

Simulation Of 3-Ph To 3-Ph Cycloconverter Fed Variable Speed Drive

Keshav B Negalur^{#1}, A.S.Joshikulkarni^{#2}

^{#1}Department of Electronics and Communication Engineering, KLS VDRIT, Haliyal-581329, India

^{#2}Department of Electronics and Communication Engineering, KLS VDRIT, Haliyal-581329, India

Abstract- With harmonic distortion becoming an ever increasing concern in Variable Speed Drive (VSD) applications, virtually all Drive, manufacturers now consider limiting the generation of input current harmonics to be an important issue in their designs. This has led us to the introduction of various drives which should give us considerable reduction in the harmonic distortion. In practical application, the three-phase to three-phase cycloconverter is commonly required to derive a three-phase output from a three-phase input. The most logical method for producing a three-phase output is to use three symmetrical independent dual converters one for each output phase. As in the case of a rectifier or phase controlled converter circuit, from the view point of reducing the external harmonic voltages and current to a minimum, the pulse number of the cycloconverter circuit should be as high as possible. Cycloconverters enable conversion of AC power to AC power without any intermediate DC link. They are suitable for running induction and synchronous motors. Depending on their topologies they can drive both single-phase and three-phase motors. This paper simulates the working of an induction motor drive with a three-phase to three-phase Cycloconverter. The simulation was carried out using MATLAB-Simulink.

Key Words— AC drive, Cycloconverter, Induction motor, Simulation, Simulink.

I. INTRODUCTION

Cycloconverter is a device which converts AC power at one frequency directly to an AC power at another frequency without any intermediate DC stages. The output is at a lower frequency than that of the input. Cycloconverter also enables operation of loads at any power factor. Cycloconverter is categorized in the group of line-commutated converters. Using Cycloconverter for large AC machines is suitable. This is because of its high efficiency, simple circuit design and natural commutation. Cycloconverters are used in high power applications such as driving induction motors and synchronous motors. Cycloconverters are phase controlled and generally use thyristors for phase commutation. Their applications include but are not limited to: Mine winders, Cement mill drives, Scherbius drives, Rolling mill drives etc. In a line commutated Cycloconverter, the supply frequency is greater than the load frequency. Cycloconverter is attractive for AC motor drives because a fixed input frequency can be converted to an adjustable output frequency at an adjustable voltage. A Cycloconverter has the facility for continuous and independent control over both its output frequency and voltage. This frequency is normally less than one-third of the input frequency. The Cycloconverters are normally used to provide either a variable frequency from a fixed input frequency or a fixed frequency from a variable input

frequency. Because of the unidirectional current carrying property of the individual converters, it is inherent that the positive half-cycle of load current must always be carried by the positive converter and the negative half cycle by the negative converter, regardless of the phase of the current with respect to the voltage. The Cycloconverter utilized in this paper is three phase to three phase bridge cycloconverter. The main advantage of using a Cycloconverter is that it allows flow of power in both directions.

II. RELATED WORK

Dr. Sulochana Wadhvani and Vishnu Goyal[1] proposed simulation of six pulse cycloconverter excited Induction machine for controlling A.C. motors at low speed drives especially in high power application. This paper discusses the simulink model of six pulse three phase to three phase cycloconverter controlled induction motor. The logic control circuit of cycloconverter for positive and negative converter selection circuit has been developed with different types of gates and pulse generators. In this simulation, time period of pulse generators of converter selection circuit is changed to control output frequency of cycloconverter. LC filter circuit designed to reduce harmonics from cycloconverter controlled output voltage. High number of pulses will not complicate the control circuits, because it will just increase the number of these control circuits. Increasing number of pulses will improve the cycloconverter output waveforms and will decrease the harmonic component values.

Sandeep Pande and Hashit Dalvi[2] proposed simulation of cycloconverter based three phase Induction motor. 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. 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.

Vinamra Kumar Govil and Yogesh Chaurasia[3] proposed Modeling & Simulation of PWM Controlled Cycloconverter FED Split Phase Induction Motor. Single Phase induction motors are widely accepted motor due to their energy efficient characteristics. To drive varying mechanical loads for long duty the machine needs to be controlled to increase its efficiency and minimize transient. To control the output parameters of the motor i.e., Speed and Electromagnetic torque the fixed frequency of the system is varied for which a Cycloconverter is employed along with PWM technique to increase the system efficiency. The Cycloconverter is built on with IGBT due to its improved dynamic performance and efficiency and reduction in the level of audible noise. Low driving power and a simple drive circuit due to the input MOS gate structure. It can be easily controlled as compared to current controlled devices (Thyristor, BJT) in high voltage and high current applications. With the help of PWM the output voltage control can be obtained without addition of any external components and PWM minimizes the lower order harmonics, while the higher order harmonics can be eliminated using a filter.

Manfred Grötzbach, Member, IEEE, and Reiner Redmann proposed Line Current Harmonics of VSI-Fed Adjustable-Speed Drives. Voltage-source-inverter (VSI)-fed adjustable-speed drives are frequently used in energy-saving applications like speed regulation of pumps and fans. The power supply of the inverter consists of a diode rectifier feeding a large dc-link capacitor. Thus, very high line current harmonics occur if no inductance is provided for current smoothing. Assuming ac choke inductance, this paper presents diagrams in order to predetermine easily the Harmonic distortions of the line current. The parameters considered are ac reactance, dc capacitor, and the actual drive loading. With this, a more detailed description of the injected current harmonics of VSI-fed drives is achieved in order to improve the accuracy of harmonic analysis purposes.

III. PROPOSED WORK

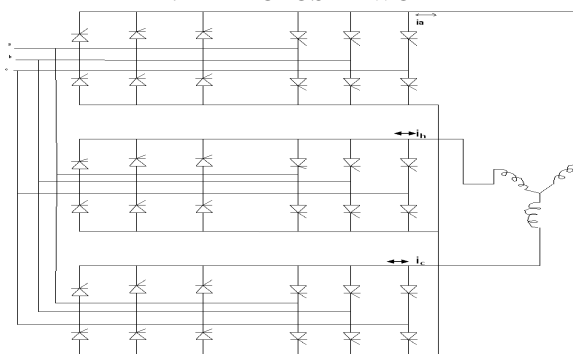


Fig. 1 Three phase to three phase Bridge Cycloconverter

Fig.1. This Cycloconverter is used for running three phase Induction motors and synchronous machines. A cycloconverter can supply loads of any power factor even if the input is lagging. It is clear from the Fig. 1 that there are two groups of SCRs per phase. One group is responsible for producing the positive alternations and is known as the positive group; the other produces the negative alternations and is called the negative group. Each group consists of three SCRs, thus in total six SCRs are required per phase. This means in all 18 SCRs are required for the whole circuit. The method of connecting the phase-controlled converters governs their operation in three modes. These are the non-circulating, the circulating, and the semi- circulating current modes.

A. Circulating current mode

In circulating current mode both of the converters operate at all times producing the same fundamental output voltage. When one converter is in rectification mode, and the other one is in inverter mode and vice-versa. If both of the converters are producing pure sine waves, then circulating current would be absent. This mode applies a smoother load voltage with fewer harmonics.

B. Non-circulating current mode

In this mode, circulating currents are not allowed to flow. When the current becomes zero, both the positive and negative converters are blocked. They stay in OFF state till the load current decreases. Then, depending on the polarity one of the converters gets switched ON. With each zero crossing of the current, the converter which was disabled before the zero crossing is enabled.

C. Hybrid System

The non-circulating current mode cycloconverter and the circulating current cycloconverter can be combined to give a hybrid system, which has the advantages of both. The resulting cycloconverter looks like a circulating mode Cycloconverter circuit, but depending on the polarity of the output current only one converter is enabled. When the load current decreases below a threshold, both of the converters are enabled. Thus, the current has a smooth reversal. When the current increases above a threshold in the other direction, the outgoing converter is disabled. This hybrid operates in the blocking mode most of the time. The efficiency is slightly higher than that of the circulating current cycloconverter but much less than the non-circulating current mode cycloconverter. Mainly, the output waveform is a function of the converters control algorithm. In practical application, the three-phase to three-phase cycloconverter is commonly required to derive a three-phase output from a three-phase input. The most logical method for producing a three-phase output is to use three symmetrical independent dual converters

one for each output phase. As in the case of a rectifier or phase controlled converter circuit, from the view point of reducing the external harmonic voltages and current to a minimum, the pulse number of the cycloconverter circuit should be as high as possible. The motor considered here was a three-phase induction motor.

IV. INDUCTION MOTOR

Induction motors are the AC motors which are employed as a prime mover in most of the industries. An induction motor is only a part of a variable speed drive assembly. As such the IM is fed from power electronics converter (PEC), but indirectly in most cases from the industrial power grid.

1) Steady State Equivalent Circuit

When the IM is fed in the stator from a three-phase balanced power source, the three-phase currents produce a traveling field in the airgap. This field produces emfs both in the stator and in the rotor windings: E_1 and E_2 . A symmetrical cage in the rotor may be reduced to an equivalent three-phase winding. The frequency of E_{2s} is f_2

$$f_2 = f_1 - np_1 = ((f_1 / p_1) - n) p_1 = ((n_1 - n) / n_1) n_1 p_1 = S f_1$$

This is so because the stator mmf travels around the airgap with a speed $n = f / p$ while the rotor travels with a speed of n . Consequently, the relative speed of the mmf wave with respect to rotor conductors is $(n_1 - n)$ and thus the rotor frequency f_2 is obtained.

Now the emf in the short-circuited rotor “acts upon” the rotor resistance R_r and leakage inductance L_{rl}

$$E_{2s} = SE_2 = (R_r + j\omega_s L_{rl}) I_r \quad \dots\dots\dots 1$$

$$E_{2s}/S = E_2 = ((R_r / S) + j\omega_s L_{rl}) I_r \quad \dots\dots\dots 2$$

If Equation (1) includes variables at rotor frequency $S\omega_1$, with the rotor in motion, Equation (2) refers to a circuit at stator frequency ω_1 , which is with a “fictitious” rotor at standstill.

Now after reducing E_2 , I_r , R_r , L_{rl} to the stator Equation (2) yields:

$$E_2' = E_1 = [R_r' + R_r' ((1/S) - 1) + j\omega_s L_{rl}'] I_r' \quad \dots\dots\dots 3$$

$$E_2'/E_1 = (K_{w2} W_2 / K_{w1} W_1) = K_E; K_{w2} = 1, W_2 = 1/2 \text{ for cage rotors}$$

$$I_r'/I_r = (m_1 K_{w1} W_1 / m_2 K_{w2} W_2) = K_I; W_2 = 1/2, m_2 = N_r \text{ for cage rotors} \quad \dots\dots\dots 4$$

The stator phase equation is given by:

$$-E_1 = V_s - I_s (R_s + j\omega_s L_{s1}) \quad \dots\dots\dots 5$$

As there is current (mmf) in the rotor, the emf E_1 is produced Concurrently by the two mmfs (I_s, I_r').

$$E_1 = d\Psi_{1m}/dt = -j\omega_s L_{1m} (I_s + I_r') \quad \dots\dots\dots 6$$

If the rotor is not short-circuited, Equation (3) becomes

$$E_1 = (V_r / S) = [R_r' + R_r' ((1/S) - 1) + j\omega_s L_{rl}'] I_r' \quad \dots\dots\dots 7$$

The division of V_r (rotor applied voltage) by slip (S) comes into place as the derivation of (7) starts in (1) where

$$SE_2 - V_r = (R_r + j\omega_s L_{rl}) I_r' \quad \dots\dots\dots 8$$

The rotor circuit is considered as a source, while the stator circuit is a sink. Now Equations (5) through (8) constitute the IM equations per phase reduced to the stator for the rotor circuit.

The steady state equivalent circuit of IM is shown in Fig. 2.

2) No-Load Motor operation

When no mechanical load is applied to the shaft, the induction motor works on no-load. In terms of energy conversion, the IM input power has to cover the core, winding, and mechanical losses. The IM has to develop some torque to cover the mechanical losses. So there are some currents in the rotor. However, they tend to be small and, consequently, they are usually neglected.

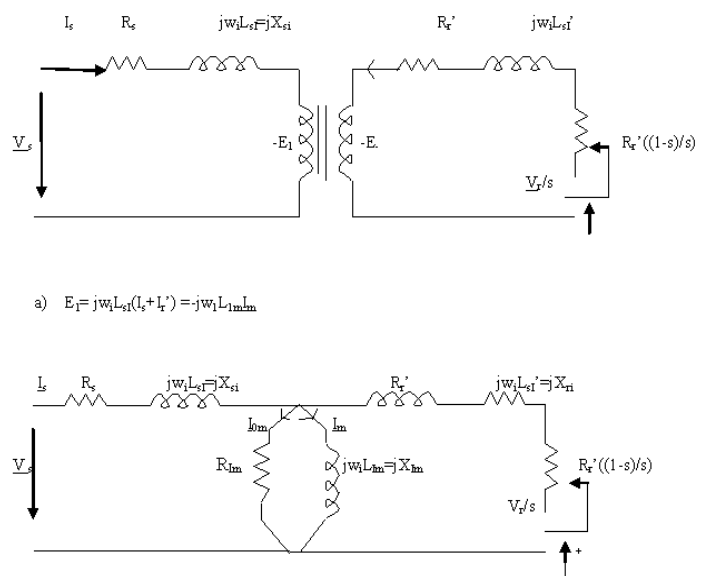


Fig. 2 Steady-state equivalent circuit of Induction Motor

V. SIMULATION RESULTS

The cycloconverter was run at no-load at 10 Hz frequency. The same test was conducted for a load of (Mechanical Power) =10000w.

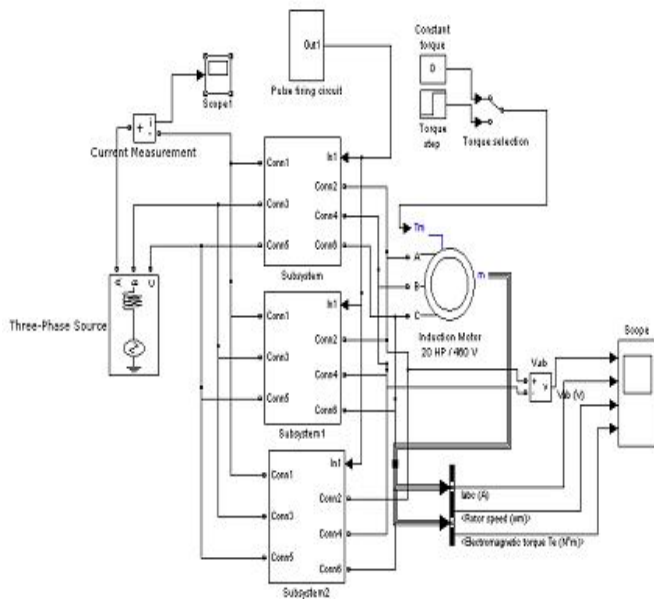


Fig 3. Simulation circuit for Cycloconverter fed VSD

The results are given below:

A. No Load(Mechanical Power) =0, Frequency at 10 Hz

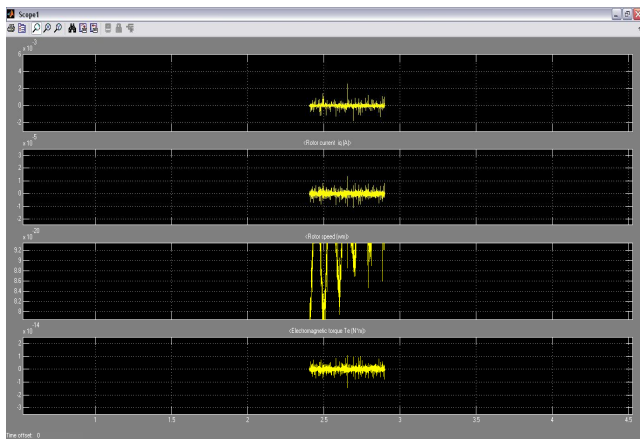


Fig. 4 Input current waveform at no load and 10 Hz frequency for a single motor phase A

For the cycloconverter model used in this paper it can be said that it is not suitable for running variable speed drives under no load conditions.

B. For Load(Mechanical Power) of 10000w, Frequency at 10 Hz

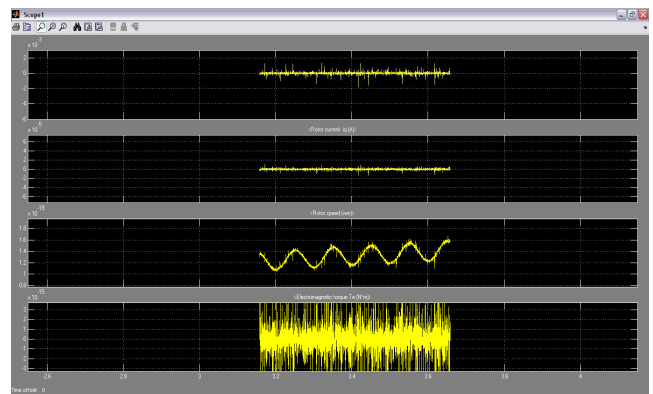


Fig. 6 Input current waveform at 5 N-m loads at 10 Hz frequency for a single motor phase A.

When run under load the proposed cycloconverter fed variable speed drive shows a reduction in the input line current harmonics and also the magnitude of the harmonic current decreases. Hence when variable speed drive is run under load the three phase to three phase cycloconverter provides lesser harmonic content thus improving the performance of the variable speed drive.

VI. CONCLUSION

The Cycloconverter was simulated using simulation toolbox in MATLAB. From simulation we can check the current waveforms and corresponding harmonic spectra for different load conditions. It is seen that with increase in the load the line current harmonics reduce at the input side of the three-phase to three-phase Cycloconverter. This results in reduced Total current harmonic distortion.

REFERENCES

- [1] Dr. Sulochana Wadhvani, Member and Vishnu Goyal, Ph.D Student, Non Member (INTERNATIONAL JOURNAL OF ELECTRICAL ENGINEERING & TECHNOLOGY (IJETT)) Volume 3, Issue 2, July – September (2012), pp. 76-83.
- [2] Sandeep Pande, Hashit Dalvi Department of Electrical Engineering, G.H.Raisoni Engineering College, Nagpur, India (INTERNATIONAL JOURNAL OF ADVANCES IN ENGINEERING & TECHNOLOGY, JULY 2011).
- [3] Vinamra Kumar Govil and Yogesh Chaurasia, Dept.of Electrical Engg. Adesh Institute of Engg. & Technology, Faridkot, Punjab, India and Dept. of Electrical & Electronics Engg. Saroj Institute of Technology and Management, Lucknow, Uttar Pradesh, India.
- [4] Manfred Grotzbach, "Line current harmonics of VSI fed adjustable speed drives", IEEE Transactions on Industrial Applications, vol.36, no.2, March 2000, pp.683-690.