Performance Analysis of Step up and Step down Cyclo converter.

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***Abstract*— Cycloconverters directly convert ac power of one frequency to ac power of variable frequency. This variable frequency ac power can then be used to directly control the speed of ac motors. By using ac voltage controller magnitude of the voltage can be controlled and frequency can't be controlled but with Cyclo converters frequency also controlled. The drawbacks of voltage source inverter and ac voltage controllers are overcome by using Cyclo converter.**

For lower speed motors step down Cyclo converter is used. For high speed motors step up Cyclo converters are preferred. Cyclo converters are mainly used in variable speed motors such as Cement mill drives, Scherbius drives, Ore grinding mills, Mine winders and Rolling mill main drives. In this paper the performance of step up and step down Cyclo converter are analyzed to an no load conditions.

Keywords—Step up and Step down Cyclo converter,variable frequency.

I. INTRODUCTION

Converter is a static device which converts ac to ac, ac to dc, dc to dc and dc to ac voltage or frequency. Thyratrons, mercury arc rectifiers, magnetic amplifiers, rheostatic control etc. Were being used in conventional power controllers but now they are replaced by power electronic controllers using semiconductor devices. In earlier times we use Mercury-arc rectifiers for scheming electrical power, but the range for applications of mercury-arc rectifiers was partial. In current systems the conversion is performed with semiconductor switching devices such as diodes, thyristors, and transistors[1].

There are four different conversions between DC and AC power sources. These conversions are done by circuits called power converters. The converters are classified as:

- Rectifiers – from single phase or three phase AC to variable voltage DC
- Choppers – from DC to variable voltage DC
- Inverters – From DC to variable magnitude and variable frequency, single phase or three phase AC
- Cyclo converters - From single-phase or three-phase AC to variable magnitude and variable frequency, single-phase or three-phase AC

AC to AC converters are classified as indirect converters and direct converters. In indirect converter multi stage conversion is possible, single stage conversion is not possible whereas in direct converters single stage conversion is possible. Whatever disadvantages are there in indirect converters those can be reduced by using direct converters.

At present ac voltage controllers used for controlling the output voltages whereas fixed ac input voltage convert into variable ac output voltage and Cyclo converters used for controlling the output frequency whereas fixed input frequency convert into variable output frequency. For controlling the output frequency and voltage ac voltage controllers and Cyclo converters both used.

AC converters are those which converts ac to ac power. These converters are classified into indirect and direct converters. The converter which converts ac to ac voltage by using intermediate dc link is known as indirect converter. In this configuration first ac voltage convert into dc voltage and this stage is known as rectifier stage afterwards it converts dc voltage into ac voltage by using inversion process. This output voltage can be used to drive the ac motors.

In indirect converters single stage conversion is not possible and for converting ac power into ac power two stage conversion is possible. The first stage will be the input ac converts into dc by using rectification process. Afterwards in second stage dc can be converted into ac by using inversion process. While converting into ac to dc and then dc to ac dc link converter is used. In indirect converters the usage of reactive elements will be more due to this the system will be bulky. The output also not purely sinusoidal. By using these converters power factor cannot be control and the control circuitry will be complex.

The disadvantages of indirect converters are overcome by using direct converters. The ac to ac power conversion in single stage is possible. No need of dc link converters are used, due to this harmonic content will be reduced. The following are the different types of direct converters.

A large percentage of electricity infrastructure in the world is based on AC Generation, transmission, and distribution networks using AC have dated back to the1800s. The conversion takes a given AC source and delivers AC power with different amplitude, frequency, or number of phases. For example, high voltage transmission can be converted to low voltage distribution via a step-down transformer. This is a simple way for a magnitude change.

However, electricity networks and variable-speed motor drives show that magnitude conversion is not sufficient by itself. As previously mentioned, there are two main approaches to AC-

AC power conversion. The first one is the two-stage process called a DC-link converter. The concept is to first use a rectifier to change the input AC to a DC waveform. This DC stage will have capacitors and inductors to store energy from the input. This DC stage will then pass through and serve as the input to an inverter to produce the AC output waveform. Benefits of this system are the flexibility in output amplitude, frequency, and phase. However, with intermediate filters on the DC bus as well as output filters, the system is larger and more complex. The second approach to AC-AC conversion is the one-stage method such as the Cyclo converter. This avoids the intermediate DC bus and switches directly from the input AC waveform to create the output AC waveform. The benefits of this system are less filtering complexity and large power capability. However, there is an upper limit to the output frequency which is proportional to the input frequency. One of the first commercially used Cycloconverters was developed in 1930. German locomotive engines required a low frequency of 16.6 Hz in order to generate large amounts of torque. However, the electrical line frequency was 50 Hz. A combination of a transformer and large tube thyristors allowed for obtaining the desired output amplitude and frequency. With advances in thyristors technology, Cycloconverters are a very efficient and straight forward platform for very high power AC-AC conversion, typically in excess of 100 kW [2].

II. CYCLO CONVERTER

The ac voltage controllers provide a variable output voltage, but the frequency of the output voltage is fixed and the harmonic content is also high, at a low output voltage range. A variable output voltage at variable frequency can be obtained from two stage conversion. However, cyclo converters can eliminate the need of one or more intermediate converters.

A Cyclo converter is a direct frequency changer that converts ac power at one frequency to ac power at another frequency by ac- ac conversion, without an intermediate conversion link. The majority of Cyclo converters are naturally commutated and the maximum output frequency is limited to a value that is only a fraction of the source frequency. As a result the major applications of Cyclo converters are low speed, ac motor drives ranging up to 15,000kW with frequencies 0 to 20 Hz.

It is a device which converts fixed frequency into variable frequency as in integral multiples.

If the input frequency is reduced to output frequency then it said to be step down Cycloconverters. Similarly the input is increased to output frequency then it said to be step up Cycloconverters.

- For step up Cyclo converter → $f_o = n \times f_i$
- For step down Cyclo converter → $f_o = f_i \times (1/n)$

For step up Cyclo converter the output frequency is equal to the 'n' multiples of input frequency and for step up Cyclo converter the output frequency is equal to the '1/n' multiples of input frequency.

The Cyclo converter basic diagram consist of power supply, positive converter, negative converter and load. The basic diagram of Cyclo converter is shown in below.

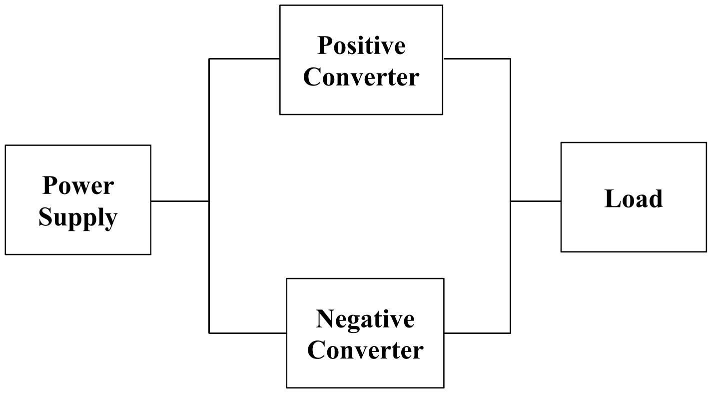

Fig.1 Basic diagram of Cyclo converter

The schematic diagram of Cyclo converter is consist of power supply, positive converter, negative converter and load.

For single phase Cyclo converters single phase ac voltage source is required and for three phase Cyclo converters three phase programmable voltage source is required. In this project for single phase Cyclo converter the power supply is taken as 230 volts, 50 Hz and similarly for three phase Cyclo converter the power supply is taken as 420 volts, 50 Hz.

In positive converter the output voltage should be positive with respect to the input. In negative converter the output voltage should be negative with respect to the input. For positive and negative converter thyristor and IGBT switches are required. In step down Cyclo converter thyristor is being used. In step up Cyclo converter IGBT is being used. In step up Cyclo converter commutation problem arises due to that IGBTs are preferred. Any three phase ac motor can be taken as load.

III. CLASSIFICATIONS OF CYCLO CONVERTERS

Generally, Cycloconverters are classified according to the number of phase of input and output AC voltages. The tree diagram of the Cyclo converter is shown in below figure.

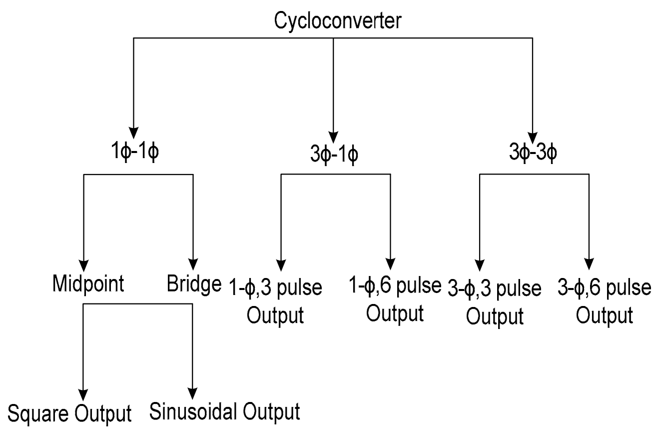

Fig. 2 Classification of Cyclo converters

A. Advantages of cycloconverters:

- Direct frequency conversion without any intermediate stage.
- Power transfer in either directions.
- Operates in any power factor
- Capable of regeneration over the complete speed range, down to standstill.
- Commutation failure leads only to blown-off of individual fuses only.
- Delivers a high quality sinusoidal waveform at low output frequencies since it is fabricated from a large number of segments of the supply waveform.
- This is often preferable for very low speed applications.

B. Disadvantages of cycloconverters:

- Large number of thyristors are required in a Cyclo converter.
- Complex control circuitry.
- The power factor is low, particularly at reduced output voltages.

C. Applications:

The following are some applications where Cycloconverter drives are used.

- Rolling mill main drives
- Mine hoist drives
- Ship propulsion
- Cement mill drives
- Scherbius drives
- Ore grinding mills
- Mine winders

IV. THREE PHASE TO THREE PHASE CYCLOCONVERTER

If the outputs of 3Ø-1Ø converters of the same kind are connected in wye or delta and if the output voltages are $2\pi/3$ radians phase shifted from each other, the resulting converter is a three-phase to three-phase (3Ø-3Ø) Cyclo converter. If the three converters connected are half-wave converters, then the new converter is called a 3Ø-3Ø half-wave Cycloconverter. If instead, bridge converters are used, then the result is a 3Ø-3Ø bridge Cycloconverter. 3Ø-3Ø half-wave Cycloconverter is also called a 3-pulse Cyclo converter or an 18-thyristor Cycloconverter. On the other hand, the 3Ø-3Ø bridge Cycloconverter is also called a 6-pulse Cyclo converter or a 36-thyristor Cyclo converter. The three-phase Cyclo converters are mainly used in ac machine drive systems running three-phase synchronous and induction machines. They are more advantageous when used with a synchronous machine due to their output power factor characteristics. A Cyclo converter can supply lagging, leading, or unity power factor loads while its input is always lagging. A synchronous machine can draw any power factor current from the converter. Cyclo converters are used in Scherbius drives for speed control purposes driving wound rotor induction motors [3].

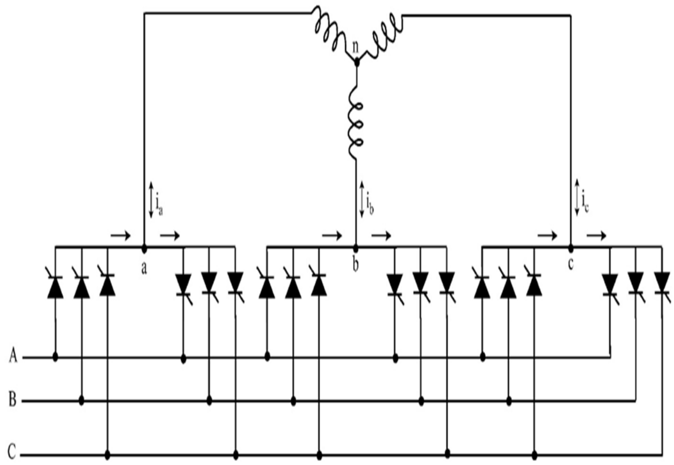

Fig.3 3Ø-3Ø half-wave Cyclo converter

A. Three phase to three phase step-up cycloconverter:

In three phase to three phase step down Cyclo converter the output frequency can be reduced to multiples of integers. The positive converter operates for half the period of the output frequency and the negative converter operates for the other half period. The analysis of this converter is similar to that of single phase Cyclo converters.

Here f/3 and f/6 configuration have been explained. In this configuration total 18 switches have been used. In this each switch is conducting for 120°. While positive converter changes to negative converter or negative converter changes to positive converter the phase shift will be 180°.

B. Three phase to three phase step-down cycloconverter:

In three phase to three phase step up Cyclo converter the output frequency can be increased to multiples of integers. The positive converter operates for half the period of the output frequency and the negative converter operates for the other half period. The analysis of this converter is similar to that of single phase Cyclo converters.

Here 6f and 3f configuration have been explained. In this configuration total 18 switches have been used. In this each switch is conducting for 120°. While positive converter changes to negative converter or negative converter changes to positive converter the phase shift will be 180°.

V. SIMULATION AND RESULTS

A. Simulation for 3Ø-3Ø step-down cycloconverter with f/3 configuration:

In this type of Cyclo converter the frequency will be reduced from 'f' Hz to 'f/3' Hz. It means the time period increased from 'T' sec to '3T' sec. In three phase Cyclo converter with 'f/3'Hz frequency three pulse generators are used for each thyristor. Based on switching of thyristors, consider the values of time period and pulse width values in pulse generator block. With R – load the waveforms have been shown below. If the load will be RL – load then the output waveform will be similar for certain value of inductor. The value of inductor will be consider upto 6H after that the waveform will be distorted.

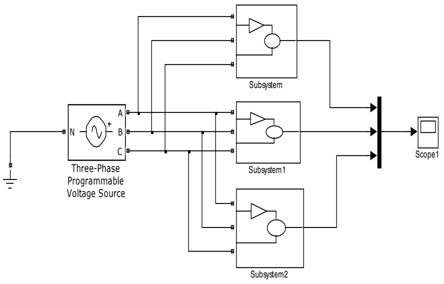

Fig.4 Three phase to three phase cyclo converter with f/3 configuration

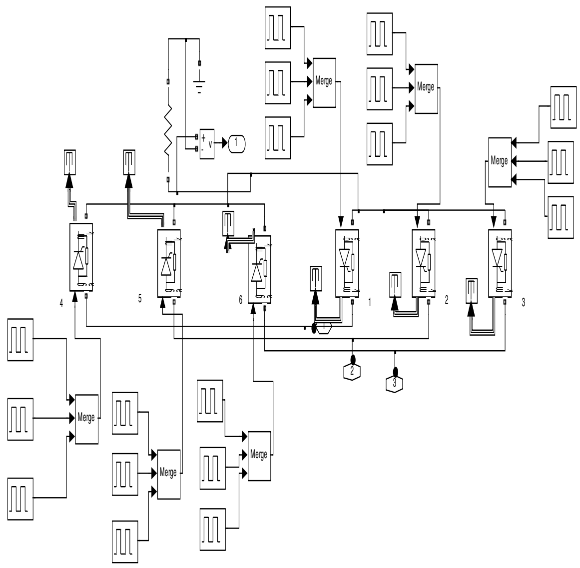

Fig.5 Sub system of three phase to three phase Cycloconverter with f/3 configuration

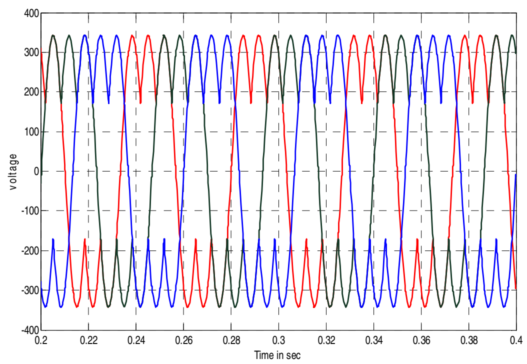

Fig.6 Waveforms of three phase to three phase Cyclo converter for f/3 configuration without firing angle

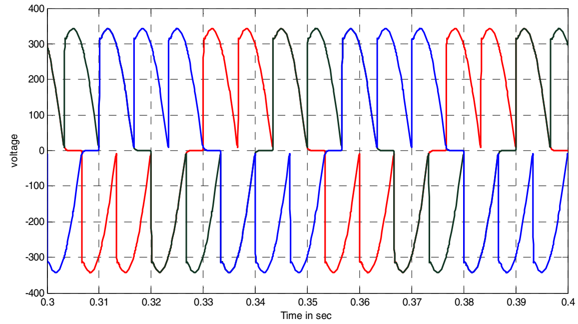

Fig.7 Waveforms of three phase to three phase Cyclo converter for f/3 configuration with 60^0 firing angle

B. Simulation for 3Ø-3Ø step-down cycloconverter with f/6 configuration:

In this type of Cyclo converter the frequency will be reduced from 'f' Hz to 'f/6' Hz. It means the time period increased from 'T' sec to '6T' sec. In three phase Cyclo converter with 'f/6'Hz frequency six pulse generators are used for each thyristor. Based on switching of thyristors, consider the values of time period and pulse width values in pulse generator block.

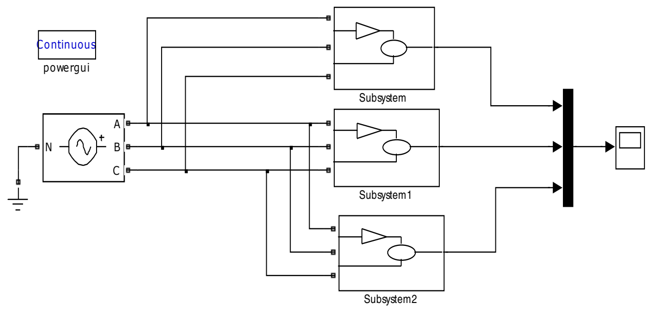

Fig.8 Three phase to three phase Cyclo converter with f/6 configuration

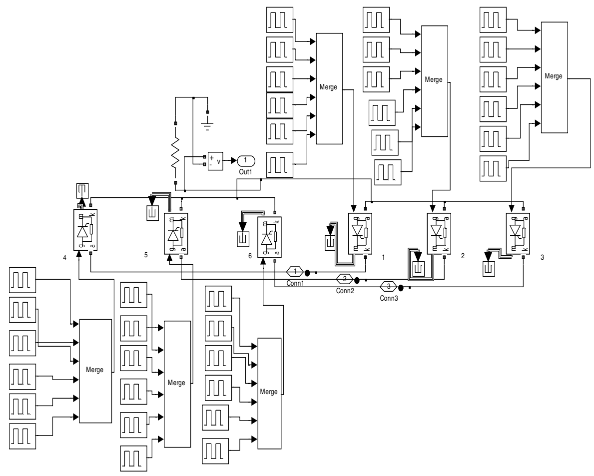

Fig.9 Sub system of three phase to three phase Cyclo converter with f/6 configuration

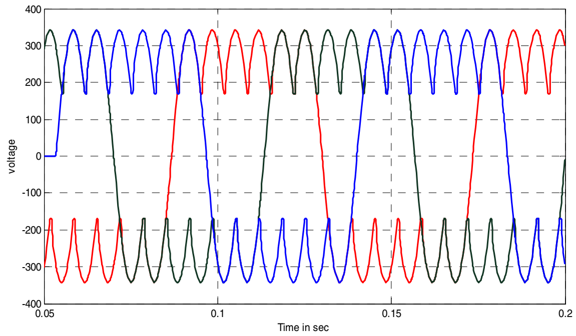

Fig.10 Waveforms of three phase to three phase Cyclo converter for f/6 configuration without firing angle

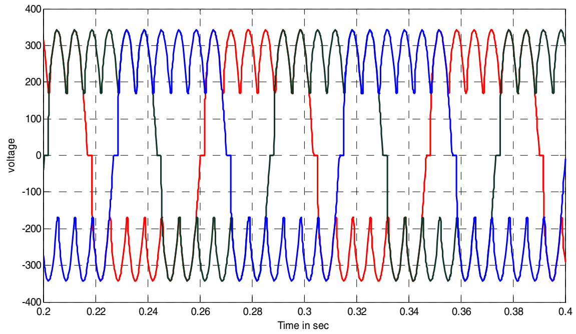

Fig.11 Waveforms of three phase to three phase Cyclo converter for f/6 configuration with 30^0 firing angle

C. Simulation for 3∅-3∅ step-up cycloconverter with f/3 configuration:

In this type of Cyclo converter the frequency will be increased from 'f' Hz to '3f' Hz. It means the time period reduced from 'T' sec to 'T/3' sec. In three phase Cyclo converter with '3f' Hz frequency only one pulse generator is used for each IGBT. Based on switching of IGBTs, consider the values of time period and pulse width values in pulse generator block. With R – load the waveforms have been shown below. If the load will be RL – load then the output waveform will be similar for certain value of inductor. The value of inductor will be consider from 250H to infinite before that the waveform will be distorted.

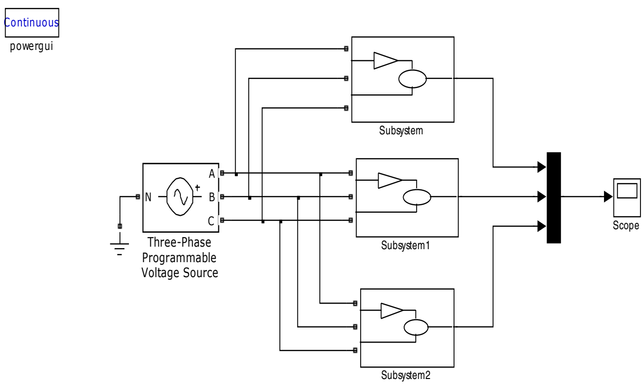

Fig.12 Waveforms of three phase to three phase cyclo converter with 3f configuration

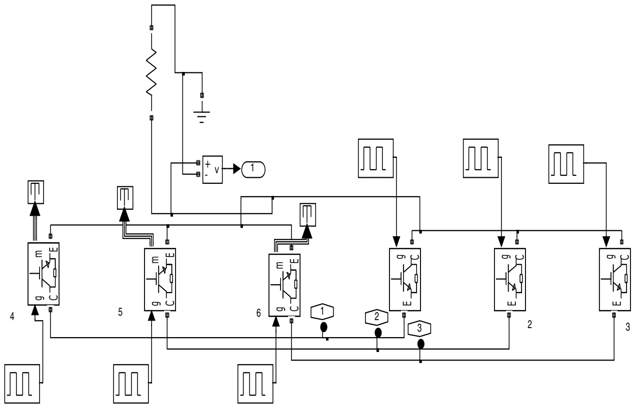
Fig.13 Sub system of three phase to single phase Cyclo converter with 3f configuration

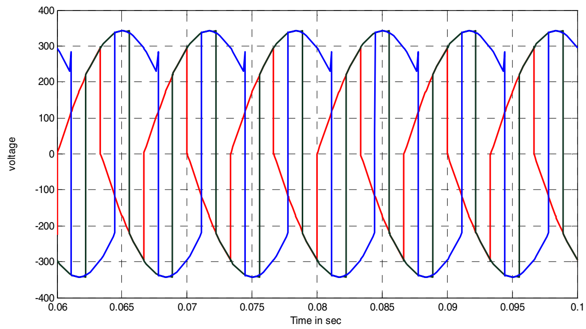

Fig.14 Waveforms of three phase to three phase Cyclo converter with 3f configuration

D. Simulation for 3∅-3∅ step-up cycloconverter with f/6 configuration:

In this type of Cyclo converter the frequency will be increased from 'f' Hz to '6f' Hz. It means the time period reduced from 'T' sec to '6T' sec. In three phase Cyclo converter with '6f'Hz frequency two pulse generators are used for each IGBT. Based on switching of IGBTs, consider the values of time period and pulse width values in pulse generator block.

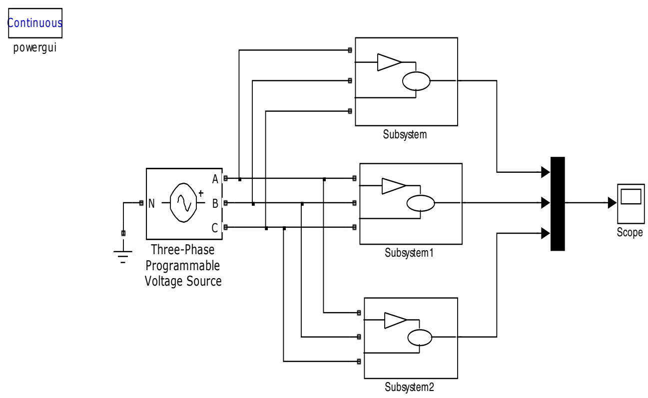

Fig.15 Three phase to three phase Cyclo converter with 6f configuration

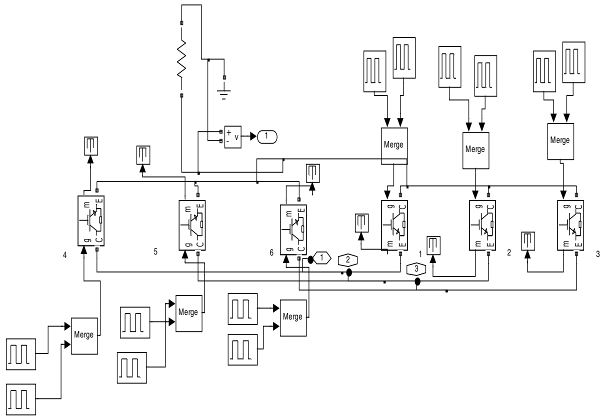

Fig.16 Sub system of three phase to three phase Cyclo converter with 6f configuration

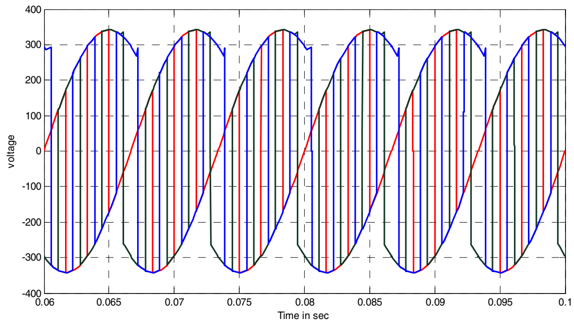

Fig.17 Waveforms of three phase to three phase cyclo converter with 6f configuration

VI. CONCLUSION

Cyclo converters with different configurations have been simulated and analyzed. Three phase to three phase step up and step down Cyclo converters with different configurations have been simulated and analyzed. Input and output waveforms have been compared for different types of Cyclo converters. Without and with firing angles also Cyclo converters have been simulated. Under no load condition.

References

[1] BurakOzpineci, Leon M. Tolbert, "Cycloconverters", University of Tennessee-Knoxville, Knoxville, USA.

[2] Gilliom, Jonathan, "Simulation and Performance of a High Frequency Cycloconverter", Monterey, California, USA, 2006.

[3] Cyril w. lander, "power electronics third edition-frequency conversion page no.181-195"

[4] Rezgar Mohammed Khalil, Maamoon Al-Kababjie, "Modeling and Simulation of multi-pulse Cyclo convereter fed AC induction motor and study of output power factor", Vol.15, No.1, University of Mosul, Iraq, 2005

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