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# ANALYSIS OF TOTAL HARMONICS DISTORTION USING MULTIPULSE CONVERTER

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## Abstract

The work presents a deep effort towards analyzing line commutated controlled multi-pulse converters for solving the harmonic problem. The effect of increasing the number of pulses on the performance of AC to DC converters has been analyzed. For performance comparison the major factors considered are the ripple percentage, form factor and the total harmonic distortion (THD). The effects of load variation on multi-pulse AC to DC converters have also been investigated. This work presented 6, 12, 24 and 36 pulse converters.

**Key Words**: Multipulse converter, Harmonics distortion, Ripple counters.

## 1. Introduction

Three-phase controlled rectifiers have a wide range of applications, to large high voltage direct current (HVDC) transmission systems from small rectifiers. They are used for electrochemical processes, wide range of motor drives, controlled power supplies, traction equipment and other applications. The commutation process can be classified into two important categories namely: Line-commutated controlled rectifiers and Force-commutated pulse width modulated rectifiers

There are several techniques primarily adopted for the mitigation of harmonics in a 3-phase converter and multi-pulse converters fall in the same category of remedial measures. Multi pulse converters are the most fundamental solution for harmonic problem in a three-phase converter system. With the advancements in technology advances these converters and other power electronic devices with integrated magnetic featuring high input power quality and better performance would be required by many industrial, commercial applications, power supplies. The effect of increasing the number of pulses of AC to DC converters directly alters its performance parameters like ripple percentage, form factor and the total harmonic distortion.

Multipulse converters are converters providing more than six pulses of DC voltage per cycle from AC input or the converter having more steps in AC input current than that of six pulse bridge rectifier supply current. Phase shifting transformers are used to derive multipulse phase supply from three-phase AC mains using different combinations of transformer windings such as star, delta, zigzag, polygon, fork etc. In this thesis we use zigzag transformer.

The phase-shifting transformers play a key role in the multi-pulse rectifier's performance. Jiaopu et.al [1] discussed commonly used basic connections of phase-shifting transformer, such as Scott, polygon, star/delta, extended-delta and zigzag and gave the analyses and comparisons between them. Focusing on 12-pulse phase-shifting transformers, the research highlighted possible strategies from basic connections to 12-pulse phase-shifting transformers which illustrate the evolution and its basic principles which may be extended to higher pulse converters.

Singh et.al [3] analyzed the performance of multi-pulse electronic load controller for isolated asynchronous generator, as load controller conventional electronic based six pulse uncontrolled rectifier contains large content of harmonics.

A comparative study of three phase controlled multi pulse converters was presented by [4] for biomass, gas turbine, wind system based power plant, diesel, hydro, , and incorporated input current shaping of controlled rectifier using multi-pulse current shaping concept.

The author Xigeng et.al [6] introduced the realization of phase-shifting of the multi-pulse converter transformer and the method for calculating stretch phase-shifting angle, triangle voltage and the 7 number of windings and analyzed the simulation for the 30-pluse rectification system based on this transformer. Arvindan et.al [7] proposed two 24-pulse rectifier topologies based on phase shifting using conventional magnetic over PSCAD environment.

## 2. Controlled Rectifiers

There are two types of conversion techniques , one is uncontrolled in which diodes are implemented and other is controlled in which thyristors are implemented respectively [8].The performance improvement is achieved for total harmonics distortion (THD) in input current, DC voltage ripples and form factor. Three-phase controlled rectifiers have a wide range of applications, to large high voltage direct current (HVDC) transmission systems from small rectifiers. They are used for electrochemical processes, wide range of motor drives, controlled power supplies, traction equipment and other applications.

## 2.1Three-phase Half-wave Rectifier

To control the load voltage, the half-wave rectifier uses three common-cathode thyristor arrangements. The thyristor will conduct (ON state), when the anode-to-cathode voltage VAK is positive and a firing current pulse iG is applied to the gate terminal. An angle α controls the load voltage by delaying the firing pulse.

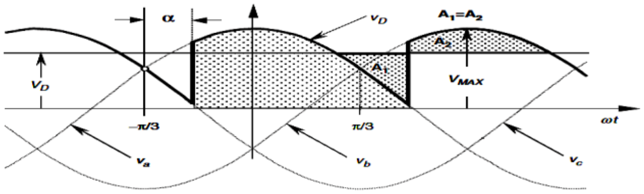


**Fig 1: Instantaneous DC voltage VD, firing angle α and average dc voltage VD of half wave rectifiers.**

The thyristor goes to the non-conducting condition (OFF state) when the following thyristor is switched ON, the current reached a negative value.

$$V_D = \frac{V_{Max}}{2/3\pi}\int_{-\frac{\Pi}{3}+\alpha}^{\frac{\Pi}{3}+\alpha} \cos\omega t.\, d(\omega t) \qquad (1)$$

## 2.2Six-pulse or Double Star Rectifier

The thyristor side windings of the transformer shown in Fig.2, form a six-phase system, resulting in a six-pulse star point (midpoint connection). Disregarding commutation overlap, each valve conducts only during 60◦ per period.

$$V_D = \frac{V_{Max}}{\pi/3}\int_{-\frac{\Pi}{6}+\alpha}^{\frac{\Pi}{6}+\alpha} \cos\omega t.\, d(\omega t) \qquad (2)$$

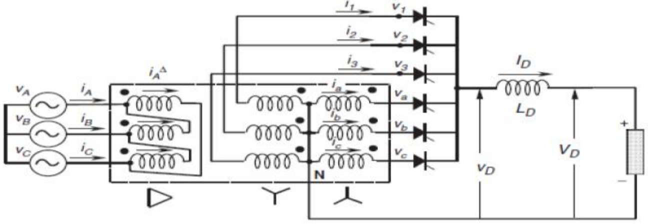


**Fig 2: Six-pulse rectifier**

## 2.3 Three-phase Full-wave Rectifier

Parallel connection via inter phase transformers permits the implementation of rectifiers for high current applications. For high voltage series connection is also possible, as shown in the full-wave rectifier of Fig.3. With this arrangement, it can be seen that the three common cathode valves generate a positive voltage with respect to the neutral, and a negative voltage is produced by the three common anode valves.

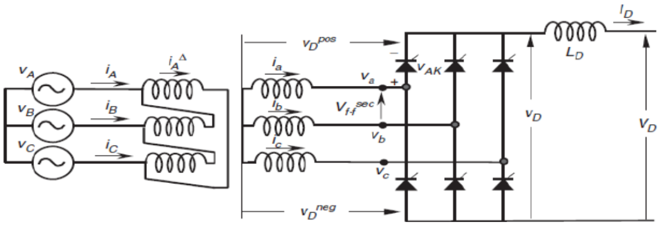


**Fig 3: Three-phase full-wave rectifier**

$$V_D = \frac{2V_{Max}}{2\pi/3}\int_{-\frac{\Pi}{3}+\alpha}^{\frac{\Pi}{3}+\alpha} \cos\omega t.\, d(\omega t) \qquad (3)$$

## 2.3Harmonic Distortion

The currents of the line-commutated rectifiers are far from being sinusoidal. For example, the currents generated from the 3 phase full wave rectifier have the following harmonic content.

$$i_A = \frac{2\sqrt{3}}{\Pi}\left(\cos\omega t - \frac{1}{5}\cos 5\omega t + \frac{1}{7}\cos 7\omega t - \cdots..\right) \quad (4)$$

Some of the characteristics of the currents, obtained from Eq. (3.35) include: (i) the absence of triple harmonics; (ii) the presence of harmonics of order 6k ± 1 for integer values of k; (iii) those harmonics of orders 6k+1 are of positive sequence; (iv) those of orders 6k − 1 are of negative sequence; (v) the rms magnitude of the fundamental frequency is,

$$i_{1=\sqrt{6}/\Pi}\ I_D \qquad (5)$$

and the rms magnitude of the nth harmonic is

$$I_n = i_1/n \qquad (6)$$

## 3. Formulation of Pulse converters

The 12-pulse rectifier was obtained with a 30◦ phase shift between the two secondary transformers. The basis for increasing pulse configurations is provided by the parallel transformers. For instance, the operation of 24 pulses is achieved by means of four transformers with 15◦ phase shift, and 48-pulse operation requires eight transformers with 7.5◦ phase shift. An ingenious and very simple way to reach high pulse operation is shown in Fig.4. This configuration is called dc ripple reinjection. It consists of two parallel converters connected to the load through a multistep reactor. The reactor uses a chain of thyristor-controlled taps, which are connected to symmetrical points of the reactor.

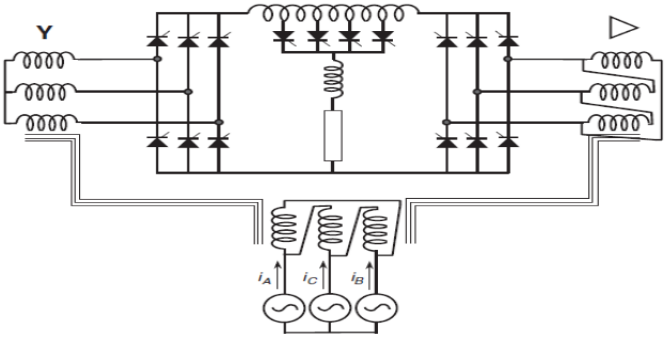


**Fig 4: DC ripple reinjection technique of pulse operation**

The thyristors located at the reactor is fired at the right time; high-pulse operation is reached. The pulse level operation depends on the number of thyristors connected to the reactor. The basic level of operation is multiplied to the two converters.

## 3.1 HVDC Power Transmission

The use of HVDC systems for interconnections of asynchronous systems is an interesting application. Some continental electric power systems consist of asynchronous networks such as those for the Texas, Quebec networks in North America, and islands loads such as that for the Island of Gotland in the Baltic Sea make good use of the HVDC interconnections.

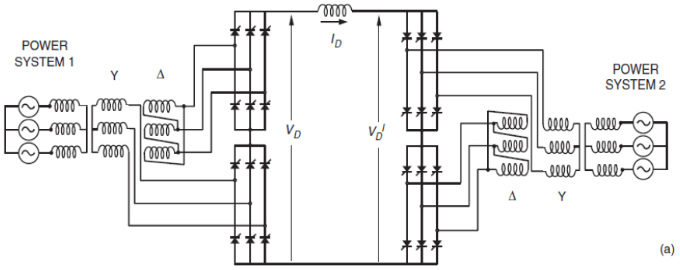


**Fig 5: Typical HVDC circuit system**

# 4. Simulation Model of Pulse Converters

The present ac–dc converters are cost-effective for universal line and commercial voltage applications but are unreliable and fault prone for higher power applications. Thus, to lighten these problems, multi stage and multi pulse converters have been developed with the flexibility to compliment with custom power switching modes. For high and ultra high voltage levels the soft switching multi pulse converters offers attractive merits because the component count suffices with the cost of the system.

## 4.1Six-Pulse Converter

A six pulse thyristorized converter circuit is shown in Fig 6, below. A star-zigzag transformer is used at input side of the converter in order to provide a variable phase shift if desired.

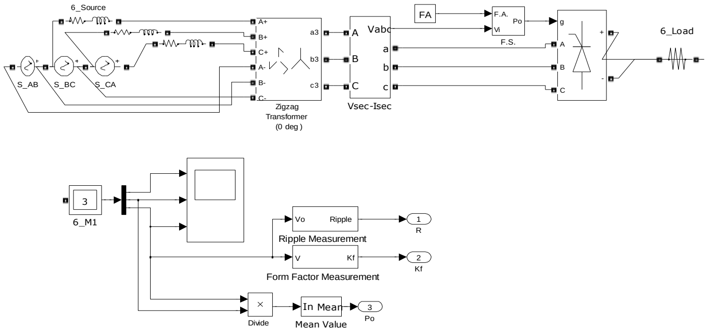


**Fig. 6 Six pulse controlled converters with resistive load**

## 4.2 Twelve-Pulse Converter

A twelve pulse thyristorized converter circuit is shown in Fig 7. Two star-zigzag transformers are used at input side of the converter in order to provide a variable phase shift along with two universal bridges.

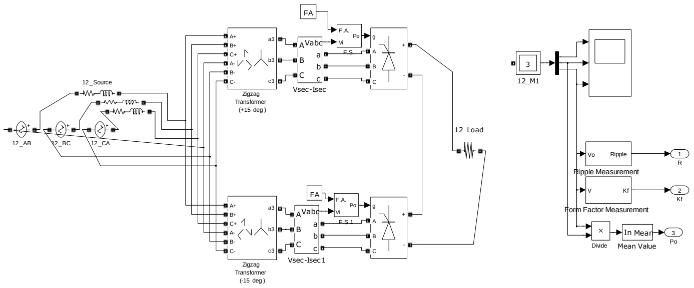


**Fig. 7 Twelve pulse controlled converters with resistive load**

## 4.3 Twenty Four-Pulse Converter

The below Fig 8, A which is shown below is having a twenty four pulse thyristorized converter circuits. Along with two universal bridges in each group at input side the converter requires 4 star-zigzag transformers, two on each positive phase group and negative phase group

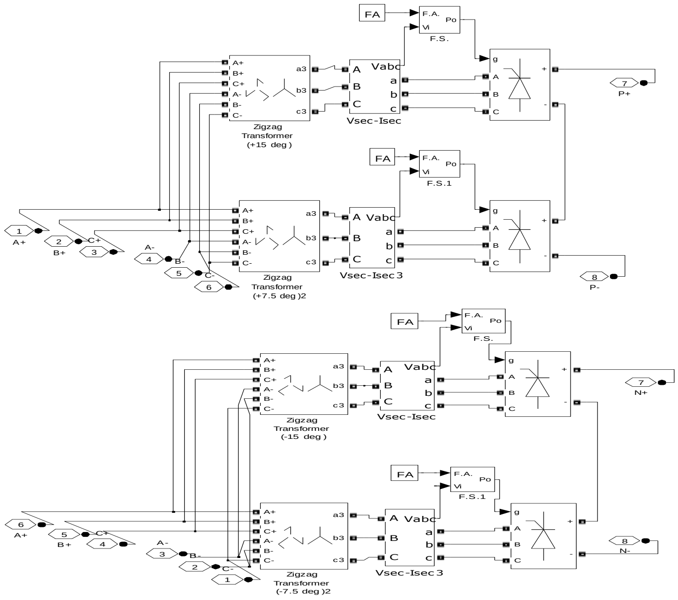


**Fig. 8 Twenty Four pulse controlled converters with resistive load**

## 4.4 Thirty Six-Pulse Converter

The simulation model for thirty six pulse thyristorized converter circuit is shown in Fig.9. The converter requires 6 star-zigzag transformers at input side of the converter, 3 in positive phase group and 3 in negative phase group along with three universal bridges in each group

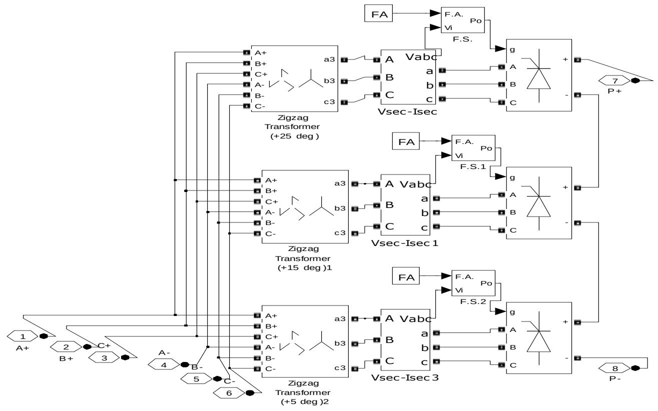


**Fig. 9. Thirty six pulse controlled converters with resistive load**

## 5. Results and Discussion

The six and 12 pulse converter model based upon simulation for an output power of 5000 watts provided for voltages, load current and source current, are illustrated in Fig.10.

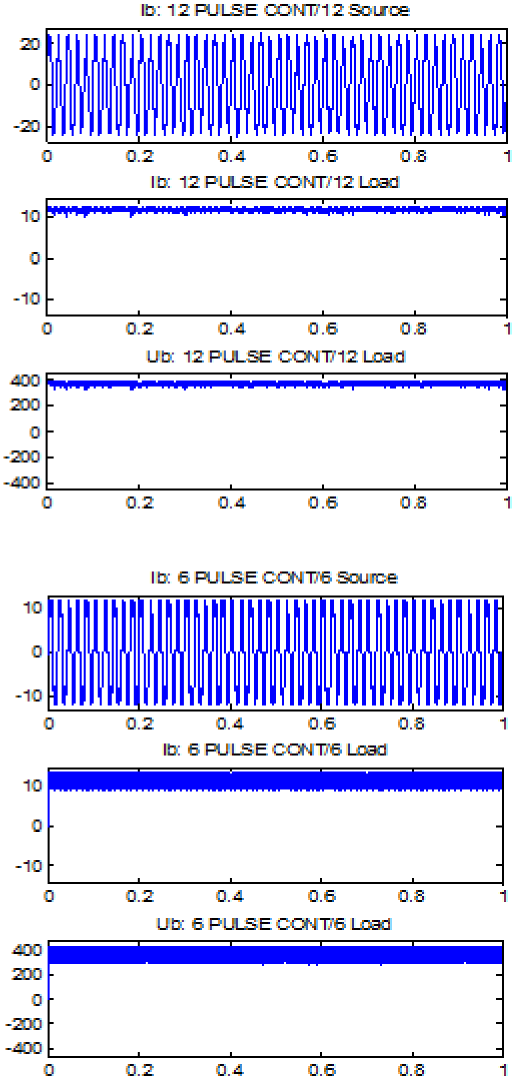
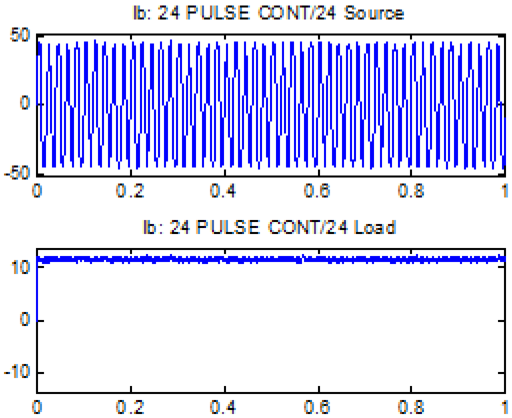


**Fig.10.Ripple factor, form factor and mean value of voltage respectively of 12 and 6 pulse generator**



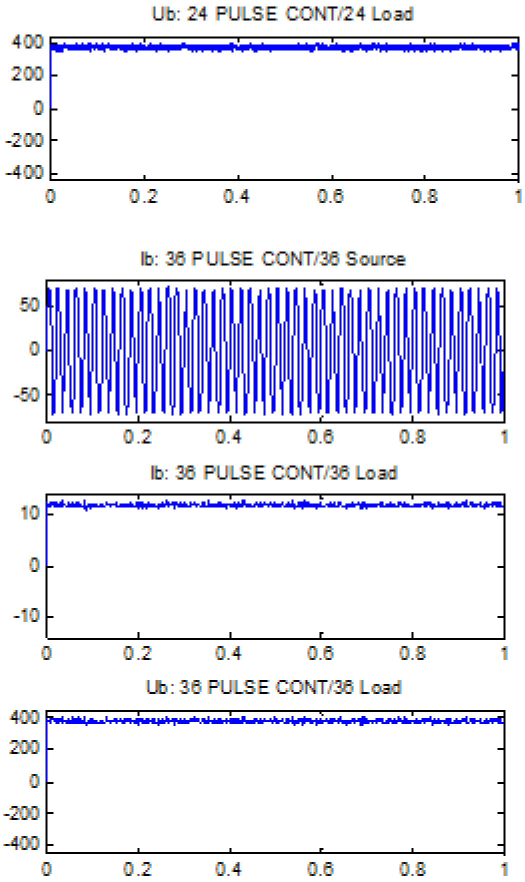


**Fig.11.Ripple factor, form factor and mean value of voltage respectively of 24 and 36 pulse generator**

## 6. CONCLUSION

An analysis of simulation results was performed and the following conclusions can be drawn without loss of generality.

1. Increasing the number of converter pulses reduces the voltage ripples.

2. Form factor is also improves though insignificantly.

3. The harmonics in the supply system are almost eliminated.

4. The voltage ripples increase as the firing angle is increased.

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