# MITIGATION OF HARMONICS USING THYRISTOR BASED 12 PULSE VOLTAGE SOURCE PWM RECTIFIER

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## Abstract

*Three-phase thyristor rectifiers have been used in industries for obtaining a variable dc voltage, but they have a problem of including large lower-order harmonics in the input currents. For high-power applications, a 12-pulse configuration is useful for reducing the harmonics, but it still includes the (12m ± 1) th (m: integer) harmonics. In order to further reduce the harmonics, this paper proposes to supply a ramp wave voltage at the input of a 12-pulse phase-controlled rectifier. Theoretical investigation to reduce harmonics is presented, and a strategy to control the regulated voltage and unity power factor at input side based on 12 pulse modulation technique.*

*This paper discuss the impact of using 3-phase and 12-pulse rectifier circuit commonly found in unity power factor at input ac mains and regulate output voltage. The 12-pulse topology is known to be more expensive, but produce the least input current harmonics. However, the latter statement is completely true under balanced line conditions. In practice, the lines are inherently unbalanced. Hence, the question of whether the 12-pulse rectifier will indeed perform better in terms of the harmonics injected to the line is still under on-going discussions. This presents the modelling and simulation of both rectifier topologies to compare their input current and regulated output voltage harmonics. The rectifiers are modelled using the MATLAB/SIMULINK simulation model and several common cases conditions will be simulated to compare their harmonic levels.*

***Keywords**: Pulse Width Modulation (PWM), unity Power factor (UPF).*

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## 1. INTRODUCTION

Power electronics equipments become more widely used. Unfortunately, the standard diode bridge rectifiers at the input side cause several problems as: Low input power factor, high values of harmonic distortion of ac line currents, and harmonic pollution on the grid. In recent years, the research interest in the area of PWM rectifiers has grown rapidly [1] [2]. The PWM rectifier offers several advantages such as: control of DC bus voltage, bi-directional power flow, unity power factor, and sinusoidal line current. Many pulse-width modulation (PWM) techniques have been adopted for these rectification devices to improve the input power factor [9]. The phase and amplitude control (PAC) seems to be the simplest structure and provides a good switching pattern. The current regulating fashion in synchronous frame has the advantages of fast dynamic current response, good accuracy, fixed switching frequency and less sensitive to parameter variations. Several strategies [10]–[14] were proposed for 12-pulse diode rectifiers to further reduce the ($12m \pm 1$) th harmonics.

When a three-phase input is available, rectifiers can come in a variety of pulses such as the 6-pulse and 12-pulse. As the number of pulses increases, the input characteristic improves. This results from a greater number of pulses in a given period which is due to the larger number of devices used [4] [5] [6] [7] [8]. This, in turn, makes the 12-pulse rectifier more costly. However, the analysis commonly done to exhibit the advantage of lower input harmonics, control of DC bus voltage, bi-directional power flow, unity power factor, and sinusoidal line current for the 12-pulse is done [4][5][6]. For high-power applications, a 12-pulse configuration is useful for reducing the harmonics, but it still includes the (12m ± 1) th (m: integer) harmonics. In order to further reduce the harmonics, this paper proposes to supply a ramp wave voltage at the input of a 12-pulse phase-controlled rectifier.

## 2. PROBLEM FORMULATION

### 2.1 Current control and balance of the neutral point at the DC-side:

It is possible to separately control the input current shape in each branch of the bridge by inserting a bidirectional switch into the node. The switch controls the current by controlling the magnetization of the inductor. Switching charges the inductor which drives the current through the bidirectional switch. Deactivating the switch increases the current to bypass the switch [3]. This results in a negative voltage across the inductor and drains it. This demonstrates the ability of the topology to control the current in phase with the mains voltage (PFC capability).

## 2.2 Maintaining regulated output voltage:

To draw input current for longer periods boost-type switching regulators are used [9]. If the output voltage is too high, the regulation element will normally be commanded to produce a lower voltage.

Ripple factor is the variation of the amplitude of DC (Direct current) due to improper filtering of AC power supply which can be improved by increasing the number of pulses.RF=vrms/vdc.

Harmonics must be mitigated on the secondary side of the transformer to provide proper input to the rectifier. A better Transformer utilization factor is obtained using three phase 12 pulse rectifier.

$$\mathrm{TUF} = {}^{\mathrm{V_{DC}}}\!/_{\text{Effective Transformer VA Rating}}$$

## 3.12 PULSE PWM RECTIFIER MODEL

Twelve-pulse configuration consists of two sets of converters connected as shown in fig1. The currents generated from the Graetz rectifier have the following harmonic content:

### i. Star connection

$$\mathrm{i_A} = \frac{2\sqrt{3}}{\pi}\mathrm{I_D}\left(\cos\omega t - \frac{1}{5}\cos 5\omega t + \frac{1}{7}\cos 7\omega t - \frac{1}{11}\cos 11\omega t + \cdots\right)$$

### ii. Delta connection

$$\mathrm{i_A} = \frac{2\sqrt{3}}{\pi}\mathrm{I_D}\left(\cos\omega t + \frac{1}{5}\cos 5\omega t - \frac{1}{7}\cos 7\omega t - \frac{1}{11}\cos 11\omega t + \cdots\right)$$

**iii. The resultant AC current** is given by the sum of the two Fourier series of the star and delta Connection

$$\mathrm{i_A} = 2\left(\frac{2\sqrt{3}}{\pi}\right)\mathrm{I_D}\left(\cos\omega t - \frac{1}{11}\cos 11\omega t + \frac{1}{13}\cos 13\omega t - \frac{1}{23}\cos 23\omega t + \cdots\right)$$

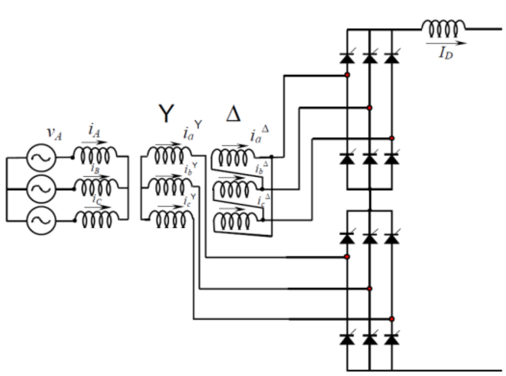


**Fig-1** Circuit diagram of 12-pulse Configuration

## 3.1 Simulink model diagram

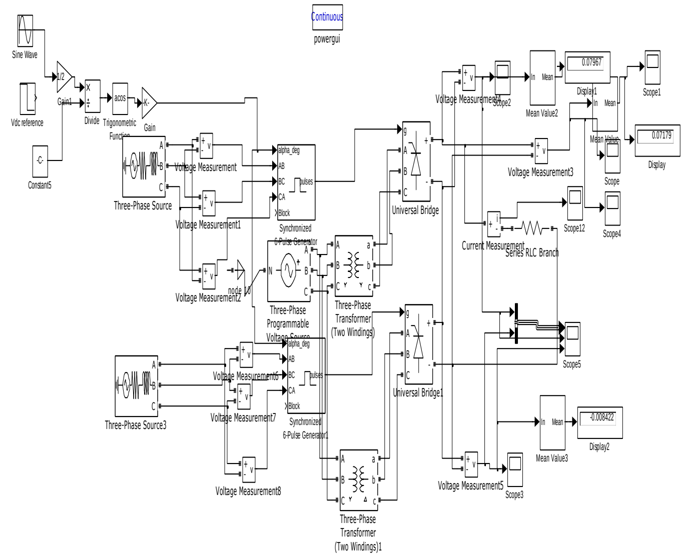


**Fig-2** Simulink model of 12 pulse PWM rectifier

Thyristor based voltage source twelve pulses PWM rectifier is a combination of two six pulse rectifier with R load has been considered.

## 3.2 Comparison of the various factors required for obtaining pure DC link output, for three pulse and twelve Pulse Bridges:

| Parameters | 3 phase star | 12pulsebridge |
|---|---|---|
| Rectified voltage-$V_{DC}$ | 0.827. $V_s$ | 3.308. $V_s$ |
| RMS output voltage-$V_L$ | 0.84. $V_s$ | 3.310. $V_s$ |
| Form factor-FF | 1.0165 | 1.00005 |
| Ripple factor-RF | 0.182 | 0.01 |
| Rectification Ratio-η | 0.986 | 1.00 |
| Transformer utilization factor-TUF | 0.73 | 0.97 |
| Fundamental ripple frequency-$f_R$ | 3. $f_{mains}$ | 12. $f_{mains}$ |

## 4. ANALYSIS OF THYRISTOR BASED 12 PULSE AND IGBT BASED 3 PHASE RECTIFIER MODEL.

The essential requirements for the bridge are:

- Secondary voltage is sinusoidal
- $V_s$ (t)= $V_s$ sinωt

- Resistive load
- Ideal devices(no device losses)

Series connection for high voltage is also possible, as shown in the full wave rectifier of circuit. With this arrangement, it can be seen that the three common cathode valves generate a positive voltage respect to the neutral, and the three common anode valves produce a negative voltage. The result is a dc voltage twice the value of the half wave rectifier. Each half of the bridge is a three-pulse converter group. This bridge connection is a two-way connection, and alternating currents flow in the valve-side transformer windings during both half periods, avoiding DC components into the windings, and saturation in the transformer magnetic core. These characteristics made them also called Graetz Bridge the most widely used line commutated thyristor rectifier. The configuration does not need any special transformer, and works as a six-pulse rectifier. The series characteristic of this rectifier produces a DC voltage twice the value of the half-wave rectifier. The load average voltage is given by:

$$V_D = \frac{3\sqrt{2}.V_{f-f}^{sec}}{\pi}\cos\alpha \approx 1.35V_{f-f}^{sec}\cos\alpha$$

Where VMAX is the peak phase-to-neutral voltage at the secondary transformer terminals, Vf-N rms its rms value, and Vf-f sec the rms phase-to-phase secondary voltage, at the valve terminals of the rectifier. Where as

The three phase voltage source rectifier structure. In order to setup math model, it is assumed that the AC voltage is a balanced three phase supply, the filter reactor is linear, and IGBT is ideal switch and lossless [5].

Average DC voltage:

$$V_{dc} = \frac{3\sqrt{3}\sqrt{2}V_{rms}}{\pi} \;;\quad V_{dc} = \frac{3\sqrt{3}\sqrt{2}V_{rms}}{\pi}\text{Cos}\alpha$$

## 5. SIMULATION RESULTS

At t=200 ms, a 10-kW load is switched-in. We can see that the dynamic response of the DC regulator to this sudden load variation (10 kW to 20 kW) is satisfactory. The DC voltage is back to 500 V within 1.5 cycles and the unity power factor on the AC side is maintained.

Comparison of IGBT based 3-phase rectifier and Thyristor based 12pulse PWM model with sine as input signal.

### 5.1 The transient response of the output voltage during the load variation.

**Case (i)**

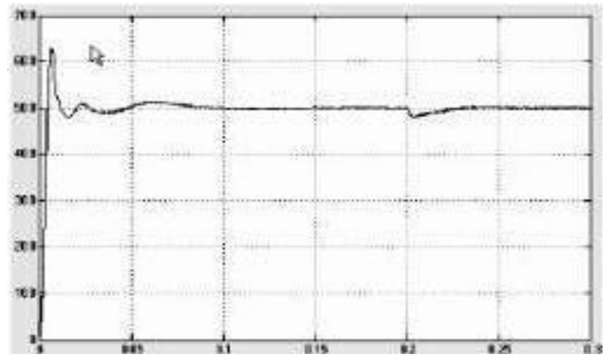

**Fig-3** DC link voltage obtained using three pulse Rectifier

**Case (ii)**

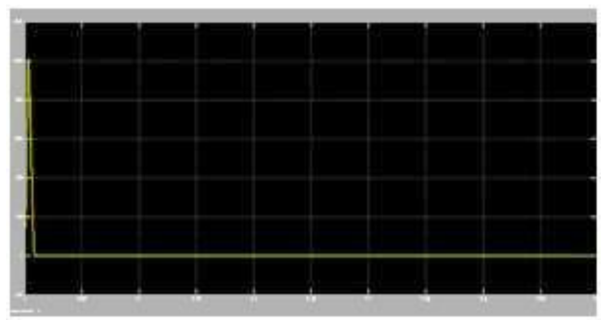

**Fig-4** DC link voltage obtained using twelve pulse rectifier

Simulation results show that the DC-Link voltage is little affected and the ripple is very weak, which indicates that the controller can achieve DC voltage constant.

### 5.2 Transient response of input current for a step load change.

**Case (i)**

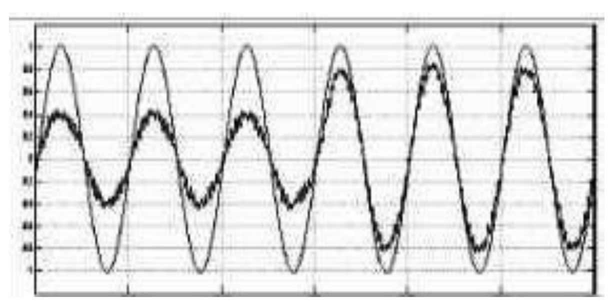

**Fig-5** Three phase source voltage and source Currents in three pulse rectifier

Time (sec) in X-axis and Phase voltages in Y-axis. Simulation results here uu, uv, Uw and iu, iv, iw are each phase voltage and current of grid, respectively .we can see the power factor is near 1 and the currents are also sinusoidal, which means the controller achieves harmonic suppression. (b) Shows that the DC-Link voltage is little affected and the ripple is very weakly, which indicates that the controller can achieve DC voltage constant.

**Case (ii)**

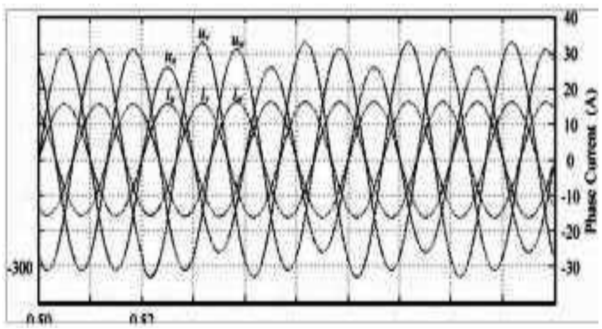


**Fig-6** Three phase source voltage and source currents in twelve pulse rectifier

## CONCLUSIONS

This paper specifies the MATLAB/SIMULATION model. Comparison of performance for 3 pulse and 12 pulse PWM rectifiers is done. Best result of ripple factor, efficiency, and unity input power factor at input mains, harmonics reduction and regulated output voltage is obtained using twelve pulse PWM rectifier. As the number of pulses increases harmonic reduction will be better and hence a better DC link output voltage is achieved. This idea can be extended by using different control strategies like z-converters.

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