International Journal For Technological Research In Engineering
Volume 8, Issue 11, July-2021 *ISSN (Online): 2347 - 4718*

A COMPARATIVE STUDY & DESIGN OF PWM RECTIFIER USING DIFFERENT CONTROL SCHEMES

[1]Sneha V More, [2]Mr. Sanket Patel
[1]P.G. Scholar, [2]Assistant Professor
Electrical Department
SIGMA INSTITUTE OF ENGINEERING, VADODARA, GUJARAT, INDIA

Abstract: - To solve the problem of harmonic pollution to the power grid that caused by traditional diode rectifier and phase con-trolled rectifier, the unit power factor PWM rectifier is designed. This paper presents the modeling, simulation and analysis of an AC-DC converter based PWM rectifier. It provides a suitable control algorithm for a pulse width modulation rectifier which reduces ripple from the DC voltage at output side as well as shapes the input current as sinusoidal as possible. The basic objective of a PWM rectifier is to regulate the DC output voltage and also ensure a sinusoidal input current and unity power factor operation. This is implemented by high speed IGBT / MOSET switches connected in VSI topology. The output voltage is controlled by switching these IGBTs / MOSFETs and higher order ripples at the output can be easily eliminated with the help of passive filters. Lower order harmonics are eliminated using PWM technique. The control subsystem generates gating pulse to the VSI converter by passing the output voltage and input currents through a network consisting of comparator, discrete PI controller and discrete PWM generator. The outputs of this generator are the gating pulses to be applied to the PWM rectifier. By this control method, we have tried to reduce the input current harmonic distortion and bring the input current and voltage in same phase as well as make it sinusoidal. The control of modulation index (m) and phi has been shown in the closed loop system. The influence of the discussed modulation methods on the line current distortion and the switching frequency has been examined. The simulation results of the presented techniques have been demonstrated and concluded for various load.
Keywords: - PWM, Rectifier, IGBT/MOSFET,Matlab-Simulink etc.

1. INTRODUCTION

The AC-DC conversion is used increasingly in a wide diversity of applications: power supply for microelectronics, household-electric appliances, electronic ballast, battery charging, DC-motor drives, power conversion, etc

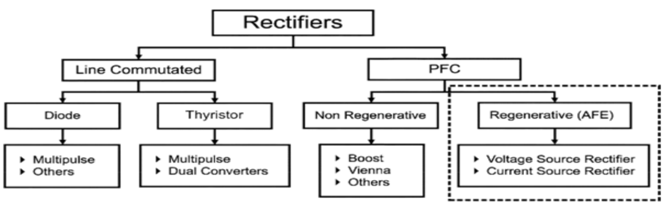


Figure-1 Classifications of Rectifier

The rectifiers take a number of forms, including vacuum tube diodes, wet chemical cells, mercury-arc valves, stacks of copper and selenium oxide plates, semiconductor diodes, silicon-controlled rectifiers and other silicon-based semiconductor switches. Historically, even synchronous electromechanical switches and motors have been used. Early radio receivers, called crystal radios, used a "cat's whisker" of fine wire pressing on a crystal of galena (lead sulphide) to serve as a point-contact rectifier or "crystal detector". AC-DC converters can be classified between topologies working with low switching frequency (line commutated) and other circuits which operate with high switching frequency. For AC-DC conversion we have three types of switches available, uncontrolled switches (Diodes), semi-controlled switches (SCR / Thyristors) and, fully controlled switches (IGBTs / MOSFETs). Harmonics are present in uncontrolled and semi-controlled AC-DC converters, they are called conventional rectifiers. Other disadvantages of conventional rectifiers are non- sinusoidal AC current, poor power factor and ripple in output DC voltage.

Conversion of three phase AC to DC by means of an AC-DC power converter (Fig. 1) finds it application in various areas of power electronics such as Electric drives, UPS systems, Battery management systems and Telecom power supplies to name a few. Conventionally, the diode bridge or the Thyristor Bridge has been the most commonly used AC-DC power converter for obtaining DC power from the AC grid. The use of these bridge topologies is mainly motivated due to their advantage in size, control, reliability, structural simplicity and economics.

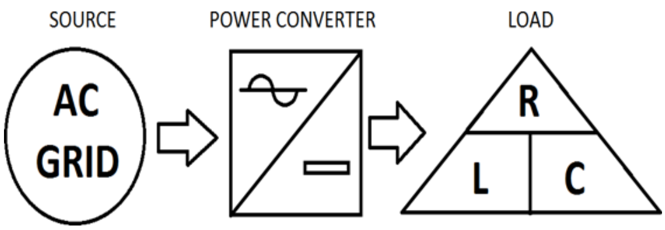


Figure 2: AC to DC conversion with combination of RLC load

Figure 1: AC-DC Power Converter However, usage of such bridge circuits is quite disadvantageous from the viewpoint of the AC grid, as they inject unwanted current harmonics (Fig. 2) of relatively high amplitudes (depending on the power level of the bridge) into the grid. Consequently, this

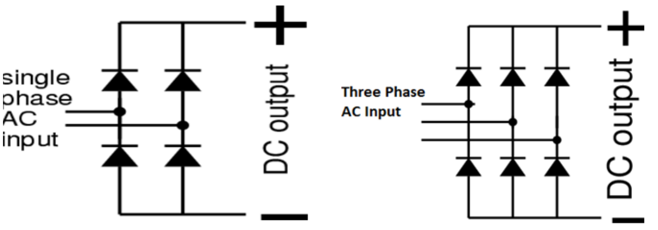
results in the distortion of the grid voltage, which can cause undesirable disturbances and hence poor power quality in the neighboring loads connected to the grid. In view of limiting this utility pollution due to power converters, standards (IEEE 519, IEC 61000-3-6)[1] have been drafted limiting the direct use of diode and thyristor bridges, with more emphasis being laid on the use of power converters which have lesser harmonic influence on the grid.

2. MODELING OF THREE PHASE BOOST RECTIFIER

As rectifiers are power electronic systems that convert input ac power to output dc power.
Rectifiers come in many types and can be classified variedly as:

- Single-phase vs. three-phase
- Half-wave vs. full-wave
- Phase controlled vs. pulse width modulated

Single-phase vs. three-phase rectifiers is a classification based on the type of ac input to the rectifier. The rectifiers shown in Figure 3(a) and 3(b) are diode rectifiers. The third classification relates to the type of semiconductor device used in the rectifier; uncontrolled rectifiers comprise of diodes as the switches, phase-controlled rectifiers comprise of SCR (silicon controlled rectifiers) and in pulse-width modulated rectifiers, IGBTs (insulated gate bipolar transistors) or power MOSFETs (metal oxide field-effect transistors) are used. The rectifier is switched using pulses that are generated using sine-triangle or space vector



pulse width modulation.

Figure 3: (a) single-phase bridge rectifier (b) three-phase bridge rectifier

The pulse-width modulated rectifiers can be further divided on the basis of the relationship between the ratios of the input and output voltages. Some examples of the pulse- width modulated rectifiers are buck, .boost, and buck-boost rectifiers. In buck rectifiers, the dc output voltage is lower in magnitude than the peak value of the ac input. Similarly, the boost rectifier has an output dc voltage that is higher in magnitude than the peak value of the ac input voltage. The buck-boost rectifier can have an output voltage, either lower or higher in magnitude when compared to the ac input, with the duty ratio of the switches determining the nature of the output.
Operation of Three-Phase Boost Rectifier
The application areas of the boost rectifier are varied and exhaustive due to the efficient utilization of power in the rectification process, and the boosting of the output voltage. The topology of the three-phase boost rectifier is shown in Figure 4.

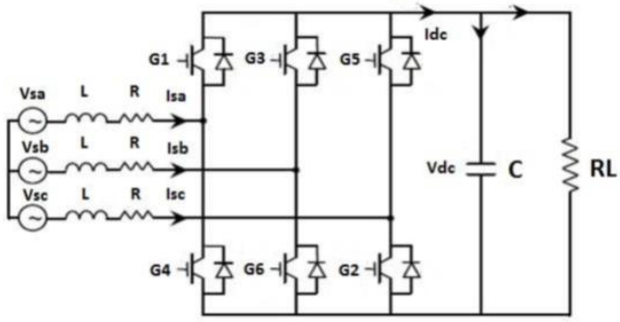


Figure 4: Topology of three-phase boost rectifier

The three-phase boost rectifier comprises of six switches that are switched using sinusoidal pulse width modulation technique. In general, the operation of a converter can be explained in terms of the input quantities, output quantities, and the switching pattern used to obtain the desired output. The switching pattern of the switches in the converter is obtained in accordance with Kirchhoff's voltage law (KVL) and Kirchhoff's current law (KCL). The ON and OFF states of a single switch are assumed to have values 0 and 1, respectively; i.e.
If the device is .ON, the switch is assigned a value = 1.
If the device is .OFF, the switch is assigned a value =0.
In a three-phase rectifier, the input ac voltages are defined and the output dc voltage is dependent on the input quantities as well as the switching pattern of the rectifier. The switching pattern for any converter can be expressed as a function, which is a mathematical representation of the switching pattern, called an existence function.

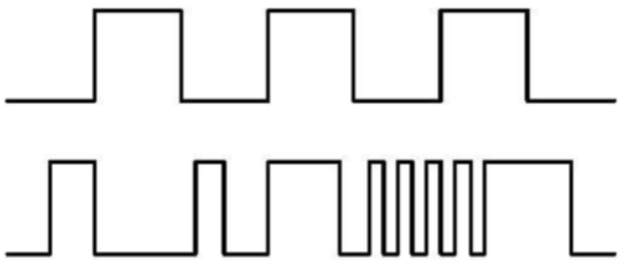


Figure 5 Modulated and un-modulated existence functions

3. SWITCHING MODES OF THREE-PHASE BOOST RECTIFIER

For the three-phase boost rectifier, the restraints on the possible modes of operation that also satisfy KVL and KCL can be mathematically expressed as

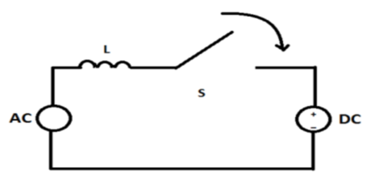
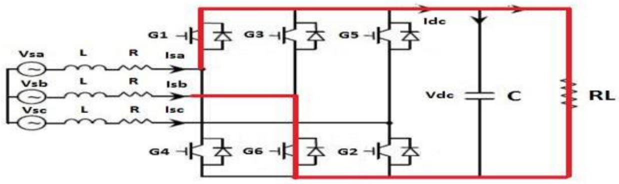


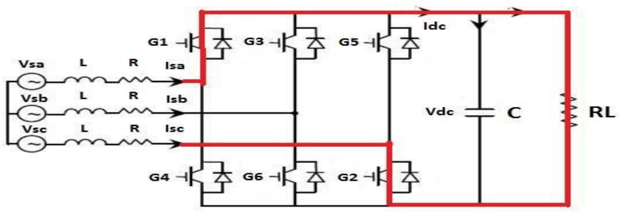
Figure 6 Simplified schematic of boost rectifier

$$G1 + G4 = 1 \quad (3.1)$$
$$G3 + G6 = 1 \quad (3.2)$$
$$G5 + G2 = 1 \quad (3.3)$$

Equations (3.1) to (3.3) shows that at no instant of time can the top and bottom devices of the same leg be ON simultaneously, as the condition would violate KVL. Assuming one switch in the top leg and one switch in the bottom leg to be ON, the boost rectifier Figure 4 can be simplified as shown in Figure 6. The six active states as shown in Table 2 can be graphically represented in Figure 7. For each state illustrated, the switches ON are specified, and a red line, indicating the switches 'ON' and thereby each active state, depicts the path of flow. Figure 7(a) illustrates the mode of operation where the top switch G1 and bottom switch G6 are ON. The switches that are ON therefore determine the path of flow of current. The second possible mode of operation is shown in Figure 7(b) where the switches G1 and G2 are ON.



(a)



(b)

Figure 7 (a) to (b): Modes of operation of three-phase boost rectifier

4. SIMULATION AND RESULT DISCUSSION

Hysteresis current control with resistive load

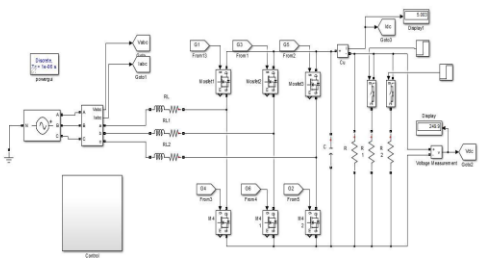


Figure 8: MATLAB/Simulink model for three phase PWM rectifier with variable resistive

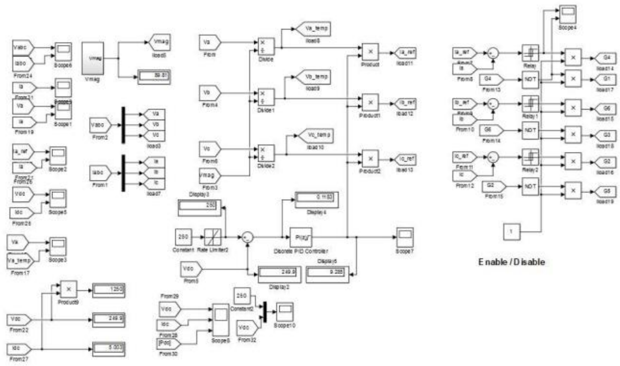


Figure-9: MATLAB/Simulink control scheme for three phase PWM rectifier with variable resistive load (subsystem)

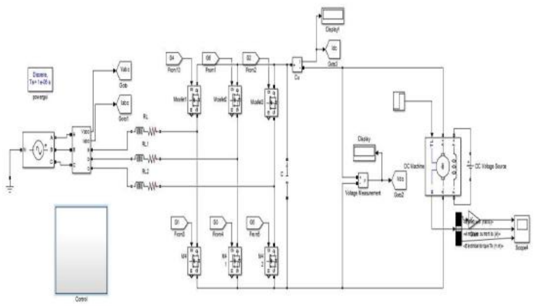


Figure 10: MATLAB/Simulink model of Hysteresis current control with DC motor load

Simulation Results

Results of three phase PWM rectifier are divided in to four parts

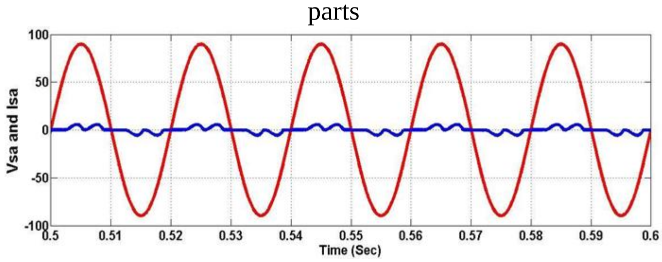


Figure 11: Waveform of source voltage (Vsa) and source current (Isa)

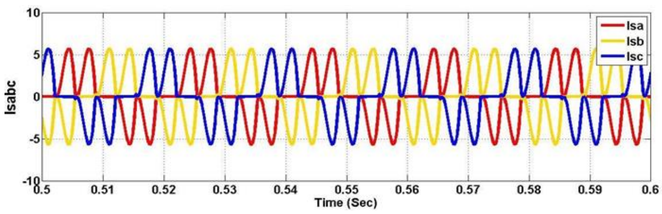


Figure 12: Waveform of source currents (Isabc) – without control

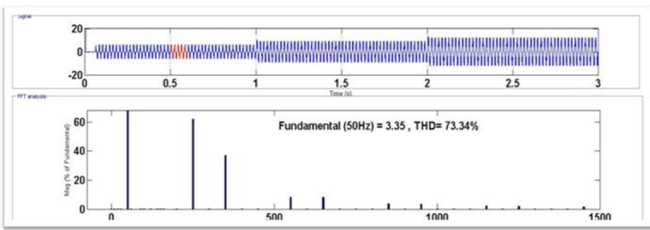


Figure 13: FFT analysis of source current and current THD = 73.34%

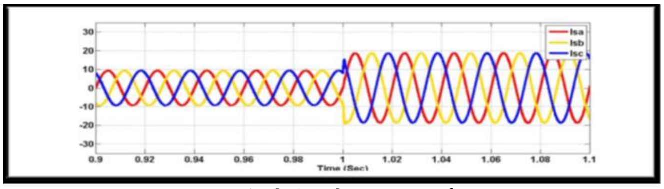


Figure 14 Source current (Isabc) with PWM rectifier-Hysteresis current control for load switching 5A to 10A

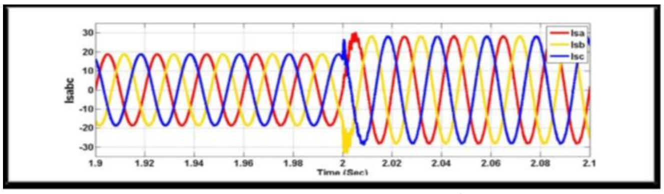


Figure 15 Source current (Isabc)) with PWM rectifier-Hysteresis current control for load switching 10A to 15A

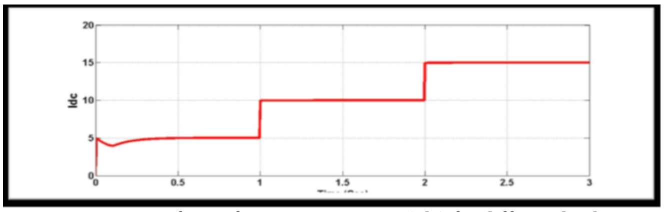


Figure 16 Waveform of output DC current (Idc) for different loading condition. (With PWM rectifier – Hysteresis current control)

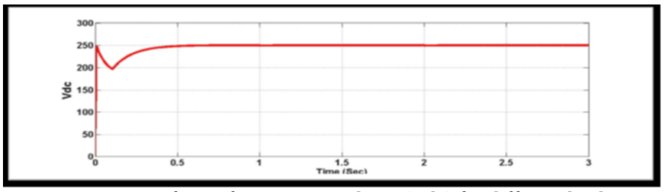


Figure 17 Waveform of output DC voltage (Vdc) for different loading condition. (With PWM rectifier – Hysteresis current control)

As this system is closed loop control, so the output voltage is stable 250V dc at every loading condition. Vdcref = 250V dc (<155V dc as Vs = 110V)

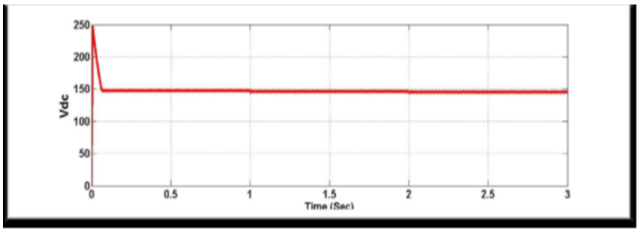


Figure 18 Waveform of output DC voltage (Vdc) for different loading condition. (Without PWM rectifier – Hysteresis current control)

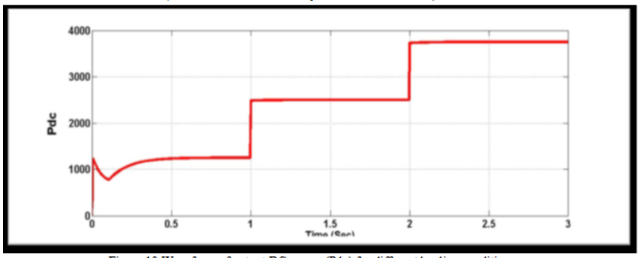


Figure 19 Waveform of output DC power (Pdc) for different loading condition. (With PWM rectifier – Hysteresis current control)

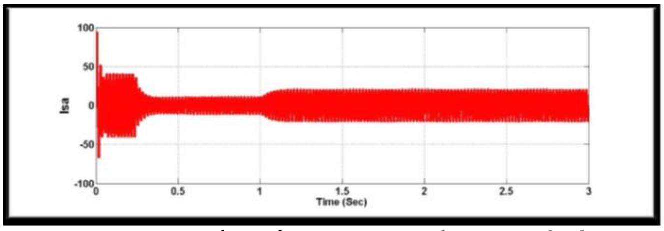


Figure 20 Waveform of source current with DC motor load (With PWM rectifier – Hysteresis current control)

Phase A current is shown in fig 33, inrush current is observed at starting. Torque is set 5 N.m. from 0 to 1 Sec. Then it is changed to 10 N.m. at 1 Sec.

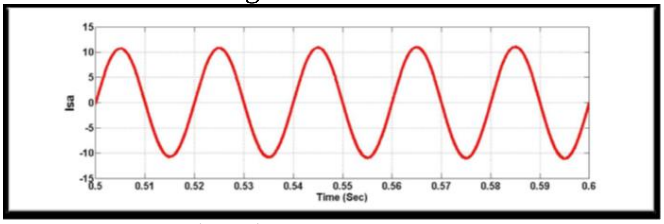


Figure 21 Waveform of source current (Isa) with DC motor load (With PWM rectifier – Hysteresis current control)

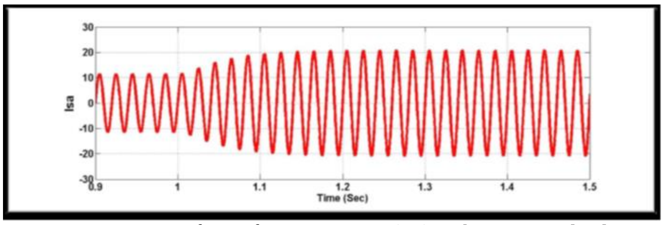


Figure 22 Waveform of source current (Isa) with DC motor load (With PWM rectifier – Hysteresis current control)

As discussed above, load current is increasing at 1 sec that effect is observing.

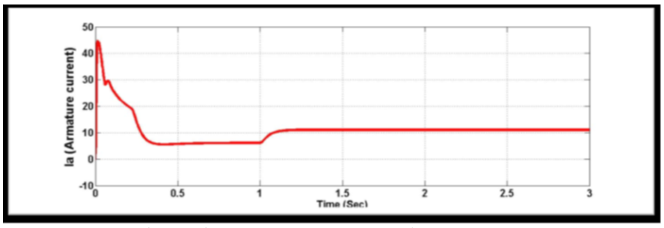


Figure 23 Waveform of armature current (Ia) of DC motor load (With PWM rectifier – Hysteresis current control)

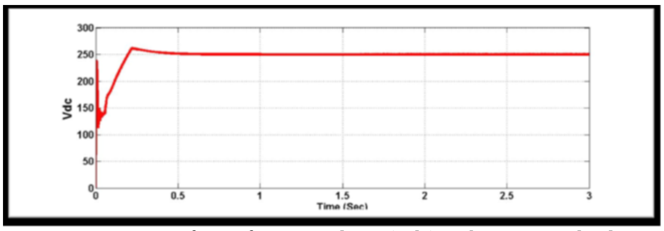


Figure 24 Waveform of output voltage (Vdc) with DC motor load (With PWM rectifier – Hysteresis current control)

5. CONCLUSION

This paper presents the modeling, simulation and analysis of an AC-DC converter based PWM rectifier. It provides a suitable control algorithm for a pulse width modulation rectifier which reduces ripple from the DC voltage at output side as well as shapes the input current as sinusoidal as possible. The basic objective of a PWM rectifier is to regulate the DC output voltage and also ensure a sinusoidal input current and unity power factor operation. This is implemented by high speed IGBT / MOSET switches connected in VSI topology. From this work of dissertation Power quality issues are discussed and three phase PWM rectifier model is proposed to mitigate current harmonics with hysteresis current control and dq based theory. Voltage and current waveforms are made in phase and sinusoidal by proposed three phase PWM rectifier model for different loads as well as in different loading conditions. Total Harmonic Distortions are diminished with the help of FFT analysis.

REFERENCES

1. PWM Regenerative Rectifiers: State of the Art José R. Rodríguez, Senior Member, IEEE, Juan W. Dixon, Senior Member, IEEE, José R. Espinoza, Member, IEEE,Jorge Pontt, Senior Member, IEEE, and Pablo Lezana(2005)
2. An Adaptive Repetitive Controller for Three-Phase PWM Regenerative Rectifiers Rabia Nazir, Alan Wood, Hamish Laird, Neville Watson Electrical and Computer Engineering Department, University of Canterbury, New Zealand.Electrical Engineering Department, Lahore College for Women University, Pakistan. ELMG Power Electronics Digital Control, New Zealand
3. Simple Direct Power Control of Three-Phase PWM Rectifier Using Space-Vector Modulation (DPC-SVM) Mariusz Malinowski, Member, IEEE, Marek Jasin´ski, Student Member, IEEE, and Marian P. Kazmierkowski, Fellow, IEEE
4. Predictive Direct Power Control of Three-Phase Pulsewidth Modulation (PWM) Rectifier Using Space-Vector Modulation (SVM) Abdelouahab Bouafia, Jean-Paul Gaubert, Member, IEEE, and Fateh Krim, Senior Member, IEEE(2010)
5. Space Vector Modulation for Two-Level Unidirectional PWM Rectifiers Ivo Barbi, Senior Member, IEEE, and Flabio Alberto Bardemaker Batista(2015)
6. Rodríguez, José R., et al. "PWM regenerative rectifiers: State of the art." IEEE Transactions on Industrial Electronics 52.1 (2005): 5-22.
7. Meifang Xue, Mingzhi He School of Electrical Engineering, Beijing Jiaotong University, Beijing Control of Unit Power Factor PWM Rectifier, China Received March, 2013
8. Kolar, Johann W.,e tal. "Review of three-phase PWM AC–AC converter topologies." IEEE Transactions on Industrial Electronics 58.11 (2011): 4988-5006.
9. Ned Mohan, Tore M. Undeland and William P. Robbins, “Power Electronics: Converters, Applications, and Design” Wiley, 3 edition (October 10, 2002).
10. Robert W. Erickson, Dragan Maksimovic, “Fundamentals of Power Electronics” Publisher: Springer; 2nd edition, January 2001.
11. Andrzej M. Trzynadlowski, “Introduction to Modern Power Electronics”, Publisher: Wiley, 2ndedition, March 2010.
12. Bimal K. Bose, "Power Electronics and Motor Drives: Advances and Trends", Publisher: Academic Press, August, 2006.
13. D. Grahame Holmes, Thomas A. Lipo, "Pulse Width Modulation for Power Converters: Principles and Practice", Publisher: Wiley-IEEE Press; 1st edition, October, 2003.
14. W. Shepherd, L. N. Hulley and D. T. W. Liang, "Power Electronics and Motor Control", Publisher: Cambridge University Press; 2ndedition, January, 1996
15. Vladimir A. Katic, Du˘san Graovac, “A Method for PWM Rectifier Line Side Filter Optimization in Transient and Steady States,” IEEE transactions on power electronics, vol. 17, no. 3, may 2002.
16. A. Karaarslan, I. Iskender “The analysis of ac-dc boost pfc converter based on peak and hysteresis current control techniques,” (IJTPE) ISSN 2077-3528

