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

Balveer Verma[1]Devendra Dohare[2]
[1]M.Tech Student [2]Assistant Professor
[1,2]DepartmentofElectricalEngineering
[1,2]MaharanaPratapCollegeofTechnologyGwalior,India

Abstract—In many uses of electrical energy, especially in industrial areas, two types of current—Direct Current and Alternating Current—are used. Usually, there is a fixed voltage and constant frequency for Single-Phase or Three-Phase AC, which is easily available. However, for different applications, various levels of voltage and/or frequency are needed. This paper presents a review of the 1-φ to 3-φ cycloconverter method using thyristors along with a 3-φ induction motor and load frequency analysis. The cycloconverter is studied in its simplest form without additional output filters or complex control methods.
I.
Key words: Cycloconverter, Thyristor, Single-Phase to Three-Phase conversion, FrequencyINTRODUCTION

I INTRODUCTION

Power electronics devices are used in many areas of the electrical power system. There have been major improvements in how these devices are controlled, analyzed, modeled, and used in real situations, especially for cycloconverters and their use in flexible-speed AC drives. This paper looks at how cycloconverters are used to power induction motors in electrical energy systems. Frequency changers are a growing area in power conversion technology. The increasing use of AC motors to generate electrical power from variable speed sources shows how important this area is. Today, frequency changer systems often use rotating machines, but most of these have been replaced by static frequency changers that use power semiconductor devices. Voltage source inverter (VSI) driven systems are commonly used in low and medium power applications, but not as much in high power situations. Current source inverter (CSI) driven systems are more common in medium voltage and high power applications. Another power electronic device called a cycloconverter is used in high power applications to drive induction and synchronous motors.

These devices are usually phase-controlled and traditionally use thyristors because they are easy to switch. The basic idea of this converter, developed and patented by Hazeltine in 1926, is to create a lower frequency alternating voltage from higher frequency multiphase AC power using a switching method.

II. CYCLOCONVERTER

Usually, AC-AC converters that use semiconductor switches are generally divided into two types: indirect converters and direct converters. Indirect converters have a DC link between the two AC systems. They consist of two converter stages and an energy storage element. These converters first turn the input AC into DC and then convert that DC back into output AC with a different voltage level. and frequency as presented in Fig1(a). In direct converter there is no need of DC link as shown in Fig 1(b) etc.

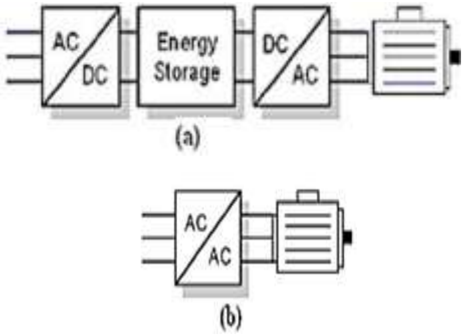

Fig.1:AC/ACConverter(a)IndirectConverter(b)Direct Converter

Cycloconvertersarethedirecttypeconvertersutilizedas apartofhighpowerapplicationsdrivinginduction 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.

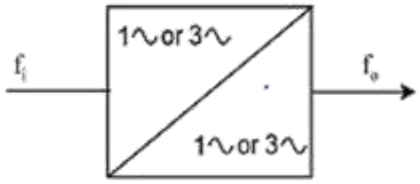

Fig.2:BlockdiagramofCycloconverter

A. A cycloconverter is a type of power controller that changes an alternating voltage at the supply frequency into another alternating voltage at the load frequency, without using a DC stage in between. In a line-commutated cycloconverter, the supply frequency is higher than the load frequency. The concept was developed in the 1930s, around the time when grid-controlled mercury arc rectifiers became available. These methods were used in Germany, where a three-phase 50 Hz power supply was converted into a single-phase AC supply at 16.67 Hz for use in electric trains. In the United States, there was a 400 horsepower system that used a cycloconverter with 18 thyratrons to supply a synchronous motor, and it operated for several years as an auxiliary drive in a power plant. However, because these early systems were not very efficient or cost-effective, they were eventually stopped. A cycloconverter is controlled by adjusting the timing of its firing pulses, which allows it to produce an alternating output voltage. By monitoring the frequency and depth of phase modulation in the converter's output, it's possible to control both the frequency and the amplitude of the output voltage. This means a cycloconverter can provide continuous and independent control over both the output

Volume: 09 Issue: 10 | Oct - 2025 SJIF Rating: 8.586 ISSN: 2582-3930

frequency and voltage. Usually, the output frequency is less than one-third of the input frequency. The quality of the output voltage wave and its harmonic distortion also set limits on how low the output frequency can go. The distortion is lower at lower output frequencies. Cycloconverters are usually used to provide a variable frequency from a constant input frequency or a constant frequency from a variable input frequency. A cycloconverter can handle loads with any power factor and allows power to flow in both directions. The output voltage wave consists of harmonic distortion components as well as the required sinusoidal part. These distortion components are a natural result of how the cycloconverter works, as it creates the output voltage by using parts of the input voltage waves. These harmonics can be reduced by using enough output channels. The distortion in the output voltage increases when the ratio of the output frequency to the input frequency increases.

B. Uses of Cycloconverter Are:
- It is used to control the speed of high power AC motors
- It is used in high frequency induction motors
- It is used in static VAR generators
- It is used as a power source in airplanes and spacecraft
- It is used in High Voltage DC (HVDC) transmission to connect two power grids that run at different frequencies

III.
Advantages of Cycloconverter
1) It can change the frequency directly, without needing any extra stages
2) It uses natural commutation, which makes the system more compact
3) It can transfer power in both directions
4) It can operate across the entire speed range, even at a complete stop
5) If there is a commutation failure, only the individual fuses blow, not the whole system
6) It produces a high quality sinusoidal waveform at low output frequencies because it uses many parts of the supply waveform.
This is especially good for very low speed applications

IV.
How Cycloconverter Works
A. Single-Phase to Single-Phase (1Ø-1Ø) Cycloconverter: This converter is made by connecting two full-wave rectifier circuits one after the other.
Figure 3 shows the working waveforms for this converter with a resistive load.

The input voltage, vs, is an AC voltage at a frequency, Vi, as shown in Figure 3a. All the thyristors are triggered at a firing angle of 0°, which means the thyristors act like diodes. The firing angle for the positive converter is called αp, and for the negative converter it's αn. The output frequency, Vo, can be changed by adjusting how many cycles the positive and negative converters work.

To get an output frequency that is a quarter of the input frequency, for the first two cycles of vs, the positive converter supplies current to the load.
It converts the input voltage into direct current, so the load gets four positive half-cycles, as shown in Figure 3b. n the next two cycles, the negative converter works and supplies current in the opposite direction.

The current waveforms are not shown in the figures because the current through a resistive load is the same as the voltage waveform but scaled by the resistance.
Also, when one converter is working, the other is not, so there is no current flowing between the two rectifiers.

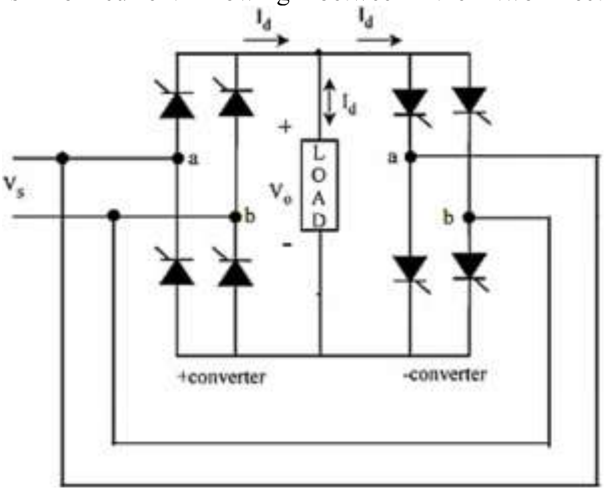

Fig.3:(a)Cycloconverter,Single-phasetosingle-phase(1ϕ- 1ϕ)

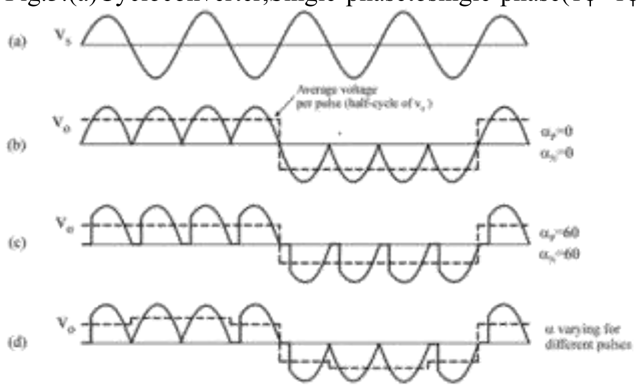

Fig.3:showscycloconverterwaveformsofSingle-phaseto single-phase
1) Inputvoltage
2) Outputvoltageforzerofiring angle
3) Outputvoltagewithfiringanglep/3rad
4) Outputvoltagewithvaryingfiringangle

Due to the frequency of the output, Vo in fig.3b is one fourth of the input voltage, i.e. fo/fi=1/4 that's why it is stepdowncycloconverter.Insteadofit,ifthecycloconverter frequency has correlation like this fo/fi>1, it's known as step-up cycloconverters. Notify that step-down cycloconvertersarefurther commonlyusedincomparestep- up ones.
The frequency of vo can be adjust by altering the figure of cycles the positive and the negative converters works. It can only change as integer multiples of fi in 1ϕ-1ϕcycloconverters.With the above operation, the 1ϕ-1ϕcycloconverter can only supply a certain voltage at a certain firing angle a. The dc output of each rectifier is:

$$V_d = \frac{2\sqrt{2}}{\pi} V \cos a \qquad (1)$$

whereVistheinputr.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
(2)

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

Fixed operation gives a rough output waveform withrichharmoniccontent.The dottedlinesinFig.3bandc demonstrate a square wave. If the square wave can be adjustedtolookmorelikeasine wave,theharmonicswould 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 a's, the less are the harmonics.

A. Three-PhasetoSingle-Phase(3ϕ-1ϕ)Cycloconverter:

There are two types of three-phase to single-phase (3ϕ-1ϕ) cycloconverters: 3ϕ-1ϕ half-wave cycloconverter (Fig. 4) and 3ϕ-1ϕ bridge cycloconverter (Fig. 5). Like the 1ϕ-1ϕ converter case, the 3ϕ-1ϕcycloconverter 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 modesand(+v, - i) and (-v, +i) inversion modes. The modulation of theoutput voltage and the basic output voltage are shown inFig. 6. It seems that α is sinusoidally modulated over the cycle to generate a harmonically idyllic output voltage.

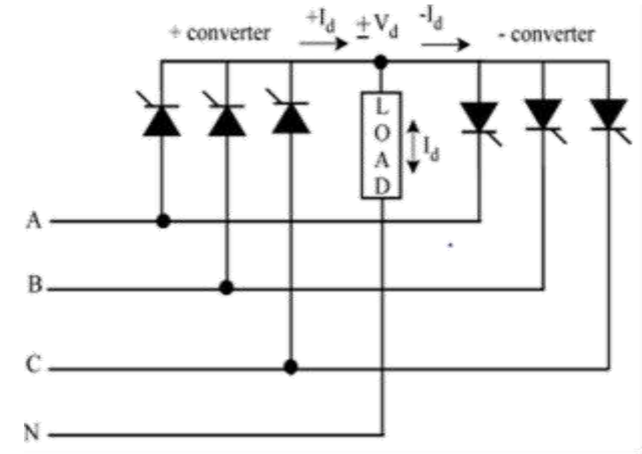

Fig.4:3f-1fHalf-WaveCycloconverter

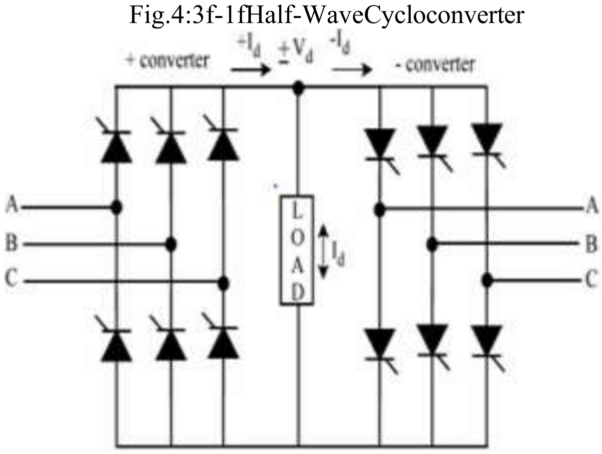

Fig.5:3ϕ-1ϕBridgeCycloconverter

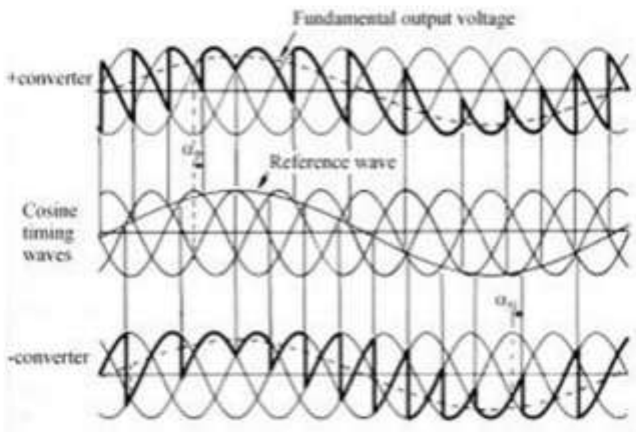

Fig.6:3ϕ-1ϕHalf-WaveCycloconverterWaveformsA)+ Converter Output Voltage B) Cosine Timing Waves C) – Converter Output Voltage

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 aP, and that of the negative converter is named a N. At the point when the polarity of the current changes, the converter beforehand providing the current is disabledandthe other one isenabled.Theloadcontinuously 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 causean undesirable voltage jump. To avoid this problem, the converters are forced to generate the same average voltageat all times. Accordingly, the accompanying condition for the firing angles ought to be met

$a_P + a_N = \pi$ ……. (1)

ThefundamentaloutputvoltageinFig.6canbegiven as:

$V_{o_1}(t) = \sqrt{2}V_o \sin\omega_o t$ ……. (2)

WhereVoisthermsvalueofthefundamentalvoltage At a time to the output fundamental voltage is

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

Thepositiveconvertercansupply thisvoltageifaPsatisfies thefollowingcondition.

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

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

Fromtheacondition(3)

$$V_{o_1} = V_{do} \cos a_p = -V_{do} \sin a_N$$

Thefiringanglesatanyinstantcanbefoundfrom eq. The operation of the 3ϕ-1ϕ bridge cycloconverter is similar to the above 3ϕ-1ϕ half-wave cycloconverter. Note that the pulse number for this case is 6.

B. Three-PhasetoThree-Phase(3ϕ-3ϕ)Cycloconverter:

In the occurrence that the outputs of3-ϕ to 1-ϕ convertersof the same type are associated in wye or delta and if the output voltages are 2π/3 radians phase movedfrom each other, the subsequent converter is a three phase to three- phase (3ϕ-3ϕ) cycloconverter. The subsequent cycloconverter are appeared in Figs. 7 and 8 with wye connections. Ifthe three converters associated are half-wave converters, then it's known as a 3ϕ-3ϕ half-wave cycloconverter.Ifinstead,bridgeconvertersareutilized, then the result is a 3ϕ-3ϕ bridge cycloconverter. 3ϕ-3ϕ half-wavecycloconverterisalsoknownas 3-pulse cycloconverter or an 18-thyristor cycloconverter. Then again, the 3ϕ-3ϕ bridge cycloconverter is likewise called a6-pulse cycloconverter or a 36-thyristor cycloconverter. The operation of each phase is clarified in the previous segment.

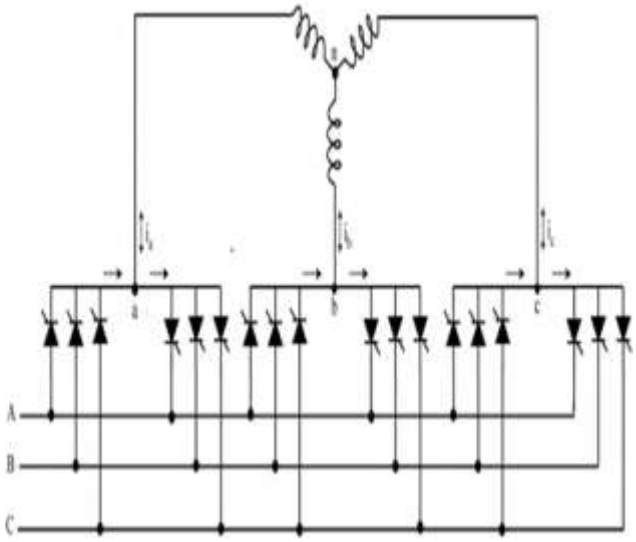

Fig.7:3ϕ-3ϕHalf-WaveCycloconverter

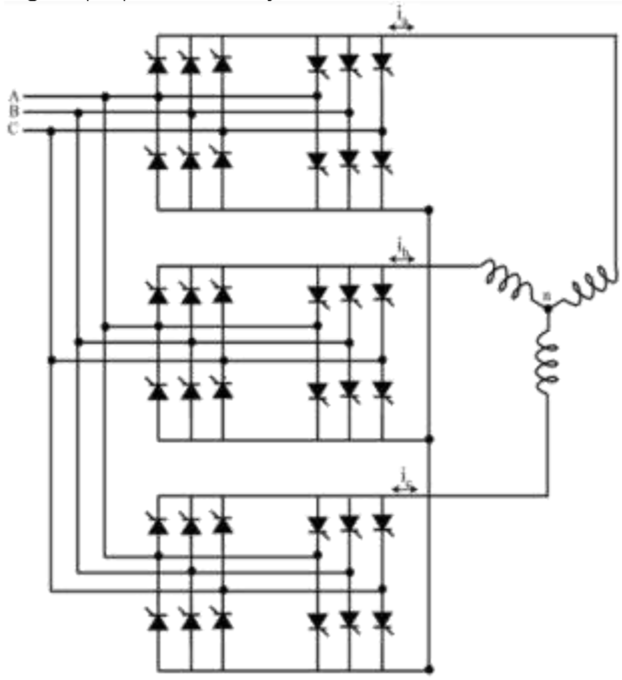

Fig.8:3ϕ-3ϕBridgeCycloconverter

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

C. Single-PhasetoThree-Phase(1ϕ-3ϕ)Cycloconverters:

In recent times, with the drop in the size and the cost of power electronics switches, single-phase to three-phase cycloconverters (1ϕ-3ϕ) 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 generatingahighfrequencyacconnection.Thesingle-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 aordinaryhfac link converter. These converters are not commercially available yet. They are in the research state

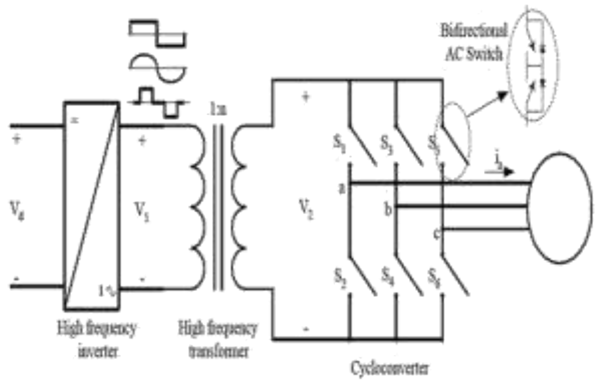

Fig.9:HighFrequencyAcLinkConverter(1fHfInverter+ (1f-3f) Cycloconverter)

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.

III. LITERATUREREVIEW

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 frequencyof 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 hasbeen 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

AshwiniKadam [4] paper present is to control the speed ofan induction motor bychangingthe 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 executedthroughchangingthesupplyvoltageand 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, whichhave beendisplayed foradjustablespeedsinglephase induction motor drives (SPIMD).thispapers explains some converter topologies which are recently used andcomparison 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-circleconstant V/f control law can't be utilized with the single- phase induction motor drives it is utilized with three phase motors.Thevarietyofthe workingfrequencyatlowerspeed range with constant load torque sources assortmentin the motor's slip. A constant V/f control is appropriate merely over the upper speed range. In any case, enhancements inthe 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 controlsystem and the, system model, with the PWM method, have been developed. The whole comparison between the proposedandstandardconfigurationshasbeencarriedoutin 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 thefault 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 bythe 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 toconvert two-phase, output of two Cycloconverter to three- phase

AbhishekPratapSingh[8]designedcycloconverter 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 matchthe torque demand ofthe 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 ratingandbetterefficiency.Theresultsacquiredusing MATLAB for single phase cycloconverter coupledinduction motor.

RadhaKrishna[9]paperpresent a system drive throughsingle-phasetothree-phasemadeoutoftwoparallel 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 ofthe systemisderived, 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 employsjustsixusualcommunicatedthyristor,thereforethe resulting Cycloconverter motor drive system was cheap and compact, thoughthis single phase to three phase modulation procedure is proposed on the premise of variable frequency method.

IV. Conclusion

A cycloconverter is a device use to convert a constant voltage constant frequency AC power to variable voltage variable frequencywithout anyintermediate DC link. Inthis paperpresentedasurveyonconversionofsinglephase(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.

References

[1] K.V.S Bharath, Ankit Bhardwaj "Implementing Single Phase Cycloconverter Using Single Phase Matrix Converter Topology with Sinusoidal Pulse Width Modulation" International Journal for Technological Research in Engineering Volume 2, Issue 6, February- 2015.

[2] BurakOzpineci, Leon M. Tolbert "CYCLOCONVERTERS" http://www.uv.es/~emaset/iep00/cycloconvertertutorial .pdf.

[3] XiaofengYang, RuixiangHao,XiaojieYou,TrillionQ. Zheng "A New Single-Phase to Three-Phase Cycloconverter for Low Cost AC Motor Drives" 978- 1-4244-1718-6/08/$25.00 ©2008 IEEE.

[4] AshwiniKadam, A.N.Shaikh "Simulation & Implementation Of Three Phase Induction Motor OnSingle Phase By Using PWM Techniques" International Journal of Engineering Research and General Science Volume 2, Issue 6, October- November, 2014.

[5] Ali S. Ba-thunya Rahul KhopkarKexin Wei Hamid A. Toliyat"Single Phase Induction Motor Drives - A Literature Survey"

[6] G. Sudhir Kumar, G. Kumaraswamy, Dr. K. Sri Gowri "Modeling of Single-Phase to Three-Phase Drive System Using Two Parallel Converters On Input Side" International Journal of Engineering Research and Applications(Ijera)Vol.3,Issue4,Jul-Aug2013,
Pp.1821-1827

[7] G. R. Sreehitha, A. Krishna Teja, Kondenti. P. Prasad Rao "Control of a Three Phase Induction Motor using Single Phase Supply" International Journal of Engineering Trends and Technology- Volume3Issue3- 2012

[8] AbhishekPratap Singh1, V. K. Giri"Modeling And Simulation Of Single Phase Cycloconverter"[Ijesat] International Journal Of Engineering Science & Advanced Technology Volume-2, Issue-2, 346 – 351

[9] Radha Krishna1, Amar kiran "Modeling of Single- Phase to Three-Phase Drive System Using TwoParallel Single-Phase Rectifiers" International Journal ofModernEngineeringResearch(IJMER)Vol.2, Issue.5,Sep-Oct.2012pp-3899-3907

[10] Kamaljeet Singh Thakur, C. S. Sharma, S. P. Phulambrikar "Modeling and Simulation of Single Phase ToThree Phase Cycloconverter for Low CostACMotorDrives"INTERNATIONALJOURNALOF INNOVATIVERESEARCH &DEVELOPMENTVol 3Issue5May2014.

[11] G. R. Sreehitha, A. Krishna Teja, Kondenti. P. Prasad Rao "Control of a Three Phase Induction Motor using Single Phase Supply" International Journal of Engineering Trends and Technology- Volume3Issue3-2012

[12] AbhishekPratap Singh1, V. K. Giri"ModelingAnd Simulation Of Single Phase Cycloconverter" [Ijesat] International Journal Of Engineering Science &Advanced Technology Volume-2, Issue-2, 346 – 351

[13] Radha Krishna1, Amar kiran "Modeling of Single-Phase to Three-Phase Drive System Using Two Parallel Single-Phase Rectifiers" International Journal of Modern Engineering Research (IJMER) Vol.2, Issue.5, Sep-Oct. 2012 pp-3899- 3907

[14] Kamaljeet Singh Thakur, C. S. Sharma, S. P. Phulambrikar "Modeling and Simulation of Single Phase toThree Phase Cycloconverter for Low Cost AC Motor Drives" International Journal Of Innovative Research & Development Vol 3 Issue 5 May2014.

[14] Nguyen, T. T. (2022). Three-Phase Induction `Motor Using Field-Oriented Control Under Variable Load Conditions. International Journal of Sustainable and Holistic Renewable Energy.

[14] Yuhendri, M., et al. (2025). Vector Control of Three Phase Squirrel Cage Induction Motor Based on IoT Technology. Engineering, Technology & Applied Science,Research,,15(4).