

A Survey on Single Phase to Three Phase Cyclo-Converter Fed Induction Motor

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Abstract— In various application of electrical energy especially in industrial areas there are two type of current, Direct Current and Alternating Current are used. Generally fixed voltage, constant frequency Single-Phase or Three-Phase AC is easily available, yet for different applications various types of magnitudes and/or frequencies are essential. This paper presents a survey on 1- ϕ to 3- ϕ cycloconverter technique using thyristor with 3- ϕ induction motor along load frequency analysis. The cycloconverter is inspected in its utmost straight forward form without further output filters or elaborate control technique.

Key words: Cycloconverter, Thyristor, Single-Phase to Three-Phase conversion, Frequency

I. INTRODUCTION

Power electronics devices have wide applications in electrical power system. Noteworthy improvements have taken place in control, analysis, modeling and practical implementation aspects of cycloconverter and their applications to the flexible-speed ac drives. This paper is the survey of applications of cycloconverter fed induction motors to electrical energy system. Frequency changers are an extending field of power conversion innovation. The increasing usage of ac motors in the production of electrical power from variable speed sources are illustrations of this area application. Currently systems of frequency changers incorporated rotating machines. These systems have been to a great extent supplanted by static frequency changers utilizing power semiconductor devices. VSI (voltage source inverter) fed drives are most widely used in low and medium power applications, but not used widely in high power applications. CSI (current source inverter) fed drives are widely used for medium voltages high power application.

Another power electronic device called cycloconverter is utilized as a part of high power application for driving induction motor and synchronous motors. They are usually phase-controlled and traditionally utilize thyristors because of their simplicity of phase commutation. The fundamental guideline of this converter, conceived and patented by Hazeltine in 1926, is to construct an alternating voltage wave of lower frequency from successive voltage waves of a higher frequency multiphase ac supply by a switching arrangement.

II. CYCLOCONVERTER

Usually, the AC-AC converters with semiconductor switches are normally classified into indirect converter which uses a DC link between the two AC systems and direct converter that offers direct conversion. Indirect converter contains of two converter stages and energy storing element, which change input AC to DC and then reconverting DC back to output ac with variable amplitude

and frequency as presented in Fig1(a). In direct converter there is no need of DC link as shown in Fig 1(b) etc.

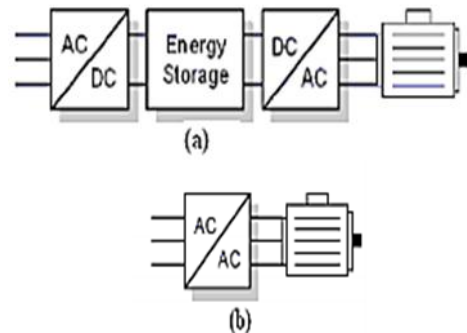


Fig. 1: AC/AC Converter (a) Indirect Converter (b) Direct Converter

Cycloconverters are the direct type converters utilized as a part of high power applications driving induction and synchronous engines. They are normally phase-controlled and they generally utilize thyristors because of their simplicity of phase compensation. The fundamental block diagram of Cycloconverter is given in Fig 2.

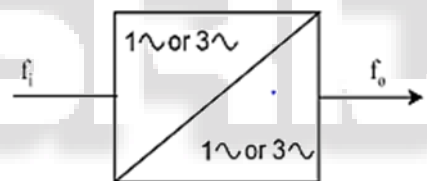


Fig. 2: Block diagram of Cycloconverter

A Cycloconverter is sort of power controller in which an exchanging voltage at supply frequency is changed specifically to an alternating voltage at load frequency with no intermediate DC stage. In a line commutated Cycloconverter, the supply frequency is more noteworthy than the load frequency. The working standards were created in the 1930s while the grid controlled mercury arc rectifier got to be accessible. The procedures were applied in Germany, where the three stage 50 Hz supply was changed over to a single phase AC supply at 16 $\frac{2}{3}$ Hz for railroad traction. In the United States, a 400 HP plan in which a synchronous motor was supplied from a Cycloconverter including 18 thyratrons was in along working for various years as a power station assistant drive. Then again, in light of the fact that these early plans were not adequately appealing technically or financially, they were discontinued. Through the timings of its firing pulses, a Cycloconverter is controlled, so it delivers a substituting (alternating) output voltage. By monitoring the frequency and depth of phase modulation of the terminating points of the converters, it is conceivable to control the frequency and amplitude of the output voltage. In this manner, a Cycloconverter has the capability for constant also autonomous control over both its output frequency and voltage. This frequency is regularly

under 1/3 of the given frequency. The nature of the output voltage wave and its symphonious distortion additionally force the restriction on this frequency. The distortion is low at low output frequencies. The Cycloconverters are typically used to give either a variable frequency from a constant input frequency or a constant frequency from a variable input frequency. A Cycloconverter can carry load of any power factor and permits power flow in both the directions. The output voltage wave shape definitely consist symphonious distortion parts additionally to the required sinusoidal component. These distortion terms are delivered as an important result of the fundamental mechanism of the Cycloconverter, whereby the output voltage is created from portions of the given voltage waves. These twists can be minimized by sufficient channels at the yield. Increments happen in the distortion of the output voltage if the proportion of the output and input frequency increments [1].

A. Applications Of Cycloconverter Are:

- used for controlling the speed of high power AC drives
- used in high frequency induction motors
- used in static VAR generators
- they are used as a power supplier in the aircrafts and space vehicles
- used in High voltage DC(HVDC) transmission for interconnecting two power grids operating at two different frequencies.

III. ADVANTAGES OF CYCLOCONVERTER

- 1) Conversion of frequency, directly without any intermediate stage.
- 2) Natural commutation – Compact system.
- 3) Transfer of Power in either direction.
- 4) Capable of reproduction over the complete speed range, down to standstill.
- 5) Commutation failure leads only to blown-off of individual fuses only.
- 6) Provides a high quality sinusoidal waveform at low output frequencies since it is created from a huge number of parts of the supply waveform. This is frequently preferable for very low speed applications.

IV. OPERATING PRINCIPLE OF CYCLOCONVERTER

A. Single-Phase To Single-Phase (1φ-1φ) Cycloconverter:

This converter comprises of consecutive association of two full-wave rectifier circuits. Fig 3 demonstrates the working waveforms for this converter with resistive load.

The input voltage v_s , is an ace voltage at a frequency, V_i as showed in Fig. 3a. All the thyristors are fired up at $\alpha=0^\circ$ firing angle, i.e. thyristors acts like diodes. Firing angle for positive converter is meant by α_p and for negative converter α_n . The frequency of V_o can be altered by shifting the number of cycles, positive and negative converters work.

Consider the working of the cycloconverter to accomplish 1/4 of the input frequency at the output. For the beginning two cycles of v_s , the positive converter acts to giving current to the load. It rectifies the input voltage; thusly, the load found four positive half cycles as found in Fig. 3b. In the subsequent two cycles, the negative converter works giving current to the load in the opposite direction.

The current waveforms are not shown in the figures due to the certainty that the resistive load current will have the similar waveform as the voltage though simply scaled by the resistance. Note that when one of the converters works the other one is impaired, so that there is no present circling between the two rectifiers.

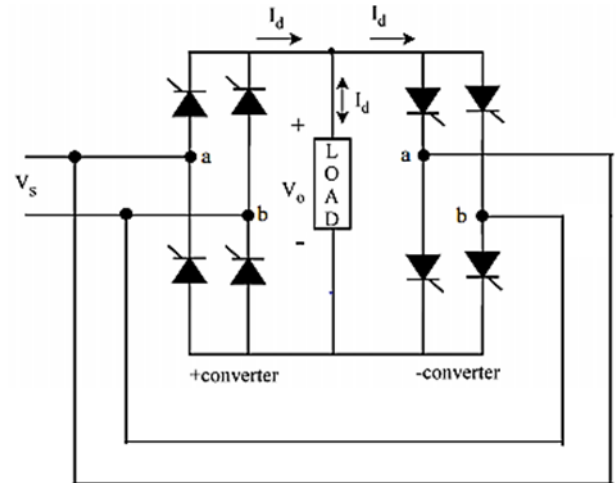


Fig. 3: (a) Cycloconverter, Single-phase to single-phase(1φ-1φ)

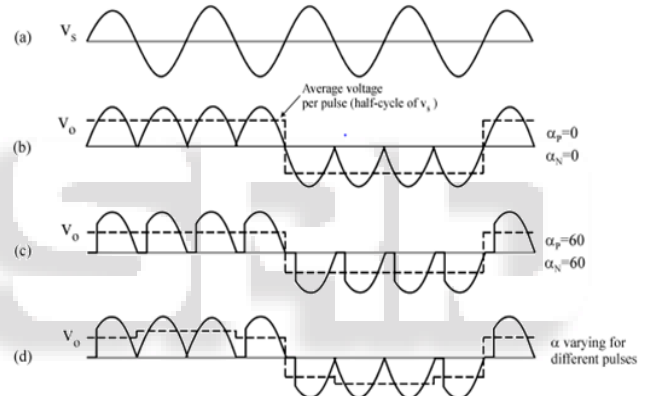


Fig. 3: shows cycloconverter waveforms of Single-phase to single-phase

- 1) Input voltage
- 2) Output voltage for zero firing angle
- 3) Output voltage with firing angle p/3 rad
- 4) Output voltage with varying firing angle

Due to the frequency of the output, V_o in fig.3b is one fourth of the input voltage, i.e. $f_o/f_i=1/4$ that's why it is step down cycloconverter. Instead of it, if the cycloconverter frequency has correlation like this $f_o/f_i>1$, it's known as step-up cycloconverters. Notify that step-down cycloconverters are further commonly used in compare step-up ones.

The frequency of v_o can be adjust by altering the figure of cycles the positive and the negative converters works. It can only change as integer multiples of f_i in 1φ-1φcycloconverters. With the above operation, the 1φ-1φcycloconverter can only supply a certain voltage at a certain firing angle α . The dc output of each rectifier is:

$$V_d = \frac{2\sqrt{2}}{\pi} V \cos\alpha \quad (1)$$

where V is the input r.m.s voltage.

The dc value per half cycle is shown as dotted in Fig. 3d. Then the peak of the fundamental output voltage is

$$V_{o1}(t) = \frac{4}{\pi} \frac{2\sqrt{2}}{\pi} V \cos\alpha \quad (2)$$

Equation 2 infers that the basic output voltage relates to α . Hence changing α , the fundamental output voltage can be controlled.

Fixed operation gives a rough output waveform with rich harmonic content. The dotted lines in Fig. 3b and c demonstrate a square wave. If the square wave can be adjusted to look more like a sine wave, the harmonics would be reduced. Hence is modulated as shown in Fig. 3d. Presently, the six-stepped dotted line is more like a sine wave with fewer harmonics. The more pulses there are with different α 's, the less are the harmonics.

B. Three-Phase to Single-Phase (3 ϕ -1 ϕ) Cycloconverter:

There are two types of three-phase to single-phase (3 ϕ -1 ϕ) cycloconverters: 3 ϕ -1 ϕ half-wave cycloconverter (Fig. 4) and 3 ϕ -1 ϕ bridge cycloconverter (Fig. 5). Like the 1 ϕ -1 ϕ converter case, the 3 ϕ -1 ϕ cycloconverter applies rectified voltage to the load. Both of them, positive and negative converters can generate voltages at either polarity, however positive converter can only supply positive current and the negative converter can only supply negative current. Accordingly, the cycloconverter can operate in four quadrants: (+v, +i) and (-v, -i) rectification modes and (+v, -i) and (-v, +i) inversion modes. The modulation of the output voltage and the basic output voltage are shown in Fig. 6. It seems that α is sinusoidally modulated over the cycle to generate a harmonically idyllic output voltage.

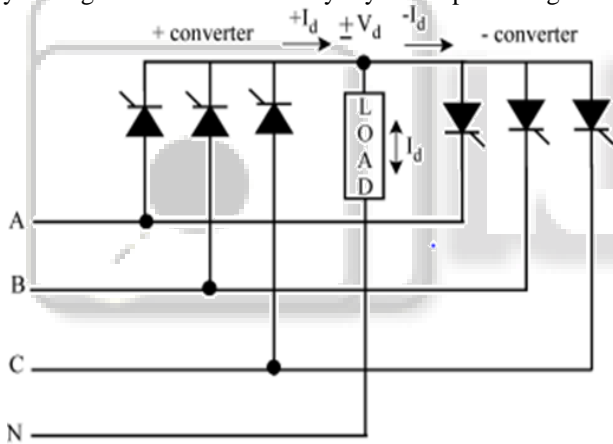


Fig. 4: 3 ϕ -1 ϕ Half-Wave Cycloconverter

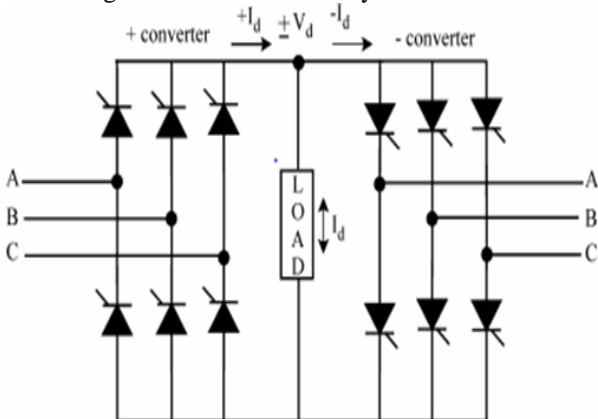


Fig. 5: 3 ϕ -1 ϕ Bridge Cycloconverter

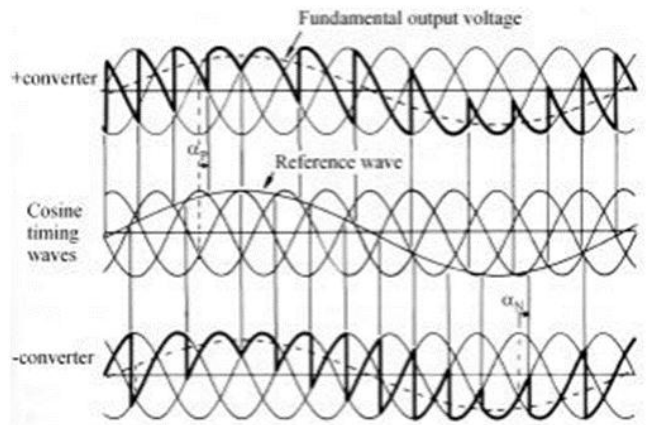


Fig. 6: 3 ϕ -1 ϕ Half-Wave Cycloconverter Waveforms A) + Converter Output Voltage B) Cosine Timing Waves C) - Converter Output Voltage

The extremity of the current defines whether the positive or negative converter should be supplying power to the load. Customarily, the firing angle for the positive converter is named α_p , and that of the negative converter is named α_n . At the point when the polarity of the current changes, the converter beforehand providing the current is disabled and the other one is enabled. The load continuously needs the essential voltage to be continuous. Subsequently, during the current polarity reversal, the average voltage provided by both of the converters ought to be equal. Else, switching from one converter to the next one would cause an undesirable voltage jump. To avoid this problem, the converters are forced to generate the same average voltage at all times. Accordingly, the accompanying condition for the firing angles ought to be met

$$\alpha_p + \alpha_n = \pi \quad \dots\dots (1)$$

The fundamental output voltage in Fig. 6 can be given as:

$$V_{o_1}(t) = \sqrt{2}V_o \sin \omega_o t \quad \dots\dots (2)$$

Where V_o is the rms value of the fundamental voltage

At a time to the output fundamental voltage is

$$v_{o_1}(t_o) = \sqrt{2}V_o \sin \omega_o t_o \quad \dots\dots (3)$$

The positive converter can supply this voltage if α_p satisfies the following condition.

$$V_{d_o} = \sqrt{2}V_o \frac{p}{\pi} \sin \frac{\pi}{p}$$

Where ($p=3$ for half wave converter and 6 for bridge converter)

From the a condition (3)

$$V_{o_1} = V_{d_o} \cos \alpha_p = -V_{d_o} \sin \alpha_n$$

The firing angles at any instant can be found from eq. The operation of the 3 ϕ -1 ϕ bridge cycloconverter is similar to the above 3 ϕ -1 ϕ half-wave cycloconverter. Note that the pulse number for this case is 6.

C. Three-Phase to Three-Phase (3 ϕ -3 ϕ) Cycloconverter:

In the occurrence that the outputs of 3- ϕ to 1- ϕ converters of the same type are associated in wye or delta and if the output voltages are $2\pi/3$ radians phase moved from each other, the subsequent converter is a three phase to three-phase (3 ϕ -3 ϕ) cycloconverter. The subsequent cycloconverter are appeared in Figs. 7 and 8 with wye connections. If the three converters associated are half-wave converters, then it's known as a 3 ϕ -3 ϕ half-wave cycloconverter. If instead, bridge converters are utilized,

then the result is a 3 ϕ -3 ϕ bridge cycloconverter. 3 ϕ -3 ϕ half-wave cycloconverter is also known as 3-pulse cycloconverter or an 18-thyristor cycloconverter. Then again, the 3 ϕ -3 ϕ bridge cycloconverter is likewise called a 6-pulse cycloconverter or a 36-thyristor cycloconverter. The operation of each phase is clarified in the previous segment.

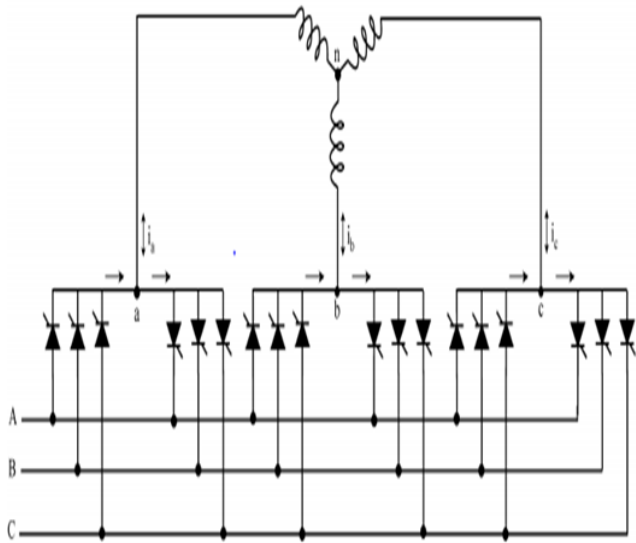


Fig. 7: 3 ϕ -3 ϕ Half-Wave Cycloconverter

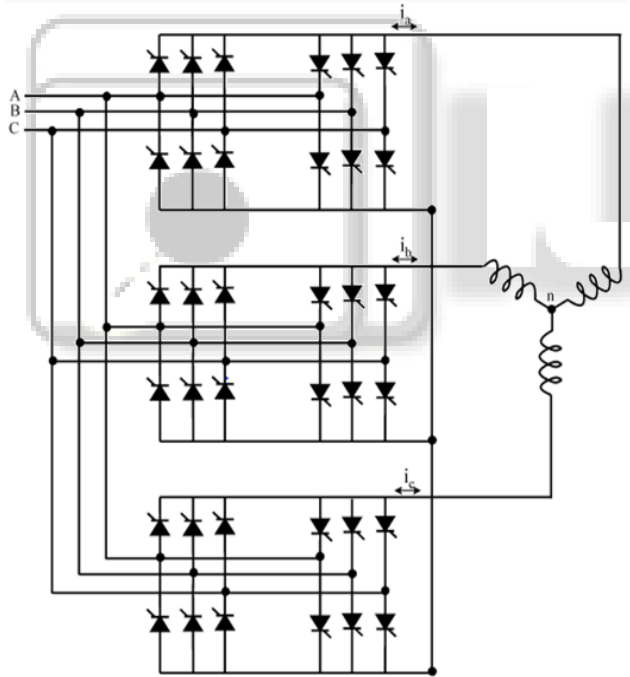


Fig. 8: 3 ϕ -3 ϕ Bridge Cycloconverter

The three-phase cycloconverter are in a general sense utilized in ac machine drive systems running three phase synchronous and induction machines. They are more beneficial when utilized with a synchronous machine due to their output power factor features. A cycloconverter can provides lagging, leading, or unity power factor loads while its input is frequently lagging. A synchronous machine can figure out any power factor current from the converter. This typical operation matches the cycloconverter to the synchronous machine. Then again induction machines can only figure out lagging current, so the cycloconverter does not have an edge paralleled with alternate converters in this facet for running an induction machine. Then again,

cycloconverter are utilized as a part of Scherbius drives for speed control purposes driving wound rotor induction motors.

D. Single-Phase to Three-Phase (1 ϕ -3 ϕ) Cycloconverters:

In recent times, with the drop in the size and the cost of power electronics switches, single-phase to three-phase cycloconverters (1 ϕ -3 ϕ) initiating more research attention. Generally, an H-bridge inverter generates a high frequency single-phase voltage waveform, which is fed to the cycloconverter either through a high frequency transformer or not. If a transformer is used, it isolates the inverter from the cycloconverter. In further, additional taps from the transformer can be utilize to power other converters generating a high frequency ac connection. The single-phase high frequency ac (hfac) voltage can be either sinusoidal or trapezoidal. There may be zero voltage intervals for control purposes or zero voltage commutation. Fig. 9 demonstrates the circuit diagram of a ordinary hfac link converter. These converters are not commercially available yet. They are in the research state

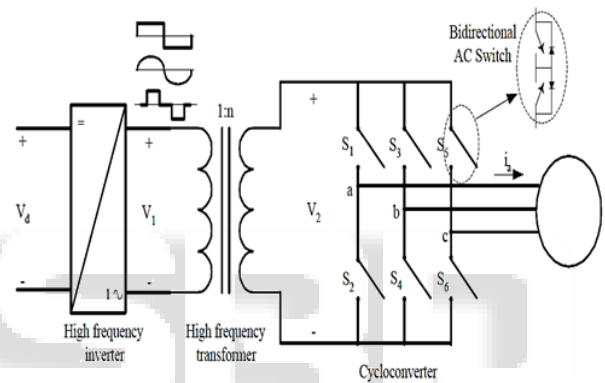


Fig. 9: High Frequency Ac Link Converter (1f Hf Inverter + (1f-3f) Cycloconverter)

Cycloconverter produce harmonic rich output voltages. When cycloconverter are used to run an ac machine, the leakage inductance of the machine filters the greater part of the higher frequency harmonics and reduces the magnitudes of the lower order harmonics labels.

V. LITERATURE REVIEW

Xiaofeng Yang [3] presented an advance single-phase to three-phase cycloconverter appropriate for driving an induction motor. By means of discrete variable frequency system, a single-phase to three-phase modulation technique is proposed the output frequency of this cycloconverter may be up to half of the input frequency. Only six commonly communicated thyristors are employed, so the subsequent cycloconverter-motor drive framework is cheap and compact. Programming in C and assembly language has been written for real-time control. The reproduction in view of Matlab /Simulink is used to foresee the presentation for the cycloconverter and induction motor toolbar

Ashwini Kadam [4] paper present is to control the speed of an induction motor by changing the frequency with three level diode clamped multilevel inverter. To get high quality sinusoidal output voltage with reduced harmonics distortion, multicarrier PWM control plan is presented for diode clamped multilevel inverter. This technique is executed through changing the supply voltage and frequency

applied to the three phase induction motor at constant ratio. The proposed system is an actual replacement for the conventional strategy which delivers high switching losses, result in poor drive performance. The simulation & implementation results reveal that the proposed circuit efficiently controls the motor speed and increases the drive presented through reduction in Total Harmonic Distortion (THD).

Ali S. Bathunya[5]] in this paper deals with writings study of several existing converter topologies, which have been displayed for adjustable speed single phase induction motor drives (SPIMD).this papers explains some converter topologies which are recently used and comparison is done. Among these, converter topologies, the adjustable frequency PWM inverter is the greatest decision for single-phase induction motor drives. Regardless, adjustable-frequency drives have not been generally utilized with single-phase induction motors. The open-circle constant V/f control law can't be utilized with the single-phase induction motor drives it is utilized with three phase motors. The variety of the working frequency at lower speed range with constant load torque sources assortment in the motor's slip. A constant V/f control is appropriate merely over the upper speed range. In any case, enhancements in the low frequency performance need to the utilization of constant power dissipation in the motor. Simulation lessons for several of the existing topologies in addition for the proposed once have been completed

G. Sudhir Kumar [6] system combines two parallel rectifiers without the use of transformers. The control system and the, system model, with the PWM method, have been developed. The whole comparison between the proposed and standard configurations has been carried out in this work. Compared to the conventional topology, the presented system permits to lessen the rectifier switch currents, the THD of the grid current and to increase the fault tolerance features.

The simulation result shows that the system is controlled suitably, with transient and event of faults.

G. R. Sreehitha [7] proposed a new topology for controlling a three-phase induction motor with single-phase supply. In this work control of Cycloconverter is done by the firing pulses. With the support of variable frequencies got the variable speeds of a three-phase induction motor. The real part of a Scott-T transformer was utilized to convert two-phase, output of two Cycloconverter to three-phase

Abhishek Pratap Singh [8] designed cycloconverter circuits and simulated and finally desired results were obtained. The single phase cycloconverter utilized for split phase motor to produce supply the torque features, whom matching with demand torque features of specific machine by the utilize of designing cycloconverter diverse desired frequency were obtained .to match the torque demand of the machine. This distinctive frequency of cycloconverter was suitable to replace fly wheel from the operating machine which reduce the reason of torsional vibration and fatigue damage of machine. Paper proposed criticism control scheme of cycloconverter fed split phase induction motor. Besides, it delivers mean for limiting the slip and hence the motor current. It implies a reduction in the cycloconverter rating and better efficiency. The results acquired using

MATLAB for single phase cycloconverter coupled induction motor.

RadhaKrishna[9] paper present a system drive through single-phase to three-phase made out of two parallel single-phase rectifiers, a three-phase inverter,an induction motor. The presented topology licenses to lessen the harmonic distortion at the input converter side, the rectifier switch currents, and displays enhancements on the fault tolerance features. Expand the number of switches, the total energy loss of the proposed system may be lower than of a conventional one. The model of the system is derived, and it is displayed that the reduction of circulating current is an essential objective in the system design. An appropriate control approach, through the pulse width modulation technique (PWM), is developed. Experimental results are presented.

Kamaljeet[10] this paper present Matlab modeling and simulation of Single phase-three phases Cycloconverter for driving three phase induction motor and analysis of torque for several frequencies. The proposed converter employs just six usual communicated thyristor, therefore the resulting Cycloconverter motor drive system was cheap and compact, though this single phase to three phase modulation procedure is proposed on the premise of variable frequency method.

VI. CONCLUSION

A cycloconverter is a device use to convert a constant voltage constant frequency AC power to variable voltage variable frequency without any intermediate DC link. In this paper presented a survey on conversion of single phase (1- ϕ) to three phase (3- ϕ) cycloconverter fed induction motor. There are several techniques use for conversion but order to have maximum converter utilization, special cycloconverter techniques have to be used. Studies of different researchers are also presented to understand the work on single to three phase cycloconverter.

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