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MATRIX CONVERTER: A REVIEW

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Abstract-

This paper presented a review on different basic features of a 3-phase to 3-phase matrix converter. The matrix converter has numerous advantages over conventional rectifier-inverter type power frequency converters. It consists of 9 bi-directional switches through which output phase is connected to any input phase. A three phase voltage-fed systemis connected to the input terminals of the converter. [1],

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I.INTRODUCTION

The term converter system is used to signify a static device that converts ac to dc, dc to ac, dc to dc or ac to ac. [2]we in this publication are basically interested in ac to ac converters. Thyratrons, mercury arc rectifiers, magnetic amplifiers, rehostatic control etc. were being used in conventional power controllers but now they are replaced by power electronic controllers using semiconductor devices. In this paper we are discussing ac to ac converters, classified below:

1.) Indirect converters(AC-DC-AC)
i) Voltage Source Inverters
ii) Current source inverters
2.) Direct converters(AC-AC)
i) Cycloconverter
ii) Matrix Converter

The main feature of the direct converters is to convert the magnitude as well as the frequency of the input into a desired magnitude. Then why do we use two of them for same grounds, in fact what is the disparity between a cycloconverter and a matrix converter. [3]

A cycloconverter is a device which would convert frequency in only integral multiples.

$$F_o = n F_i$$

$$\text{Or } F_o = F_i/n \text{ , } (n=1, 2, 3\ldots\ldots n) \quad (1)$$

The former one is known as step up cycloconverter and the later is known as step down cycloconverter. [3] Cycloconverters are direct ac to ac converters that can be categorized into naturally commutated cycloconverter (NCC) and forced commutated cycloconverter (FCC).

Whereas a matrix converter is a forced commutated AC to AC converter with a compact power circuit to provide sinusoidal output voltage with varying amplitude and frequency. It operates at unity power factor and is capable of regeneration. [4]

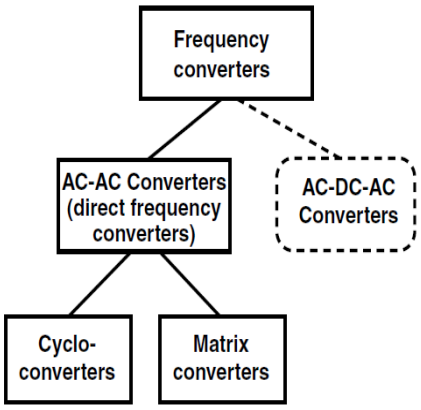

Fig.1 Block diagram representation of frequency converters

This publication is a review about various ac to ac topology that can provide both amplitude and frequency transformation. In section II we will discuss about the history of power electronic semiconductor devices, led by section III with detailed information of dc link converter, followed by section IV description of cycloconverters. In section V we will discuss about the matrix converter and its future aspect. Finallyconclusion in section VI.

II. HISTORY OF POWER ELECTRONIC SEMICONDUCTOR DEVICES

The initial high control electronic devices were mercury arc valves. Following the findings of Humphry Davy, a British chemist and inventor, who invented in the 19th century that when current flows through two rods an

electric arc isformed, when they are separated, the American inventor, Percy C. Hewitt, demonstrated in 1902 a system made up of glass bulb consisting of two electrodes one made of mercury and the other of steel, containing mercury vapor. [5]

In current systems the conversion is performed with semiconductor switching devices such as diodes, thyristors, and transistors. In earlier times we use Mercury-arc rectifiers for scheming electrical power, but the range for applications of mercury-arc rectifiers was partial.

A diode is a simple example of semiconductor devices. A p-type semiconductor is doped with a n-type of semiconductor on the same semiconductor. Current can flow from the p-region to the n-region. If a reverse voltage is applied, a depletion layer is formed and conduction stops.This depletion layer could be broked by using barrier potential.In 1947, Bell Laboratories created a switch that was controlled by voltage, which was known as a transistor. The invention of the transistor started a rapid and highly visible development in the remarkable revolution of communication and data processing.[5]

The switching speed of transistor was not fast then a fast switchable power semiconductor was developed known asthyristor, which was invented by William Shockley in 1950. A tyristor is similar to p-n diode but with extra layers inserted between the two outer p-n layers. A thyristor is a line commutated device and nota self commutated device,like a gate turn-off thyristors (GTOs). It was inventedin the middleof 1980s. A GTO is a thyristor in which if we apply negative gate current it can be turned off, this feature of GTO is not present in thyristor. [5]

Then the cycloconverters were invented and it was recognized that this provides the prospect of generating AC of variable frequency directly from a constant frequency AC supply. A cycloconverter is a very large and complicated system, as in industries and high power applications we require three-phase to three-phase cycloconverters which consist of thirty-six thyristors which make it so, hence it is generally used in high power application i.e. 1MW or above.The most commonly used applications of cycloconverters are:

- Speed Control of drives.
- Induction Heating.
- Slip-power recovery Scherbius drives
- Variable-speed,constant-frequency(VSCF) powergeneration forair-craft400Hzpower supplies

In the late 1980's Matrix Converters were invented by Alesina and Venturini. They anticipated a general model and a relative mathematical theory for converters with high frequency. The matrix converter does not need reactive components. The available output phase voltage of matrix converters isup to of the input phase voltage with full control of magnitude and phase; it does not need a dc-link capacitor or input inductor for energy storage. [5]

Two rules must be applied for safe operation:

- S.C. of input line must be avoided
- O.C. of output line must be avoided

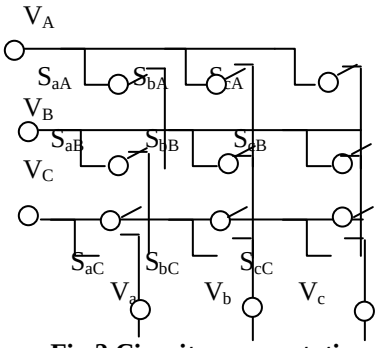

Fig.2 Circuit representation of matrix converter

III. D.C. LINKED CONVERTER

A D.C Linked converter consists of a diode rectifier, a small DC link capacitor and an open loop pulse width modulation system. The mains are connected to the input of the rectifier and the inverter output is connected to a series connection of an inductance and an EMF source, which represents the permanent magnet motor.

If the DC link current is continuous where V_{rms} is the RMS value of the line-to-line voltage of the mains the mean value of the DC link voltage will become [6]

$$\mathbf{V_{rms} = \frac{3\sqrt{2}\,V}{\Pi} = 1.35V.} \qquad \mathbf{(2)}$$

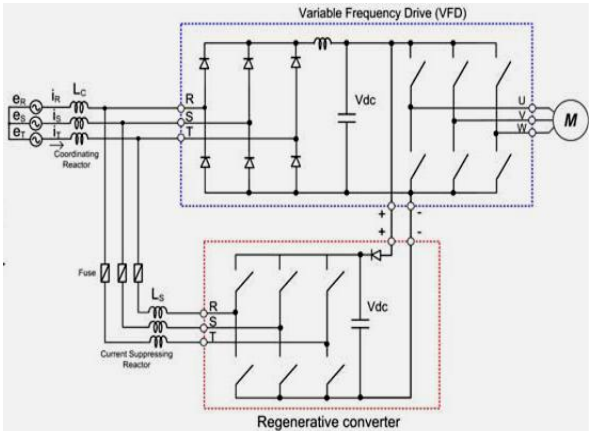

Fig. 3 Circuit representation of D.C link converter

The AC component of the DC link current can be handled using a polypropylene capacitor. This can reduce the converter size. The predictable life time of the converter is also longer than for a conformist design. [7]

IV. CYCLOCONVERTERS

The cycloconverter is introduced as a type of power controller, where an alternating voltage at supply frequency is transformed directly to a variable frequency alternatingvoltage without any dc link. This is a two-stage procedure with a midway dc stage. [7]

When 3-phase low frequency output is required, then three sets of phase-controlled 3-phase to single-phase are interconnected as shown in the figure below:

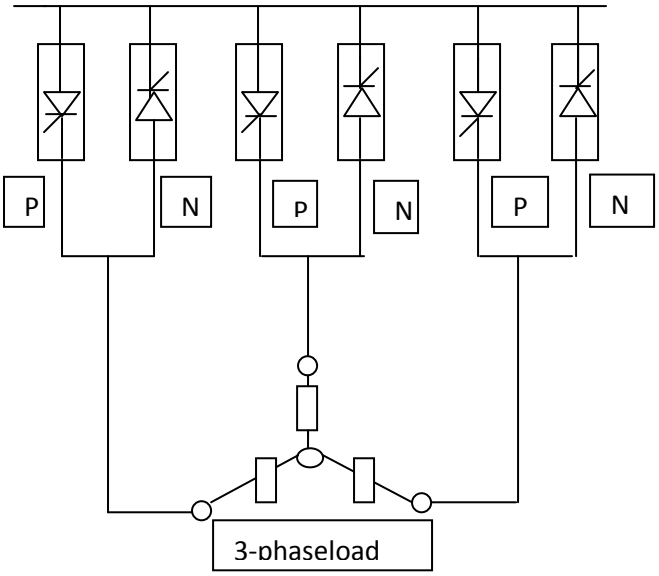

Fig.4 Circuit representation of cycloconverter $\alpha_2 = 180-\alpha_1$(3)

Where α_1 is the firing angle of the positive group and α_2 is the firing angle of the negative group [7]

Fundamental wave is generated by the two-quadrant phase converters. Positive current is carried by positive converter and negative by negative.

Advantages of Cycloconverters

- Direct frequency conversion without any intermediate stage.
- Operates at any power factor.
- Capable of regeneration.[8]

Disadvantages of cycloconverters

- Large no. of thyristors are required in cycloconverters.
- Complex control circuitry
- Output frequency is limited to integral multiples of input frequency.[8]

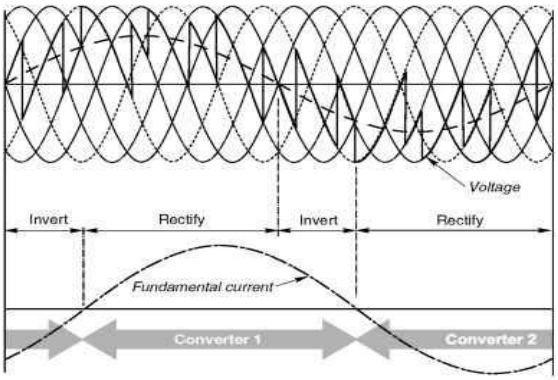

Fig.5 Output waveform of 3-phase voltage and current of cycloconverter

The shape output voltage deforms with an increase in output voltage and frequencydue to circulating current, therefore an additional inductor is used to limit the circulating current. It is used for 3-phase high power, low speed synchronous machine drives and rarely employed for induction motor drives.

New forms of cycloconverters are being invented. These new forms are influencing for more research interest.

V. MATRIX CONVERTERS

The matrix converter directly converts AC to AC despite of AC to DC to AC as in usual voltage source PWM AC Drives. They have ability to regenerate power and restrain input current harmonics.[3],[8]

The load voltage and the load frequency are controlled from zero to maximum value, using the Pulse-Width modulation techniques.

The bi-directional switches must be capable of permitting current flow in either direction.

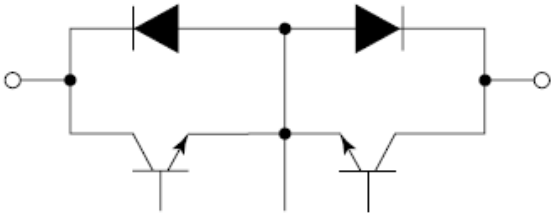

Fig.6 Bidirectional switches

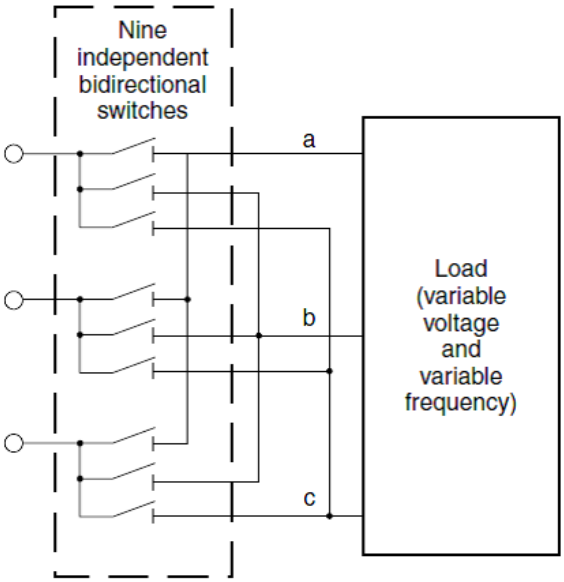

Fig. 7Block diagram representation of matrix converter

So the output voltages have to be generated unswervingly from the input voltages. When one by one sampling of each input voltage waveforms is done, the output waveform is obtained The sampling rate is greater than input and output frequencies, and the duration of each sample is mean value of the output waveform tracing the desired output waveform. Under this limitation, the maximum output voltage is equal to

v3/2 of the maximum input voltage this is an inherent limit of matrix converter.[8]

Advantages of Matrix Converters

- It has sinusoidal input and output waveforms
- Power flow in a matrix converter is bi-directional.
- Its input power factor can be controlled fully.
- Its energy storage requirement is also very low.[4]

Disadvantagesof Matrix Converters

- Its input to output voltage transfer ratio is limited to a particular value approx. 87%.
- Semiconductor devices used in matrix converters are more than Cycloconverters.
- Perceptive to disturbances.

Various Modulation control techniques of matrix converters are being used enlisted below:

- Venturini control method.
- Space vector modulation Technique

Under this technique we can use matrix converter as a space vector rectifier or as a space vector Inverter.

- Indirect space vector modulation for 3-phase matrix converter.
- Harmonic injection control of space vector modulation of matrix converter.

Matrix converters are devices which could be used for real world up to 100kW and above New devices and device technology will increase magnetism for research [4].

Applications of Matrix Converters

- Used in Aerospace industry.
- A.C fans and feed water pumps where high harmonic counter measuring is required.
- Cranes and Elevators.

VI. CONCLUSION

This publication presented a review of different conversion techniques used in the conversion of ac to dc or ac to ac. It is very important and useful to analyze all the techniques for future purposes and inventions of new techniques in each field. The invention of vector control method for converters is running slowly. Actually actions in the way of vector control of the matrix converter have appeared in recent times. [1]

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