Global Journal of Researches in Engineering: F
Electrical and Electronics Engineering
Volume 15 Issue 9 Version 1.0 Year 2015
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 2249-4596 Print ISSN: 0975-5861

Harmonics Cancellation and Alleviation of Ripple Content from AC-DC Uncontrolled Rectifier by Pulse-Multiplication Technique using Phase-Shifting Transformer

By MD Nasmus Sakib Khan Shabbir, Fatiha-Tul Jannat, Md. Atiqur Rahman, Md. Shohel Rana & Kajal Chakrabarty

Bangladesh University of Business and Technology, Bangladesh

Abstract- Harmonic distortion is a huge problem for the power systems. But harmonic distortion can be controlled using some unique methods with the utility systems. This paper discusses the impact of using 12- pulse and 24-pulse rectifier circuit. The 24-pulse topology is generally more expensive, but produces the least Input current harmonics. In this paper pulsemultiplication technique is used to mitigate the harmonic distortion from the input line current. Phase-shifting transformers are used to produce 24-pulse from 12- pulse. A comparison between 12-pulse and 24-pulse rectifier also shown in this paper. Operation of the circuits is verified through computer simulations.

Keywords: diodes, phase-shifting transformer, 12-pulse and 24-pulse rectifier.

GJRE-F Classification: FOR Code: 290901

Harmonics Cancellation and Alleviation of Ripple Content from AC-DC Uncontrolled Rectifier by Pulse-Multiplication Technique using Phase-Shifting Transformer

MD Nasmus Sakib Khan Shabbir α, Fatiha-Tul Jannat σ, Md. Atiqur Rahman ρ, Md. Shohel Rana ω & Kajal Chakrabarty ¥

Abstract- Harmonic distortion is a huge problem for the power systems. But harmonic distortion can be controlled using some unique methods with the utility systems. This paper discusses the impact of using 12-pulse and 24-pulse rectifier circuit. The 24-pulse topology is generally more expensive, but produces the least Input current harmonics. In this paper pulse-multiplication technique is used to mitigate the harmonic distortion from the input line current. Phase-shifting transformers are used to produce 24-pulse from 12-pulse. A comparison between 12-pulse and 24-pulse rectifier also shown in this paper. Operation of the circuits is verified through computer simulations.

Keywords: diodes, phase-shifting transformer, 12-pulse and 24-pulse rectifier.

I. Introduction

Development of our technology in recent years, the direction of research has shifted to power electronics from power systems to produce the most efficient energy conversion. The power electronics is giving us the opportunity to shape and control large amounts of power with better efficiency. Low cost, smaller size and high energy efficiency are possible because of power electronics. Within the next 30 years, power electronics will shape and condition the electricity somewhere in the transmission network between its generation and all its users.[1] Diode is called the first solid state electronic device. Now-a-days it becomes a weighty part of power electronic era. Diode rectifiers are used in several power systems. Diode bridge is specially used in high-power applications. Only diode contain some magnificent characteristics such as availabile, light weight, compact, high efficiency, robust for fault high current, less emission noises and etc. Three phase diode bridge constructed with six diodes. It can operate with or without transformer.

Like other non-linear devices diode also affected by harmonics. Harmonics are multiples of the

Like other non-linear devices diode also affected by harmonics. Harmonics are multiples of the

fundamental frequency. The deviation from perfect sine wave isknown as harmonic distortion. Harmonic is acceptablewithin limit. Increase in core losses due to increased iron losses in transformers occured by harmonic currents at harmonic frequencies. It also increased copper losses and stray flux losses result in additional heating, and winding insulation stresses, especially if high levels of *dv/dt* (i.e., rate of rise of voltage) are present. Temperature cycling and possible resonance between transformer winding inductance and supply capacitance, line notching problems are produced by harmonics. [2]

Several harmonic mitigation procedure are available using diode rectifiers. Some of them provide fine uncontrolled dc voltage without harmonic pollution . Every configurations cannot fullfill the demand like auto-transformer based schemes fails due to higher rating magnetic, higher number of bridges, resulting in enhancement of capital cost. [3]

This paper work with the three-phase multi-pulse AC to DC conversion system employing a phase-shifting transformer and a three-phase uncontrolled bridge rectifier between the supply and load side of the system. Every such converter provides 6-pulse ripple components on the output voltage, so in order to produce more sets of 6-pulse systems, a uniform phase-shift is required and hence with proper phase-shifting angle, 12, 18, 24, 30, and higher pulse systems can be produced.[4] Phase shifting transformer based configurations are really cost effective and reliable than others. In this paper we design a ac-dc converter with limited harmonic distortion with the help of phase shifting transformer. This paper represent an unique 24-pulse converter with bridge rectifier which is able to control harmonic distortion and provide best ripple factor in the output. This can be achieved by applying pulse-multiplication technique.

Author α σ ρ ω ¥ : Bangladesh University of Business and Technology.
e-mail: eng.sakib@gmail.com

II. Circuit Topology

a) Pulse Circuit schemes

Fig 3.1 shows a simplified circuit diagram of a three-phase twelve-pulse diode rectifier. The resistor and inductance RLin is the total inductance including the line inductance, transformer reactance, and line reactor between the utility and the rectifier. A single unit 3-phase rectifier is called 6-pulse rectifier. Thus, a 12-pulse rectifier have 2x6-pulse rectifier. Phase-shifting not only reduce the harmonic input current but also reduces the ripple on the DC output of the rectifier. Three phase full wave rectification diodes D1, D2, D3, D4, D5, D6 are numbered in order of conduction sequences and each one conduct for 120^0. The conduction sequence for diodes is D1D2, D3D2, D3D4, D5D4, D5D6 and D1D6.

When phase voltage V_{ab} starts D1D6 conduct for 60^0 and for V_{ba} the negative phase voltage starts D3D4 conduct with the supply. Similarly V_{bc} and V_{cb} phase voltage converted to dc at the supply side by connecting D3D2 and D5D6 that time. Lastly Vca and Vac converted to dc using sequence D1D2 and D5D4. The average output voltage is found:

$$V_0 = \frac{2}{\frac{2\pi}{6}} \int_0^{\frac{\pi}{6}} \sqrt{3} V_m \cos\omega t \, d(\omega t)$$

$$= 1.654 V_m ; \text{-----------------------------} \quad (1.1)$$

Where Vm is the peak value of rms voltage.

When load is purely resistive the rms value of the diode current is :

$$I_{rms} = \left[\frac{4}{2\pi} \int_0^{\pi/6} I_m^2 \cos^2 \omega t \, d(\omega t) \right]^{\frac{1}{2}}$$

$$= 0.5518 I_m \text{ -----------------------------} \quad (1.2)$$

Supply the three phases are symmetrical and are Y-connected.

The 3-phase voltage sources are defined as:

$$V_a = V_{rms} * \sqrt{2/3} \sin(\omega t + \theta * \pi/180)$$

$$V_b = V_{rms} * \sqrt{2/3} \sin(\omega t + \theta * \pi/180 - 2\pi/3)$$

$$V_c = V_{rms} * \sqrt{2/3} \sin(\omega t + \theta * \pi/180 + 2\pi/3)$$

Here line-to-line rms voltage Vrms of the three-phase source in V. The resistances and inductances of the three-phase branches are equal. The initial currents are zero.

In 12-pulse converter Y-Y and Y-Δ transformer presents the resistance and inductance values of the secondary winding are referred to the primary side. The relationship between the referred values and the real secondary winding values is:

$$Rs = Rs\_real\_value * (Np/Ns)^2$$

$$Ls = Ls\_real\_value * (Np/Ns)^2$$

The transformer has a 3-leg core, with 1 primary winding and 1 secondary winding on each leg. Primary and secondary winding ratio for Y-Y is 1 and for Y- Δ is 0.577 The nodes at the bottom are the neutral points of the Y connections.

The resistances are in Ohm and the inductances are in H.

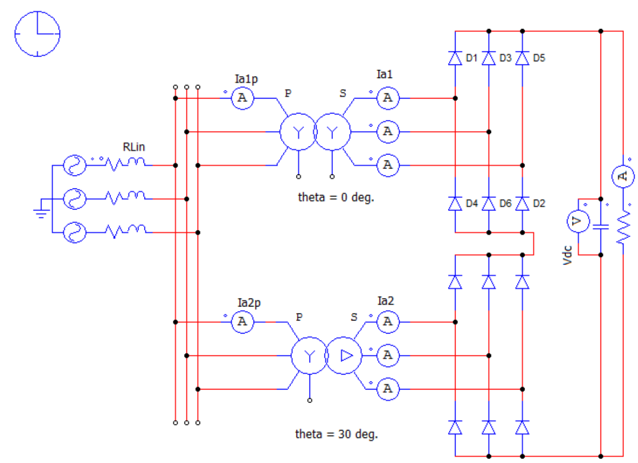

Figure 1 : 12- pulse technique with Diode Bridge

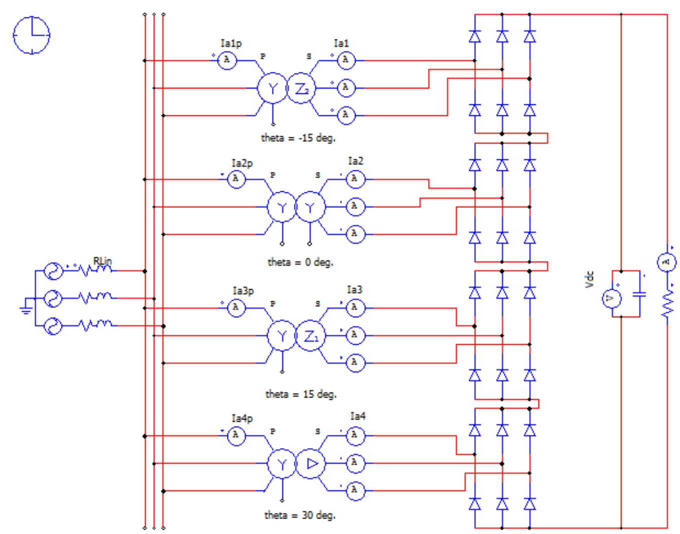

Figure 2 : 24- pulse technique with Diode Bridge

III. Parameters

A **Phase-Shifting Transformer** is a device for controlling the power flow through specific lines in a complex power transmission network. The basic function of a **Phase-Shifting Transformer** is to change the effective phase displacement between the input voltage and the output voltage of a transmission line, thus controlling the amount of active power that can flow in the line.

To degrade harmonics from input minimum phase shift calculation is as follows:

Phase shift= 60^0 /no. of converters

So 30^0 phase shift required for the 12-pulse converter. For obtaining a 12-pulse ac-dc conversion the

So 30° phase shift required for the 12-pulse converter. For obtaing a 12-pulse ac-dc conversion the phase shift between the two sets of voltages should be either 0° to 30° or +15° to -15° with respect to supply voltage. In this paper phase shift is used for the 0° to 30° phase shift is use for the transformer along with the pulse multiplication technique.

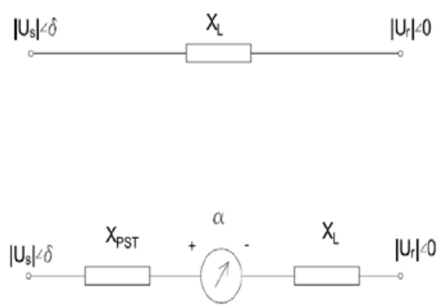

Figure 3 : Model of a transmission line with and without a PST The phase shift is controllable within certain limits.

24-pulse diode rectifier operate with four 6-pulse diode rectifier. For obtaining a 24-pulse ac-dc conversion the phase shift among four sets of voltages should be -15° to 0° and 15° to 30° with respect to supply voltage.

This transformers provide a phase shift of 0 to -30° between the secondary and primary windings. Let Θ be the angle difference between the secondary line voltage V_{ab} and the primary line voltage V_{AB}. The relationship between the angle and the winding turns are:

$$Ns2 / (Ns1 + Ns2) = \sin(30^\circ - |\Theta|) / \sin(30^\circ + |\Theta|)$$

$$Np / (Ns1 + Ns2) = 1 / (2*\sin(30^\circ + |\Theta|)) * V_{AB}/V_{ab} ;$$

where $-30^\circ <= \Theta <= 0$

Here ,

Np (Primary winding) : 1 (Number of turns of the primary winding.

Ns1(Secondary winding): 0.8966 (Number of turns of the 1st secondary winding)

Ns2(Secondary winding): 0.5176 (Number of turns of the 2nd secondary winding)

V_{AB}: Primary line voltage

V_{ab} : Secondary line voltage

To calculate phase shifting angle :

$$\sin(30^\circ - |\Theta|) / \sin(30^\circ + |\Theta|) = 0.5176 / (0.8966 + 0.5176) \quad \text{------------------------- (1.3)}$$

Using above equation we calculate the phase shift angle (Θ) for 24-pulse rectifier is 15°.

Transformer secondary current waveform for 12-pulse and 24-pulse rectifier with phase shifting.

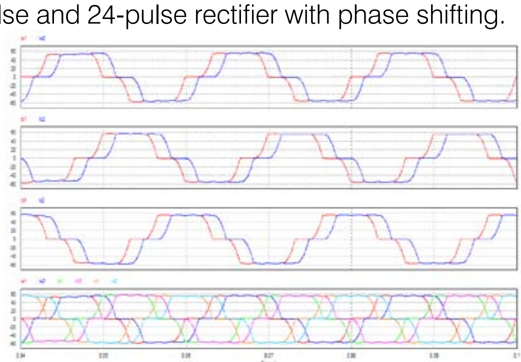

Figure 4 : 12-pulse input current waveform

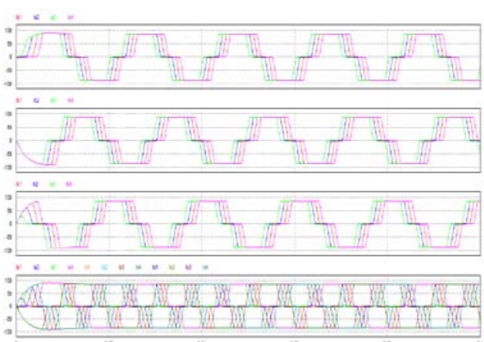

Figure 5 : 24-pulse input current waveform

THD Calculation from input current waveform:

12-pulse and 24 pulse Input current in frequency domain shown below:

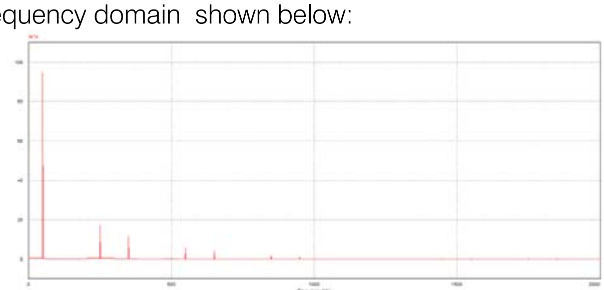

Figure 6 : 12-pulse primary current for THD calculation

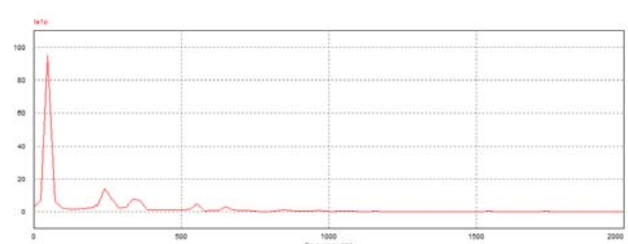

Figure 7 : 24- pulse primary current for THD calculation%

THD from 12-pulse rectifier is 20.44% whereas 24-pulse contain only 17.45% harmonic distortion. Increasing pulse number decrease 17^{th} and 22^{th} harmonics component are eliminated from 24-pulse converter.

IV. Filter Deisgn

When the instantaneous voltage Vs is higher than the instantaneous capacitor voltage Vc, the diodes conduct; and the capacitor is then charged from the supply. If the instantaneous supply voltage falls below Vs the instantaneous voltage Vc, the diodes are reverse biased and the capacitor Ce discharges through the load resistance R.

In practice, the ripple factor can be found from

$$RF = \sqrt{\left(\frac{V_{rms}}{V_{dc}}\right)^2 - 1} \qquad \text{----------------------- (1.4)}$$

From single phase ripple factor calculation assuming RF as 3% then is

$$C = \frac{1}{4fR}\left(1 + \frac{1}{\sqrt{2}\times .03}\right) \qquad \text{------------------------- (1.5)}$$

from above calculation we 12.2m capacitance for 3% RF in single phase.

Using capacitor filter in 12-pulse rectifier Vdc is shown in figure

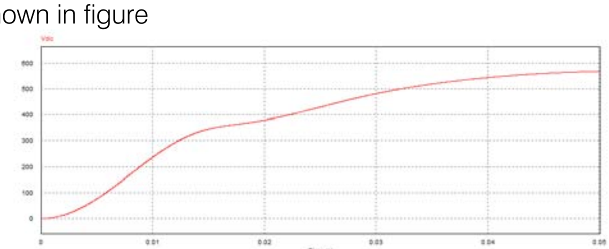

Figure 8 : 12- pulse output voltage with capacitor filter

From equation (1.4) RF calculation for 12-pulse rectifier with filter

Here,

Vrms=422.04 volt and Vdc= 385.49 volt

so, RF= 0.441 or 44.1%

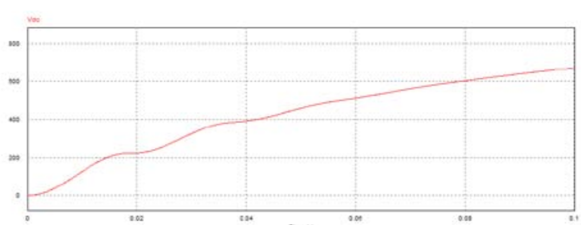

Figure 9 : 24-pulse output voltage with capacitor filter

Similarly, RF calculation for 24-pulse,

Here,

Vrms=460.07 volt and Vdc= 418.94 volt

So, RF=0.453 or 45.3%

The capacitor absorbs energy during the pulse and delivers this energy to the load between pulses, the output voltage can never fall to zero. However, if the resistance of the load is small, a heavy current will be drawn by the load and the average output voltage will fall. Also, the filter capacitor acts like a short circuit across the rectifier while the capacitor is being charged. Due to these reasons, a simple capacitor filter is not suitable for rectifiers in higher power applications.

V. Simulation Results

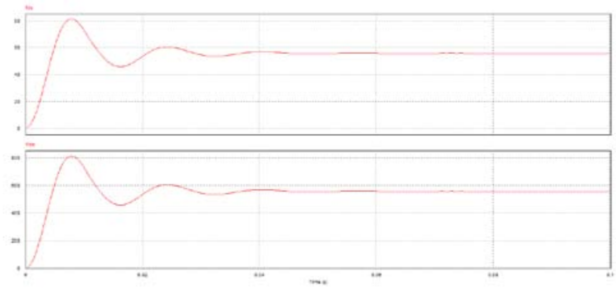

Figure 10 : 12- pulse output current and voltage without filte rRF calculation for 12-pulse without filter,

Here,

Vrms=556.31 volt and Vdc= 554.04 volt

So, RF=0.0906 or 9.06%

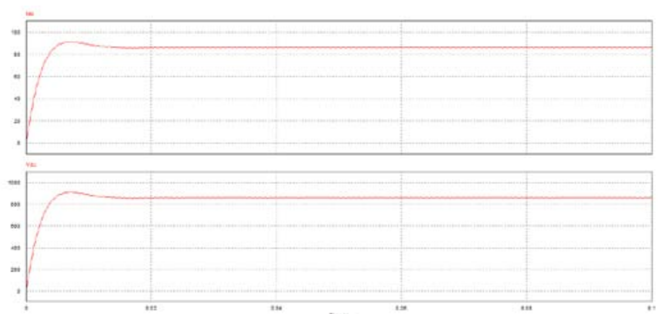

Figure 11 : 24- pulse output current and voltage without filter

Similarly, RF calculation for 24-pulse,

Here,

Vrms=854.54 volt and Vdc= 852.75 volt

So, RF=0.0648 or 6.48%

12-pulse and 24-pulse AC-DC converter with RL and RLC load:

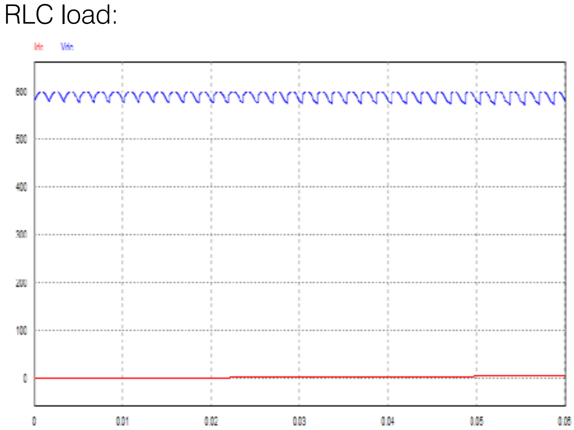

Figure 12 : 12-pulse with RL Load

Global Journal of Researches in Engineering (F) Volume XV Issue IX Version I Year 2015

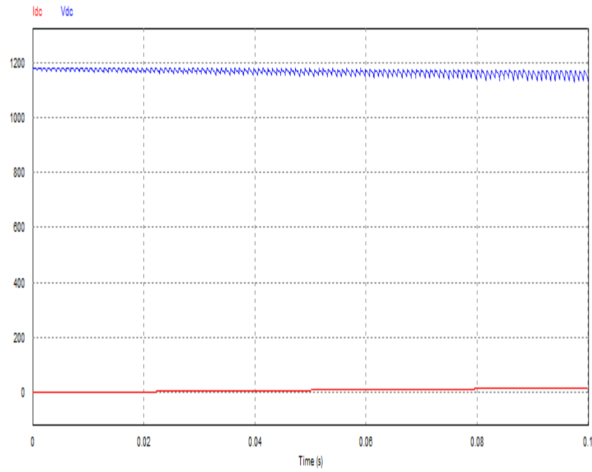

Figure 13 : 24- pulse with RL load

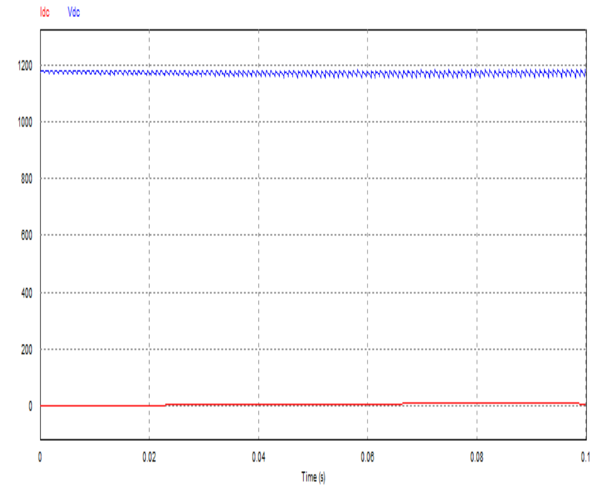

Figure 15 : 24- pulse with RLC load

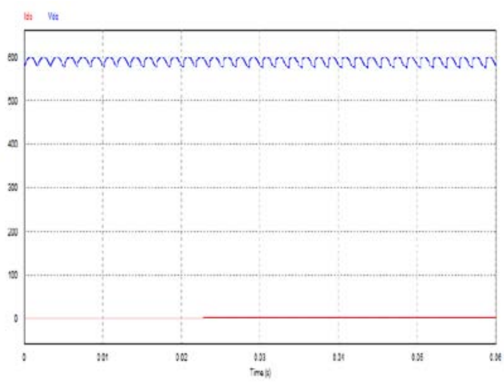

Figure 14 : 12- pulse with RLC load

Table I : Comparison Between 12-Pulse And 24-Pulse AC-DC Conversion

Properties	12-pulse rectifier			24-pulse rectifier		
	R	RL	RLC	R	RL	RLC
PF	1	.86	.88	1	.87	.92
Real Power, P(KW)	30.68	1.6	1.47	73.04	10	7.84
Vrms (Volt)	556.31	590.30	590.6	854.54	1160	1175
Irms (A)	55.3	3.14	2.82	85.45	10.2	7.31
%THD	20.44			17.45		
%RF	9.06			6.48		

VI. Conclusions

This paper present the comparison between 12-pulse and 24-pulse rectifier. After finishing necessary calculation we have seen 24-pulse contain less harmonic content in input current. It improves power factor with inductive and capacitive load.

Although detail analysis has not been described in this paper, but every inevitable information are given. The desirable features of the modified diode rectifier, such as compact, economical, efficient and reliable are added with the new 24-pulse rectifier. Some new features are joined with this configuration such as lower Ripple component and higher power factor.

References Références Referencias

1. Muhammad H. Rashid *Power Electronics Circuits, Devices And Applications* Third Edition.
2. *Harmonics in power system-causes, effects and control* usa.siemens.com/lv-drives.
3. M Kiran, L Phani Kumar and N Srinivasa Rao *'Design And Analysis of a 24-pulse AC-DC Power Converter By Employing a Pulse Doubling Technique for Asynchronous Drive.'*, vol. 3, Issue,1, April 2015,ISSN: 2345-9603.
4. Jayant Dewal and Prof. Nand Kishore*' Using Multi-Pulse Converters for Supply Current Harmonic Control'* Received 05 January, 2014 Accepted 06 February, 2014.

5. Yasuyuki NISHIDA, Hiromichi. OHYAMA, Predrag PEJOVIC and Johann W. KOLAR' *Three Phase Harmonic reducing diode rectifier'* conf. EPE-PEME 2012 ECCE Europe.
6. Y. NISHIDA ,K. MINO'*A Method to Decrease Input Current Harmonics of Three-phase Diode Rectifier by Pulse-Doubler Scheme'* conf. Proc. of IECON-06, pp. 1673-1678 (Nov. 2006, in Paris)
7. N. R. Raju, A. Daneshpooy and J. Schwartzenberg '*Harmonic Cancellation for Twlve pulse rectifier Using DC BUS Modulation'* 0-7803-7420-7/02/$17. 00 © 2002 IEEE