a minimum level, the number of pulses of the cycloconverter should be as large as possible. But this is also achieved by increasing the complexity of the circuit, which requires a relatively large number of thyristors in the circuit.

The cycloconverter circuits using converter groups of three and six pulses are shown in figure 4 and 5. The cycloconverter circuit of figure 4 shows the single phase output from the three phase supply source. In order to drive the three phase output, three such circuits are connected as shown in fig 5. It is desirable to connect the load neutral to the supply neutral when loads are unbalanced, otherwise load neutral can be left isolated. If the input voltage is of appropriate magnitude each converter group can be supplied directly from the supply source without necessary of supply transformer. If the load is to be connected to form common terminal than input supply for each converter group must be obtained from an independent source.

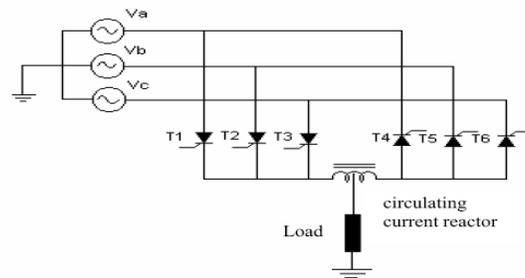


Figure 5. 3-pulse 3-phase to 1- phase dual converter

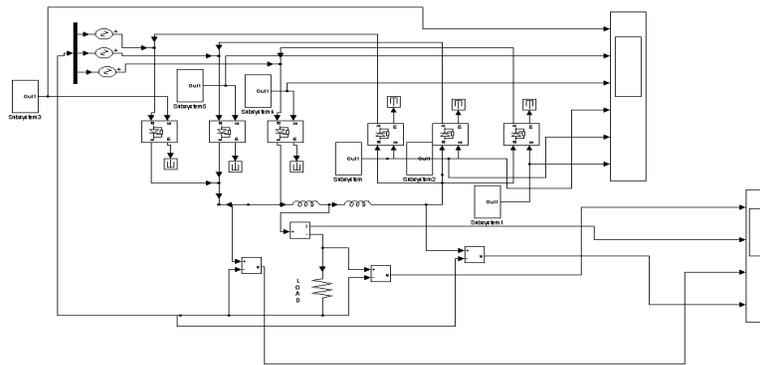
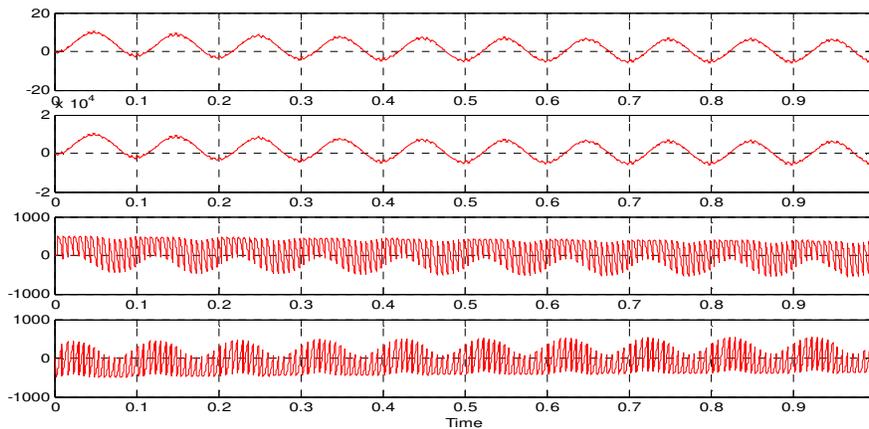


Figure 6.



Waveform of 3- phase to 1- phase

2.4 Three-Phase Input to Three-Phase Output Cycloconverter

Three identical three-phase input to single-phase output, 3-pulse (or 6-pulse in circulating current mode) cycloconverters connected together to supply a three-phase load. For a balanced three-phase output, theoretically, there is no need to connect the load neutral to the supply neutral and therefore it is not possible to have zero-sequence current components in the input lines. Another advantage of

three-phase output circuits with a floating neutral point or even without a neutral point such as the delta connection is that it provides a better harmonic content in the output line-to-line voltage due to the cancellation of the common mode voltage harmonics between the outputs.

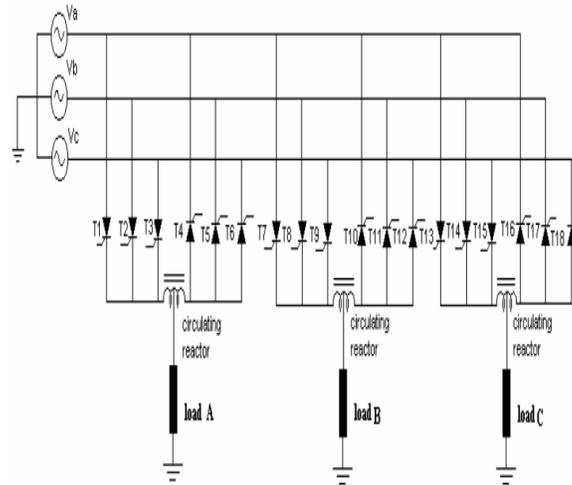


Figure 7. 3-phase to 3-phase cycloconverter

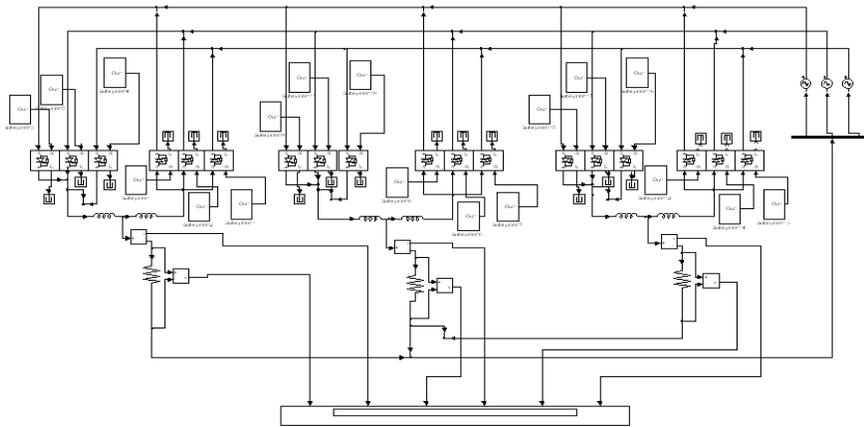
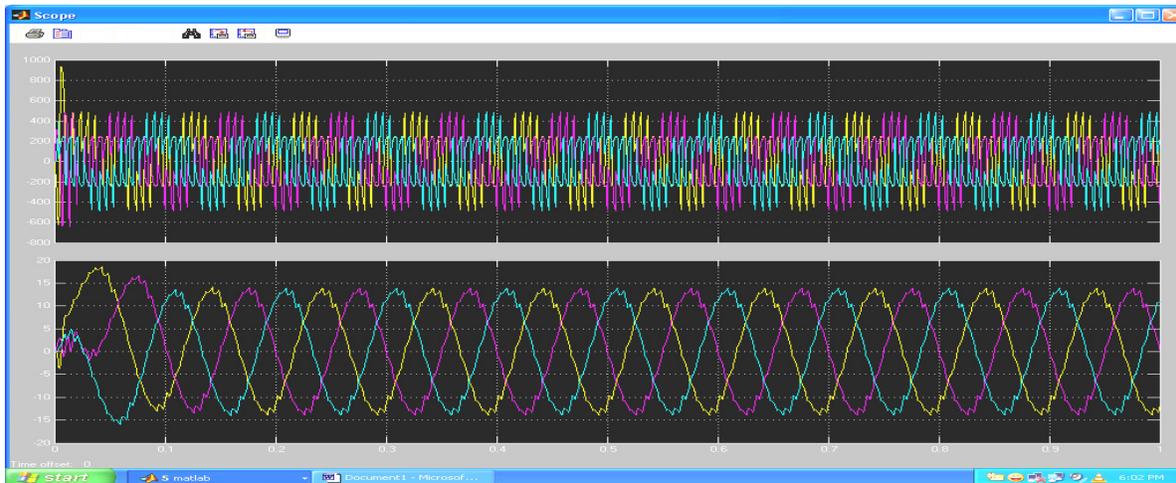


Figure 8.



Waveform of 3-phase to 3-phase

3. APPLICATION OF CYCLOCONVERTER IN INDUCTION MOTOR

A 3- phase induction motor has been connected as a load unit at the output terminals of the cycloconverter. The MATLAB SIMULINK model for the complete system has been constructed to test the efficiency and reliability of the continuous controlling of the system on the motor speed and characteristics. With the use of cycloconverter and with its power electronic circuit it is possible to deign power supply to induction motor to generate supply torque matching with demand torque.

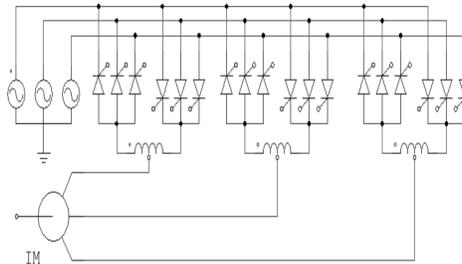


Figure 9. 3-phase to 3-phase cycloconverter with induction motor

Fig 9 shows the cycloconverter based induction motor drive. This is new technique in which with the help of MATLAB simulation software. It is possible to simulate cycloconverter circuit to get desired frequency and to operate cycloconverter circuit to derive an induction motor to generate the supply torque matching with demand torque characteristics of the machine replacing flywheel.

A control scheme is designed and simulated to control the operation of cycloconverter that Generates different frequencies in each specified Interval to drive three phase induction motor of variable frequency at variable supply voltage that generates the supply torque characteristics matching of demand torque characteristics of specific machine.

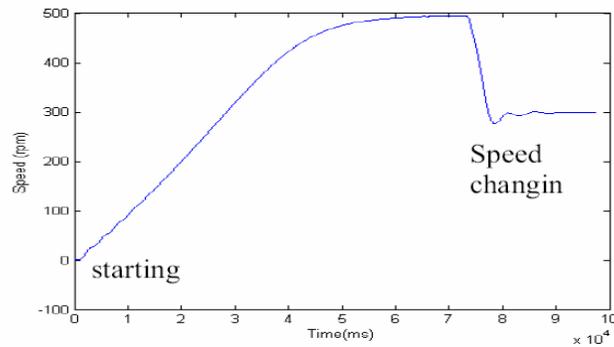


Figure 10. Motor speed due to starting and then changing the output frequency

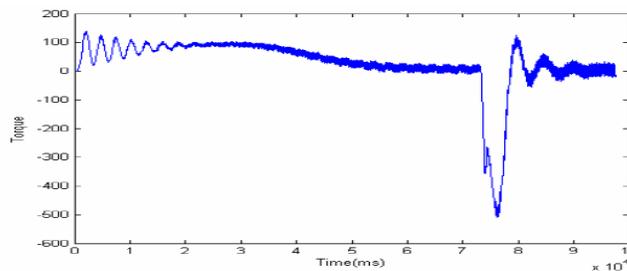


Figure 11. Motor torque during changing the output frequency

Fig. 10 illustrates the starting of the motor then change which takes place in motor speed due to changing the output frequency of the cycloconverter from (16.667)Hz to (10)Hz, and fig. 11 represents the motor torque.

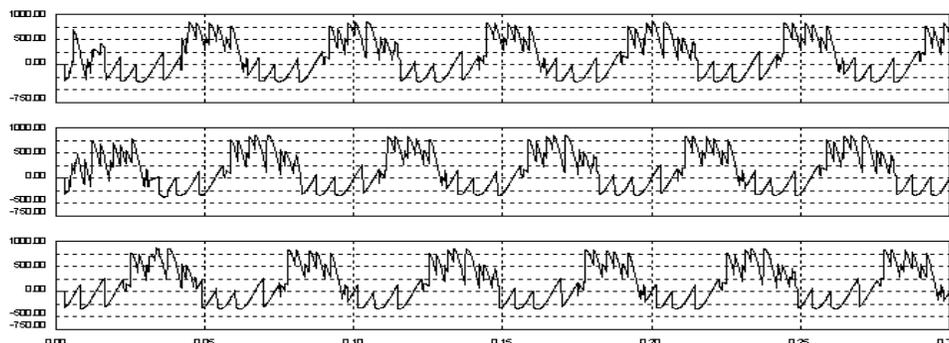


Figure 12. Three phase voltage of induction motor running with 20 Hz frequency

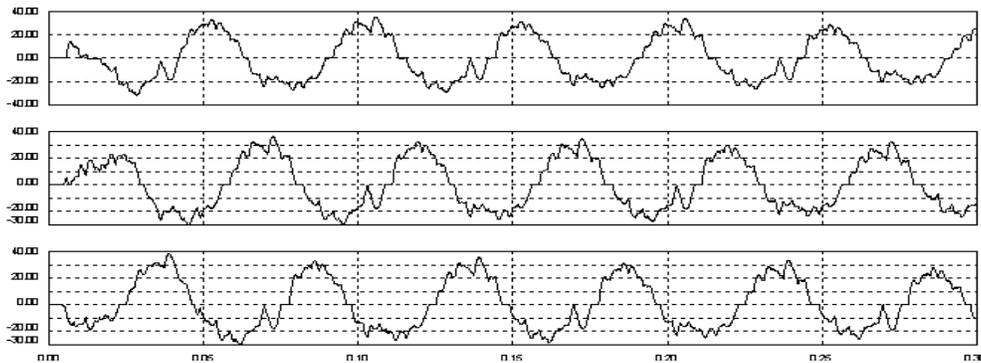


Figure 13. Three phase current of induction motor running with 20 Hz frequency

Some of the basic simulation result of three phase cycloconverter of frequency 20 Hz and given to three phase induction motor figure 12 shows the three phase voltage of induction motor running with 20 Hz frequency figure 13 shows the three phase current of induction motor running with 20 Hz frequency.

4. CONCLUSION

The cycloconverter circuits are designed and simulated and desired results are obtained. Three phase cycloconverter used for three phase 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. A method is proposed in which matlab/simulink, a widely accepted simulation and analysis tool, is used to model the complete cycloconverter drive system. This contribution will report on the results obtained using matlab for three phase cycloconverter coupled to an induction motor.

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