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Speed Control of Electromagnetic Controlled Single Phase Asynchronous Motor Using Cyclo Converter

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Abstract- It is possible to increase the efficiency of an asynchronous motor's speed by managing the functioning of a cyclo-converter, which sequentially regulates the quality characteristics of a single phase (split phase) asynchronously motor. Changing the number of poles on a single phase asynchronous motor is an approach of adjusting speed, while the other is to change the frequency. First approach is not cost-effective; nevertheless, because the number of poles cannot be altered when the system is running, the overall size of the machine also rises. In the second approach, the frequency may be varied while the motor is operating, and there is no need to modify the size of the motor. This approach makes use of a frequency altering gadget to function as a step down cyclo-converter. By adjusting the firing orientations of the cyclo-converter, it is feasible to manage the amplitude and frequency of the output voltage. In situations when the frequency response is low, the amount of distortion is quite low. The cyclo-converter eliminates the necessity for a flywheel in that machine. This work explains how speed of asynchronous motor is varied in three steps f/2, f/3, and f/4 using MATLAB/ Simulink.

Keywords- Asynchronous motor, Split phase motor, Step down Cycloconverter, MATLAB, Simulink.

I. INTRODUCTION

To control the electro - magnetic torque of motor and the rotor speed, a split phase (single phase) asynchronous machine is associated with a single phase thyristor governed cyclo-converter. The self-starting capability of single-phase motors is not present; however, the self-starting capability of split-phase motors is present [1, 2].

Split-phase motors are yet another single - celled organism motor that is frequently encountered in the real world. Among the many significant appliances that use a split-phase asynchronously motor or induction motor are air conditioners, clothes dryers, household appliances, and pumping systems, to name a few examples [3,4]. Turbocharged generators are also widely employed in the manufacturing industry. The primary winding and the starter winding of the split phase asynchronous motor are both wound twice [5].

The beginning winding, also known as the auxiliary winding or the running winding, is a type of winding that is solely utilised for the purpose of starting the motor. The primary winding has features that are low in resistance yet strong in reactive capacity. The resistance of the beginning winding is large, yet the reactance is minimal. The primary problem of the split phase asynchronous motor is that it is difficult to alter the speed of the motor using a cost-effective technology, which is the fundamental limitation of the motor.

When the electromagnetic torque of a motor is regulated, the motor speed is spontaneously maintained at a constant value, and the nature of the torque, speed, and voltage are all interdependent with the variable load applied to the motor. The frequency may be varied while the motor is operating, and there is no need to modify the size of the motor. The term "Cyclo-converter" refers to a frequency altering device that is employed in this procedure.

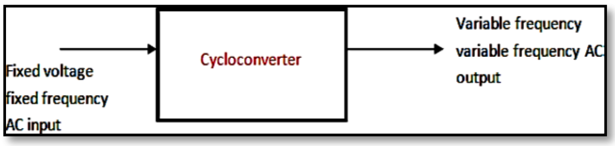

Fig 1. Basic schematic of cyclo-converter.

Cyclo-converters are utilized to convert energy (megawatts). By varying the firing angles of the cyclo-converters and the depth of modulation technique of the firing angles of the converters, the output voltage may be controlled for amplitude and frequency. The output voltage of cyclo-converter is regulated by the time of the firing pulses, which results in an intermittent output voltage. In the figure 2, each bridge comprises four transformers, and each bridge is connected in the opposite direction (back to back), allowing for the generation of both favourable and unfavourable voltage [6].

The positive converter (bridge-1) is activated when the input voltage is in the positive half cycle, and it is responsible for supplying the load current. Positive bridge is activated during the half of the input commutation period and sends current to the load during this period. Both converters should not present at the same time, since this might result in a short circuit at the input.

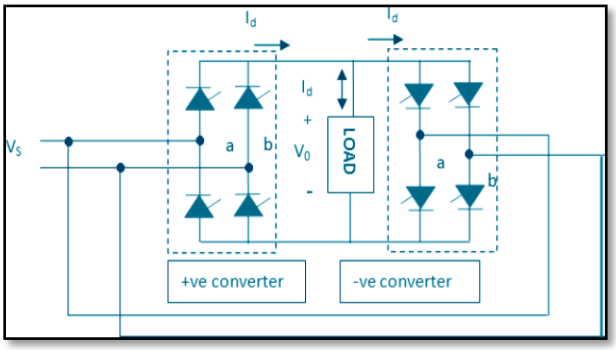

Fig 2. Single phase to Single phase Cyclo-converter.

Types of cyclo-converter are blocking mode and circulating current cyclo-converter. Mainly two types according to the output frequency are step-up and step-down cyclo-converter [7].

A cyclo-converter has the capability of providing continuous and autonomous management over both the frequency and voltage of its output. The cyclo-converter is used to alter the frequency of the supply to the single phase asynchronous motor, allowing it to run at a variety of speeds. The firing pulses of the cyclo-converter are what regulate its operation.

II. REVIEW OF LITRATURE

Asynchronous (split phase) motor are type of motor is well suited for operations where a modest starting torque is required and when beginning times are uncommon, such as the following: (a) fans (b) oil burners (c) small machine tools (d) washing machines, and so on. In order for rotors currents to also be induced, the physical speed of the rotor must be less than the speed of the rotating magnetic field of the stator; otherwise, the magnetic flux would not have been changing relatively to the armature conductors and also no currents would be created [8]. Whenever the frequency of the rotor is reduced to less than its synchronous speed, the centrifugal acceleration of the magnetic flux in the rotor accelerates, causing more current to flow through the windings and more torque to be generated. Slip is defined as the relationship between the rotational velocity of the magnetic flux induced in the rotor and the rotation rate of the rotating field generated by the stator [9].

For conventional torque curve induction motors, the discrepancy between the actual and synchronous speed ranges from around 0.5 percent to 5.0 percent of the maximum speed [10]. One of the most distinguishing characteristics of an induction motor is that it is entirely powered by induction rather than being individually stimulated as in synchronous or direct current machines or even being consciously as in permanent magnet motors [11]. When the capacitor-run designs are in operation, the second winding remains active, resulting in increased torque. A resistance start design incorporates a starter that is connected in series with the startup winding, resulting in reactance [12]. Winded rotor motors with slip rings connected to external resistances enable for the modification of the speed-torque characteristics for the purposes of acceleration control and speed control [13].

Self-starting poly-phase induction motors generate torque even when they are not in operation. Induction generator engine starting approaches include direct on-line starting, diminished reactor or auto-transformer beginning, and star-delta starting. New solid-state soft assembly and variable frequency drives are also available, as is the use of a variable frequency drive (VFDs) [14]. The maximum power of induction machines changes with load, often ranging from roughly 0.85 or 0.90 at peak charge to as low as

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around 0.20 at no load[15], owing to leakage between the stator and rotor and magnetizing reactance between the stator and rotor.

In full load operation, efficiency of motor ranges from around 85 percent to 97 percent, with the resulting engine inefficiencies being generally divided as follows: 5–15% friction and windage, 15–25% iron or core losses, 25–40% stator losses, 15–25% rotor losses, and 10–20% stray load losses [16]. These motors are easy to maintain due to their simple structure, reliability, higher efficiency, and lower cost. The distinction of these has led to its global increase in sales of up to 85% in electrical motors [17]. Split-Phase Motors are among the most affordable types of motors. They are generally available in capacities ranging from 1/20 to 3/4 horse power, and they are most typically employed on easy-starting loads rated at 1/3 horse power or less. They are also available in a broad range of synchronous speeds [18].

It is possible to convert high - voltage power (AC) electricity place at a single frequencies towards alternating current (AC) electricity at a variable but lower frequency using a cyclo-converter, which does not require the use of a direct current (DC) stage in the middle between. When it comes to extremely large changeable speed drives, cyclo-converters are employed [19].

It has gained the concern of the researchers as well as academics for performing as a variable speed controller in the rolling steel mill, cement industry applications, ship propellers, and SAG mill because of its less cost and less complexity [20]. The total harmonic distortion (THD) of the output voltage becomes very less when the output frequency is reduced [21].

III. METHODOLOGY

Split Phase induction motor simulation was performed using a single phase cyclo-converter as the load for the motor simulation.

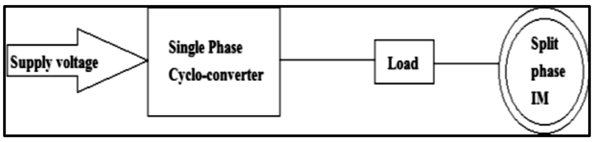
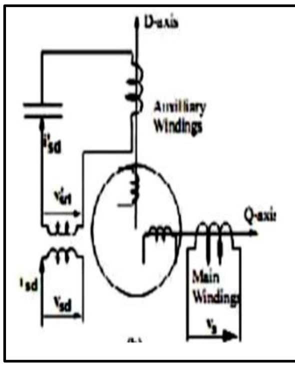


Fig 3. Schematic of Cyclo-converter Connected with asynchronous (Spilt Phase) Motor.

The simulation of the motor is provided in the stationary d-q frame in order to make the deployment of the inverter more convenient to understand and use. Because the axes of the primary and auxiliary windings are already orthogonal, the stationary d-q axes are selected such that they are aligned with the orthogonal axes of the physical windings.

$\Psi s\alpha$,$\Psi s\beta \Psi r\alpha$,$\Psi r\beta$ 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, $Ls\alpha$,$Ls\beta$,$Lr\alpha$,$Lr\beta$ are the stator & rotor inductance, and $Lm\alpha$, $Lm\beta$ are the magnetizing inductances,

ωr = Rotor speed, Electric radian/sec , Te is developed torque, TL is load torque , J is rotor moment of inertia.



$$i_{s\alpha} = \frac{L_{r\alpha}\Psi_{s\alpha} - L_{m\alpha}\Psi_{r\alpha}}{L_{s\alpha}L_{r\alpha} - L^2_{m\alpha}} \quad (1)$$

$$i_{s\beta} = \frac{L_{r\beta}\Psi_{s\beta} - L_{m\beta}\Psi_{r\beta}}{L_{s\beta}L_{r\beta} - L^2_{m\beta}} \quad (2)$$

$$i_{r\alpha} = \frac{L_{s\alpha}\Psi_{r\alpha} - L_{m\alpha}\Psi_{s\alpha}}{L_{s\alpha}L_{r\alpha} - L^2_{m\alpha}} \quad (3)$$

$$i_{r\beta} = \frac{L_{s\beta}\Psi_{r\beta} - L_{m\beta}\Psi_{s\beta}}{L_{s\beta}L_{r\beta} - L^2_{m\beta}} \quad (4)$$

The equations of motion are given by

$$T_e = p_p(L_{m\beta}\, i_{s\beta,} i_{r\alpha} - L_{m\alpha} i_{s\alpha} i_{r\beta}) \quad (5)$$

$$J\frac{d\omega_r}{dt} = T_e - T_L \quad (6)$$

Fig 5. D-Q transformation of the asynchronous motor.

1. Single Phase To Single Phase Cyclo-Converter Matlab Model:

In the figure 6, each bridge comprises four thyristor, and each bridge is connected in the opposite direction (back to back), allowing for the generation of both favorable and unfavorable voltage. Both of these bridges are powered by alternating current sources operating at 50 Hz in single phase.

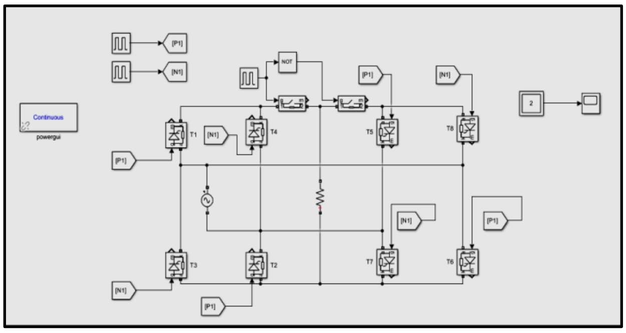


Fig 6. MATLAB model of single phase to single phase stepdown cycloconver for load R=10Ω

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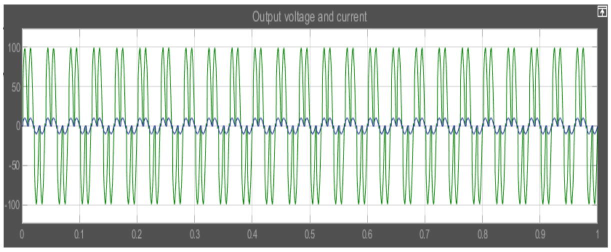

Fig 7. Waveform of output voltage and current when input frequency is 2 times the output frequency.

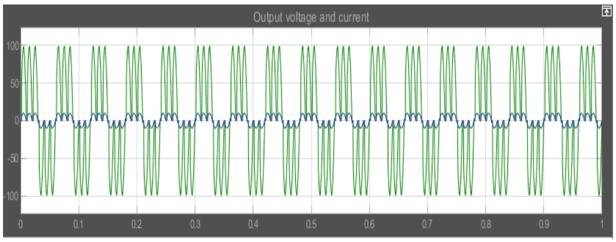

Fig 8. Waveform of output voltage and current when input frequency is 3 times the output frequency.

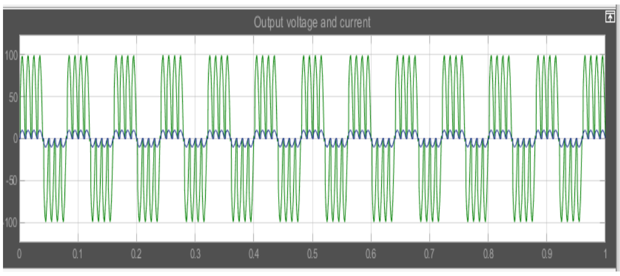

Fig 9. Waveform of output voltage and current when input frequency is 4 times the output frequency.

Split Phase induction motor simulation was performed using a single phase cyclo-converter as the load for the motor simulation. Air conditioning units and clothes dryers, as well as washers and dryers, vacuum cleaners, and water pumps, are all examples of important appliances that employ a split-phase asynchronously motor or induction motor. These motors are also extensively used in industries.

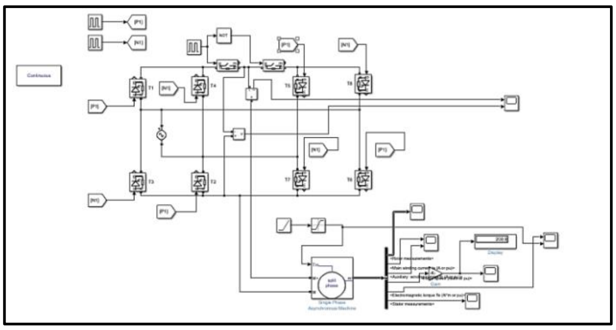

Fig 10. Split phase asynchronous motor connected with load of the Single phase to Single phase step down cyclo-converter.

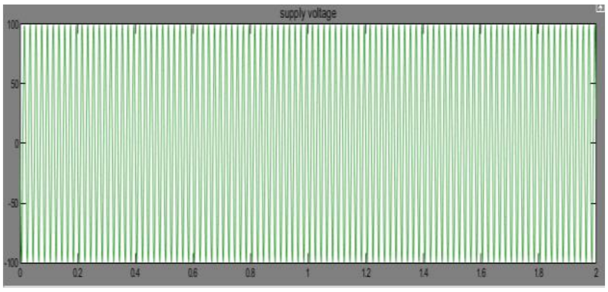

Fig 11. Waveform of supply voltage.

The waveform of the supply voltage for the single component to single phase cyclo-converter is seen in the figure 11. In the figure 12, 13, and 14, the waveforms were showed the output voltage and current when the input frequency is double, third, and fourth the output frequency, respectively.

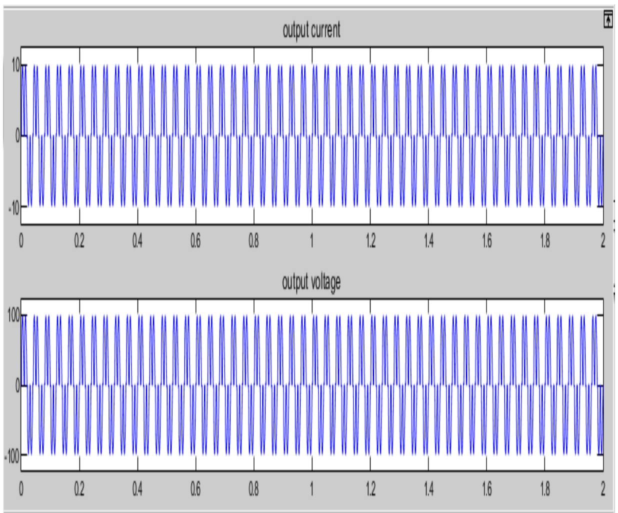

Fig 12. Waveform of output voltage & current, when input frequency is 2 times the output frequency.

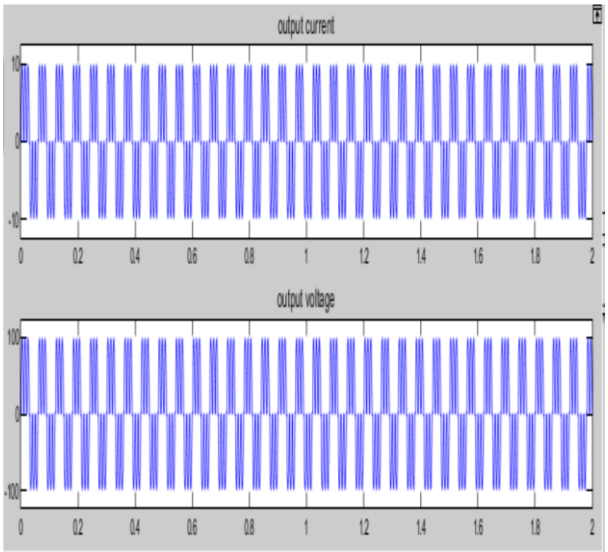

Fig 13. Waveform of output voltage & current, when input frequency is 3 times the output frequency.

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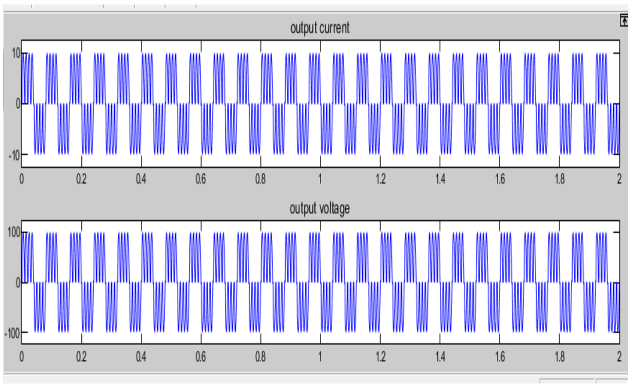

Fig 14. Waveform of output voltage & current, when input frequency is 4 times the output frequency.

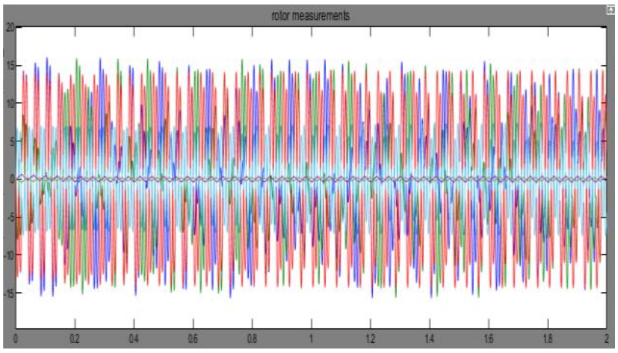

Fig 15. Waveform of Rotor measurements of the motor, when input frequency is 2 times the output frequency.

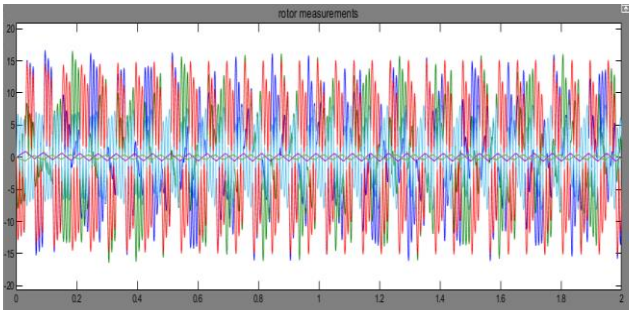

Fig 16. Waveform of Rotor measurements of the motor, when input frequency is 3 times the output frequency.

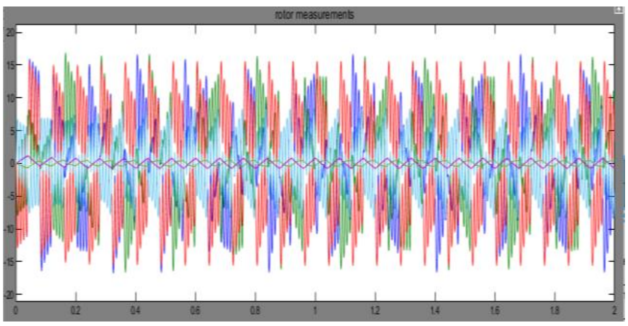

Fig 17 Waveform of Rotor measurements of the motor, when input frequency is 4 times the output frequency.

When input frequency is 1/2, 1/3 and 1/4 of the output frequency, then the rotor speed is controlled with control in electromagnetic torque.

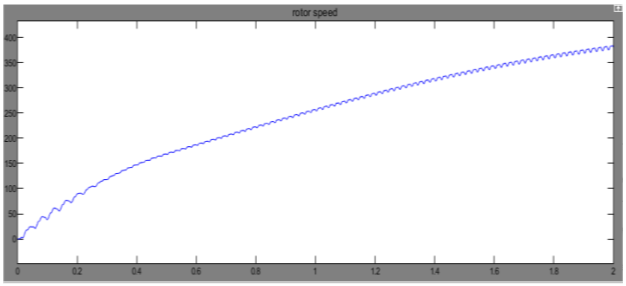

Fig 18. Waveform of Rotor speed of the motor, when input frequency is 2 times the output frequency.

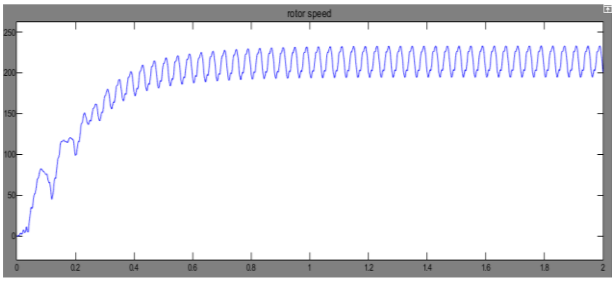

Fig 19. Waveform of Rotor speed of the motor, when input frequency is 3 times the output frequency.

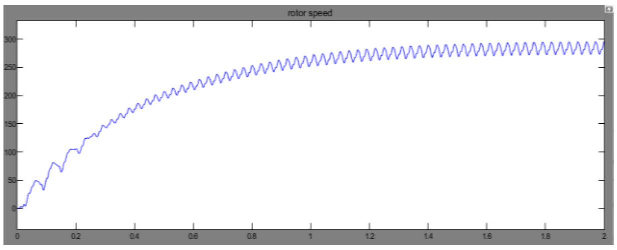

Fig 20. Waveform of Rotor speed of the motor, when input frequency is 4 times the output frequency.

Table 1. Frequency vs. Speed.

S.No.	Frequency	Actual Frequency(Hz)	Speed of rotor(rpm)
1.	f/2	25	201
2.	f/3	16.67	296
3.	f/4	12.5	381

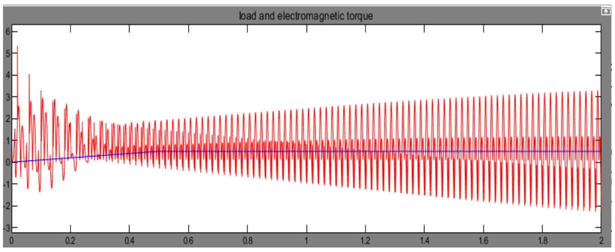

Fig 21. Waveform of load and electromagnetic torque of the motor, when input frequency is 2 times the output frequency.

IV. CONCLUSION

By employing a cyclo- converter as a Variable Frequency drive, it is possible to efficiently manage the speed of the motor, as well as the magnitude and phase difference of the motor's performance (VFD). The Cyclo-converter controls the speed of the motor by adjusting the frequency of the power supply. It also controls the electromagnetic torque by varying the frequency of the power supply. When you regulate the speed of the motor, the electromagnetic torque is automatically controlled as well.

When used to substitute the flywheel on an operational machine, the cyclo-converter minimizes the amount of rotational vibrations and fatigue damage that occurs to the machine. In this research work, the simulation of load and electromagnetic control of a motor at various frequencies is carried out using a cyclo-converter, and the output waveforms are obtained as a result of this simulation.

V. FUTURE DIRECTION

- It will be able to regulate the amplitude and frequency of the output voltage of the motor in the future using the cyclo-converter frequencies and depth of modulation technique of the firing degrees of the converters, as well as their firing angles.
- According to the findings of the research, a cyclo-converter may be used to substitute the flywheel of an operating machine, therefore reducing the source of rotational vibrations and fatigue damage to the machine.
- In industrial applications, it is necessary to manage the load and electromagnetic torque, as well as the speed of the motor and the voltage. There are a variety of techniques for controlling the electromechanical speed and torque of a motor, and this is the most straightforward and effective approach for controlling the rotor speed and motor speed. The nature of the motor's speed, horsepower, and voltage are all interdependent on the nature of the motor's variable load.
- Single-phase electric motor are much less expensive to make than most of the other types of motors, and these electric motor typically require minimal maintenance and don't require repairs very often. Single-phase motors are also very easily controlled by a variable frequency drive (VFD), which means that this motor will play an extremely important role in future work.
- This study effort not only delivers variable speed and torque, as well as variable voltage, but it also minimizes energy usage as well as audible noise emissions. As a result of this research, energy savings in the motor are realized.
- This single phase cyclo-converter also be scaled up for three phase cyclo-converter to control the speed of three phase asynchronous motor or different motors.

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