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Comparative Study of Three Phase PWM Rectifiers

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***Abstract*—Large values of harmonics causes major stress in the power system components therefore, harmonic minimization is necessary for smooth operation. With conventional control technique for converter, lower order harmonics cannot be minimized to a desired level, but with PWM controlled rectifiers, the total harmonics distortion is reduced to a minimal level and even power factor is improved. Poor power factor causes serious problems in the grid of the power system. Numbers of solutions has also been proposed as the ability to control the system to obtain unity power factor operation of a rectifier is an important feature of the rectifier topology. Certain application demands the reverse operation of the converter from load to source. The bidirectional and high switching frequency, power switch IGBT with PWM rectifier makes the power regeneration possible in the converter. This paper presents a comparative survey and study of different PWM techniques fed to regenerative rectifiers. Various topologies are studied with its control strategies which results reduced in harmonics and ripples of the output voltage and provide good power factor.**

***Index Terms*— Harmonics, unity Power factor, regeneration, IGBT, PWM rectifier.**

1 INTRODUCTION

The ac to dc converter are widely use from small to large applications, from domestic to industrial applications. Some of such applications maybe: power supplies for dc motor drives, power conversion, electric household appliances, battery charging, microelectronics etc.[3][4].The ac to dc converters maybe classified according to its commutation techniques as line-commutated converters, which work with low switching frequency and forced-commutated converters, which work with high switching frequency. The simplest line-commutated converters uses diodes to convert energy from ac to dc. The improved line commutated converters uses thyristors to control energy from ac to dc. But these line-commutated generates harmonics and reactive power [3]. Therefore, minimization of harmonics is necessary for the smooth operation of the drives. As the harmonics causes major stress in the components of power system, there are several filters and techniques used in the past to reduce and control its generation. Power factor correction is one way to reduced the harmonics. The pulse width modulation (PWM) converters where power switches like thyristor (SCR), insulated gate bipolar transistor (IGBT), Gate turn-off thyristor (GTO) or Integrated gate controlled thyristors (IGCT) are used in converters which results reduction in harmonics and improve power factor at the ac side[9].
The problems that tend to occur due to power factor variations are known and are under discussion for quite some time now. Numbers of solutions has also been proposed like static VAR compensators, passive or active filters which would improve the quality of the power that is delivered to the mains. The ability to control the system to obtain unity power factor operation of a rectifier is an important feature of the rectifier topology. The power factor (PF) is termed as the ratio of active power to apparent power. The power quality issues, which include poor power factor and high total harmonic distortion which generally associates with the operations of AC to DC converters. Serious problems can be generated in AC power lines by diode and thyristors with an increase in the current harmonics and a decrease in the displacement power factor [9]. For regenerative converters, the bidirectional power switch is needed where as in diode rectifier, power can flow only from ac to dc as it is unidirectional. Therefore, regenerative operation cannot be done using diode switch. For high power regenerative application, thyristors and GTO can be used but they are not suitable with high switching PWM frequency. Additionally, even their gate driver is costly and give complexity in the gate control [1].
However, with the advances in technology, the semiconductor power device has being produced which is a hybrid transistor of bipolar junction transistor (BJT) and metal oxide semiconductor field effect transistor (MOSFET), which is called as insulated gate bipolar transistor (IGBT). In the present day, IGBT are available with voltage rating upto 6.5kV and the current rating upto 2.4kA [6][7]. Power switch IGBT is a bidirectional switch which operates with high switching frequency from 4kHz to 50kHz with switching speeds upto one-micro second[4]. Therefore regeneration of power can be done using this switch. A PWM regenerative rectifier using power switch IGBT results in ripple reduction in the output voltage, harmonic reduction in the input current and improvement of power factor.

2 CONTROL SCHEMES OF HARMONICS AND POWE FACTOR USING PWM TECHNIQUES IN RECTIFIER

2.1 Kinds of PWM techniques used for VSR

In this research work, the different type of PWM techniques is used in rectifier for reduction of harmonics and improvement of power factor.
The PWM techniques used are given below:-
•Sinusoidal PWM
•Hysteresis PWM
•Unit vector template technique

2.2 Environmental advantages of using PWM techniques

Using PWM techniques in converter allows power to regenerate as its switches are bidirectional, which means power can flow not only from source to load but also from load to source. Using PWM rectifiers, the harmonic at the input side is reduced, the ripple at the output is decreased and the power factor variation is improved, which is why these PWM rectifies are also called as green energy converters.

3 CLASSIFICATIONS OF RECTIFIERS

The general classification of rectifiers is shown in figure 1. As seen from the figure 1, we will be studying the blocks given under the dotted lines.

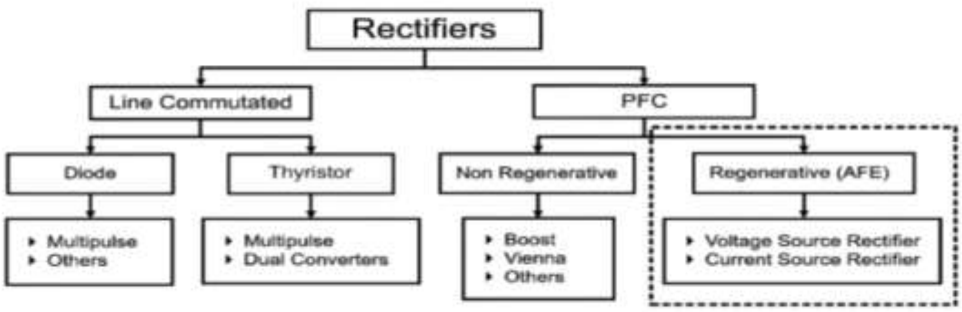

Fig 1: Classification of rectifiers

3.1 Regeneration (AFE)

The active front end (AFE) converters are such converters which can regenerate power back to the source. There are certain applications where energy flow can be reversed during the operation such as locomotives, downhill conveyors, cranes, etc. In these applications, the line-side converter must be able to deliver the energy back to the power supply, what is known as power regeneration. An active front end (AFE) is a regenerative rectifier which is capable of power regeneration, which can operate with high power factor or any active–reactive power combination [3].

The advantages of Active Front-End (AFE) converter are:
• It has regenerative operation,
• It eliminates the lower order harmonics,
• It has higher DC bus voltage, and
• It can operate at unity power factor [2].

The active front end rectifiers can be classified as (1) voltage-source rectifiers (VSRs) and (2) current-source rectifiers (CSRs). In this thesis work, the voltage-source rectifiers (VSRs) are studied with its control strategies.

4 VOLTAGE SOURCE RECTIFIERS

The voltage-source rectifier is the most widely used as com-pared with the CSR [5]. The voltage-source inverters (VSIs) as it is well known that it can reverse the power flow from load to dc source as a rectifier which means as a voltage-source rectifier (VSR). However, a stand-alone VSR requires a special dc bus able to keep the voltage Vo at a desired value without the requirement of a voltage supply. This is accomplished by using a dc capacitor C and a feedback control loop [2].

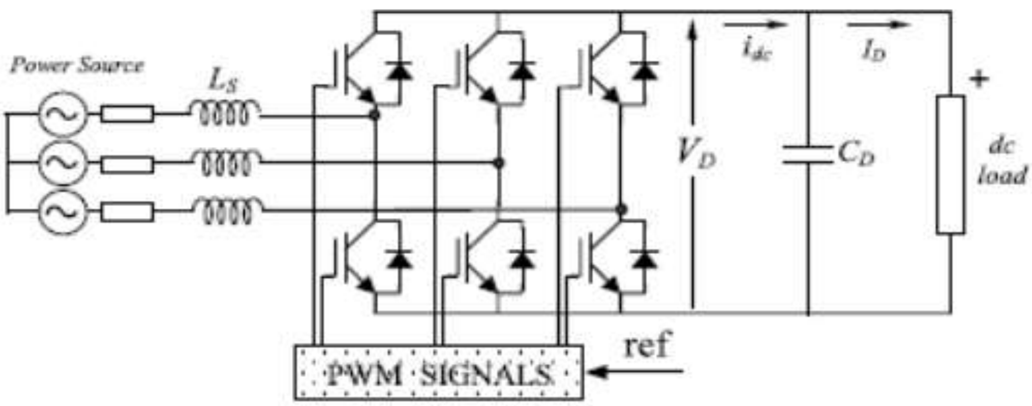

Fig 2: Voltage source rectifier

The VSRs can be classified further as-
1) Voltage-source voltage controlled rectifier
2) Voltage-source current controlled rectifier

4.1 Applications of Regenerative PWM VSRs

One of the most important and widely used applications of the VSR is in machine drives. A typical frequency converter with self-commutated rectifier and inverter link is shown in fig 3. As shown by the fig.3., the rectifier side controls the input current and the dc link voltage, whereas the inverter side controls the machine. The machine could be a synchronous machine, asynchronous machine, brushless dc machine, or induction machine. This topology is possible with reversal of speed and power. At the rectifier side, even with an inductive load like an induction machine, the source can assume the load as capacitive or resistive; therefore power factor can be controlled. The inverter can become a rectifier during regenerative braking, which is possible by making the slip of an induction machine negative or by making the torque angle of the synchronous and brushless dc machine negative[10].

5 SIMULATION MODEL AND RESULTS

5.1 Proposed Model

The ac source is an ideal balanced three-phase voltage source with frequency of 50Hz. The phase to phase voltage is 415V. The line resistor of each phase is 0.5Ω(for SPWM and Hysteresis PWM) and .38 Ω(for UTT PWM). The line inductance of each phase is 16.67mH. The output capacitor is 7500uF. In steady state, the dc voltage is set to be 750V. The switching frequency is 10800Hz.
The simulation model is shown in the diagram below :

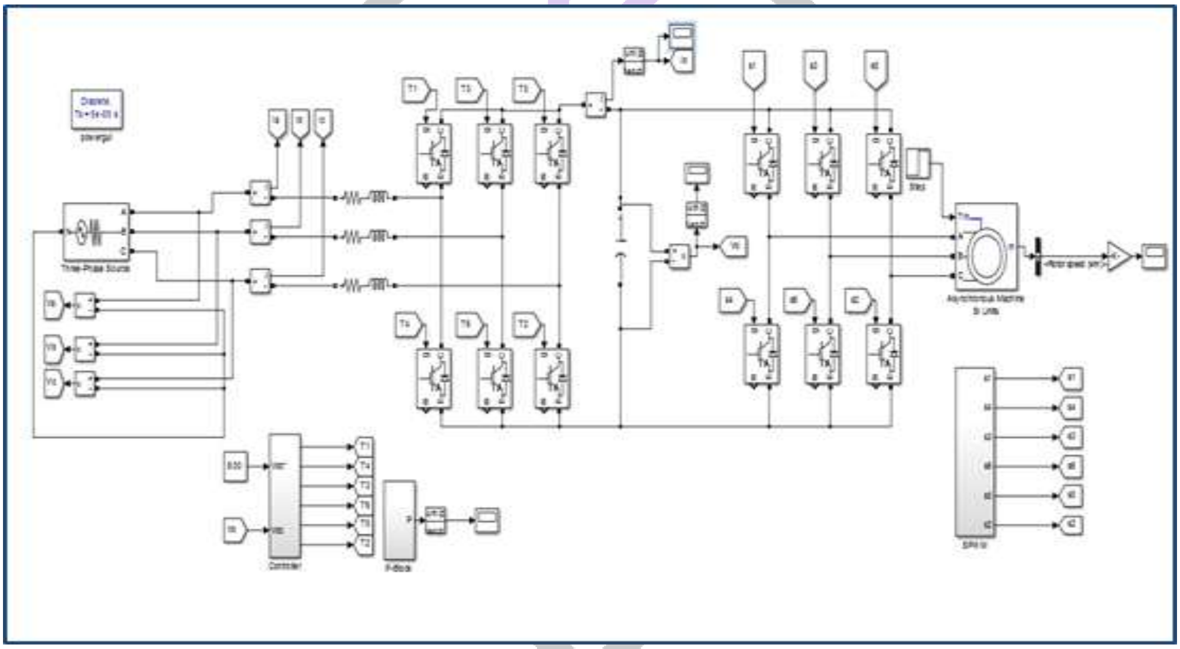

Fig 3: Simulation Model of PWM Rectifier

5.2 Controller circuit Simulink

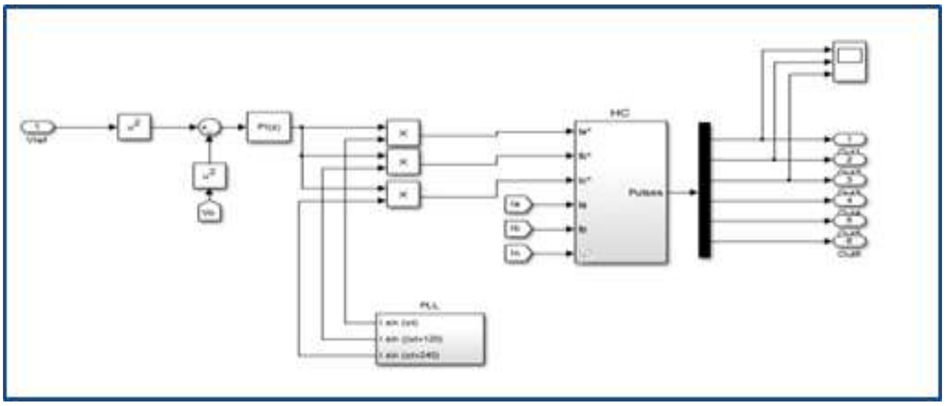

Fig 4: Hysteresis Band PWM Controller

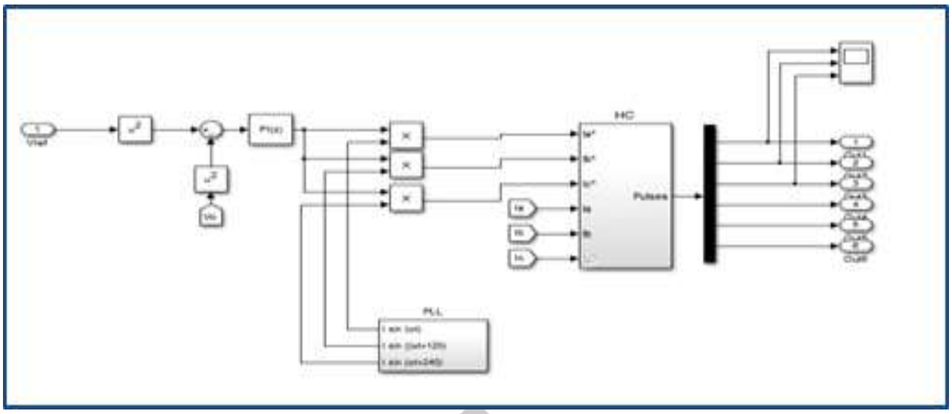

Fig 5: SPWM Controller

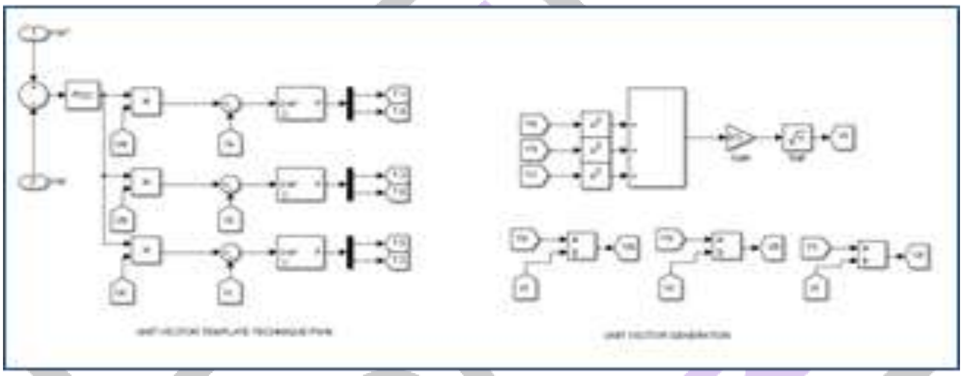

Fig 6: UTT PWM controller

6 SIMULATION RESULTS

All the results are simulated for 2sec.

6.1 Hysteresis control PWM Rectifier

6.1.1 Output Voltage

Fig 7: output voltage without load

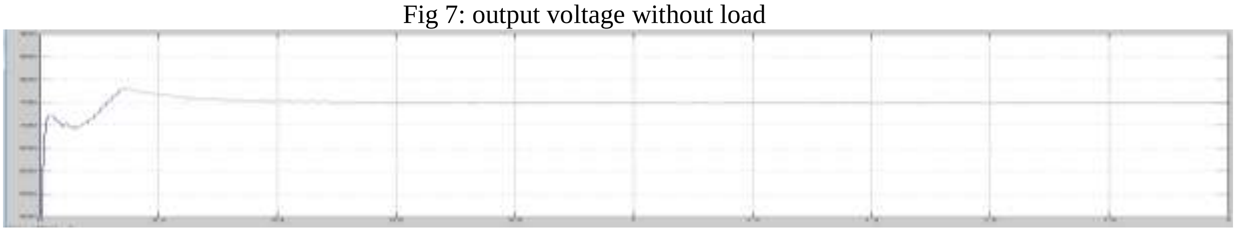

Fig 8: output voltage without load-torque

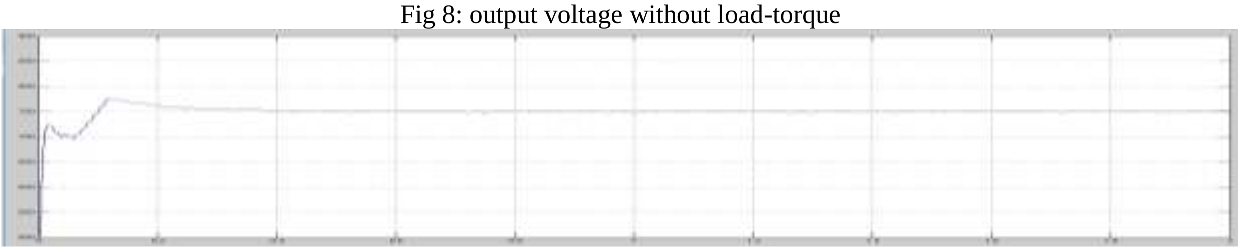

Fig 9: Output voltage at full load-torque

Fig 10: Output for step load torque

6.1.2 Speed

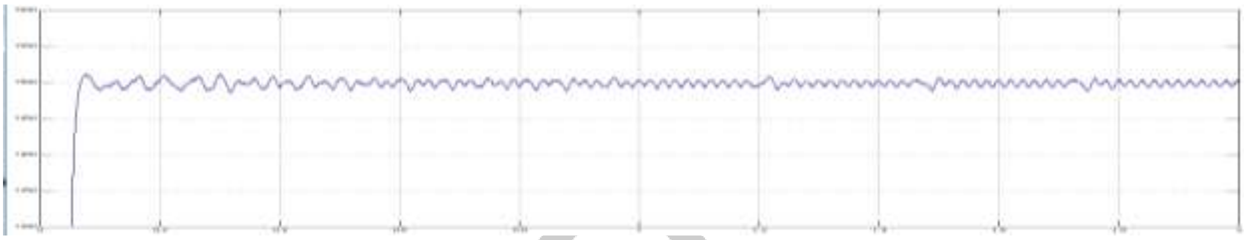

Fig 11: speed at no-load torque

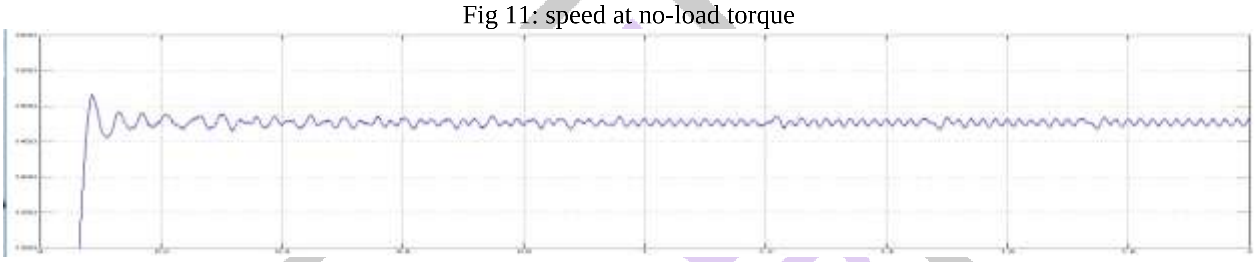

Fig 12: speed at full load-torque

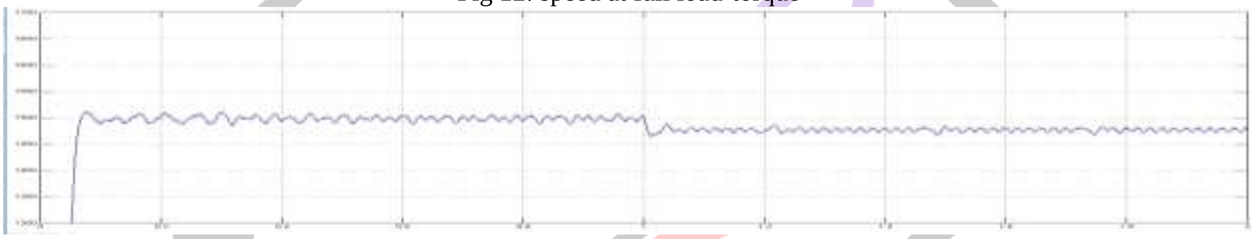

Fig 13: speed at step load frequency

6.2 Voltage-Source Current Controlled Rectifier Using SPWM Technique

6.2.1 Output Voltage

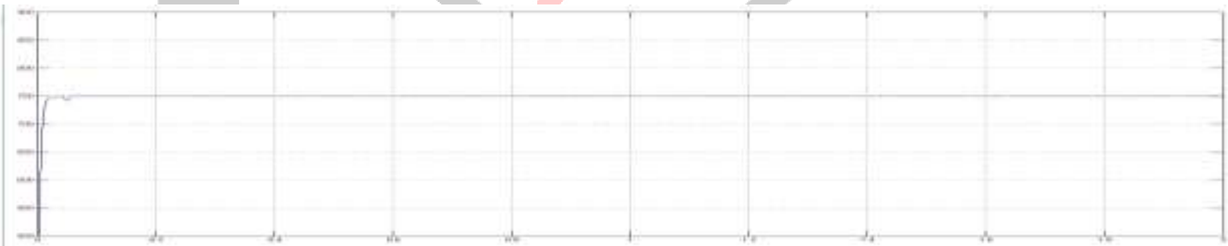

Fig 14 : output voltage without load

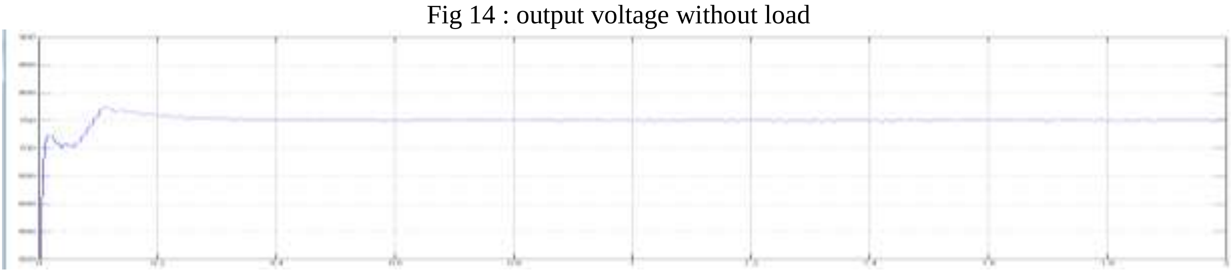

Fig 15: output at no load-torque

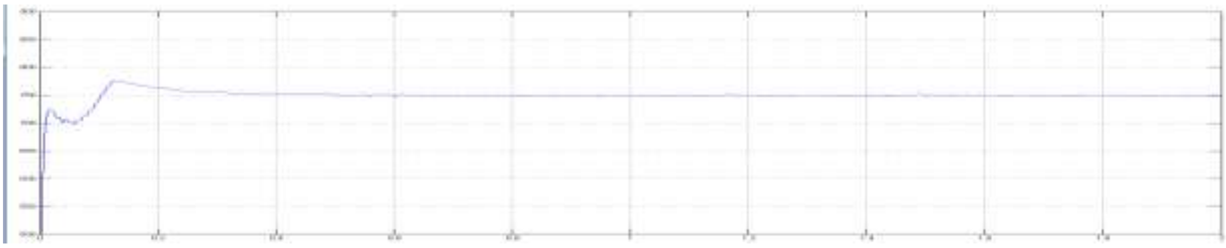

Fig 16: Output at full load torque

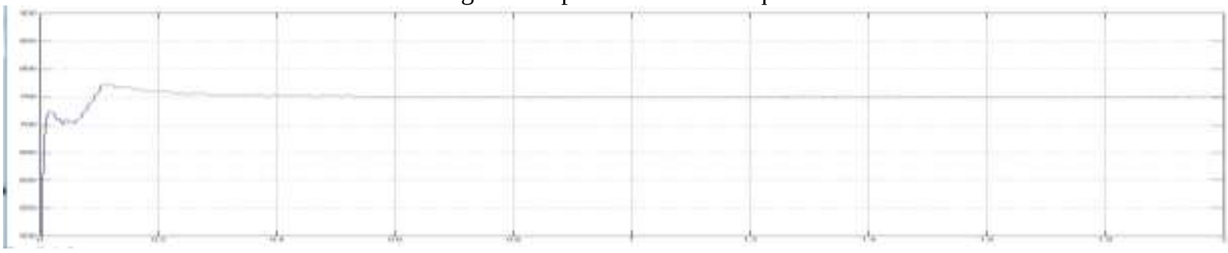

Fig 17: output at step load torque

6.2.2 Speed

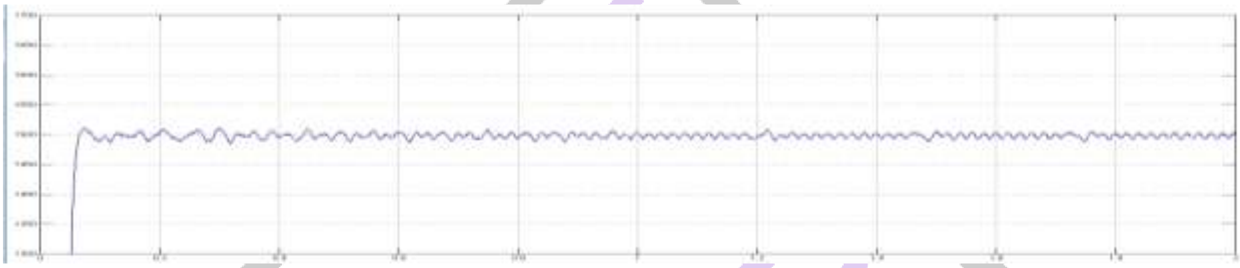

Fig 18: speed at no-load torque

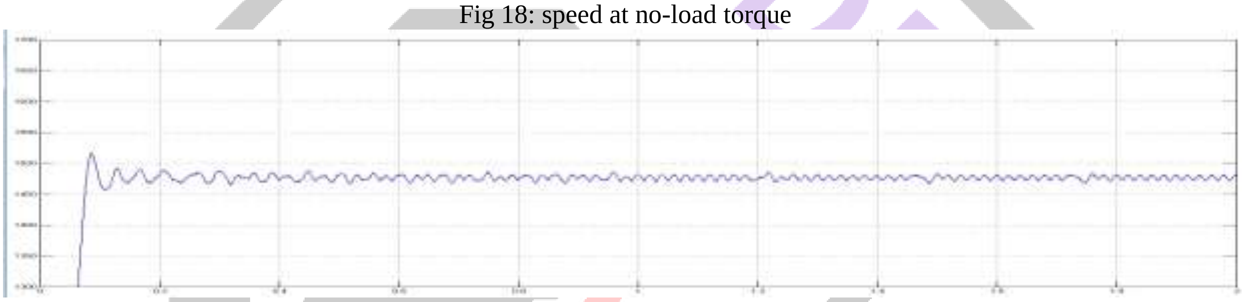

Fig 19: speed at full-load torque

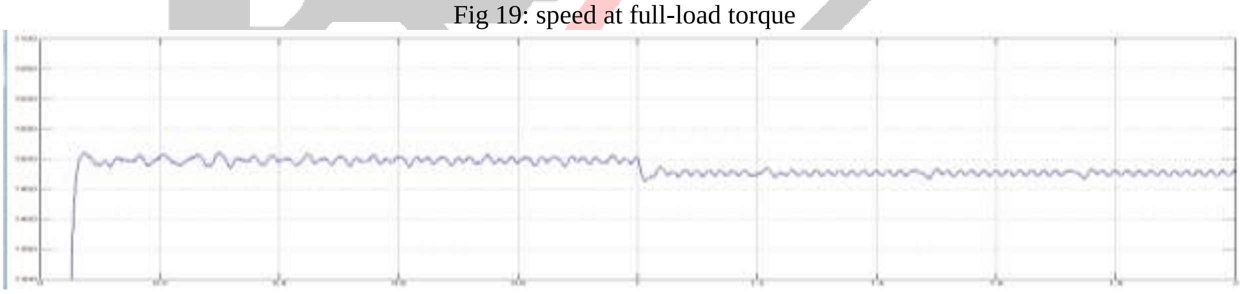

Fig 20: speed at step load torque

6.3 UTT Technique

6.3.1 Output Voltage

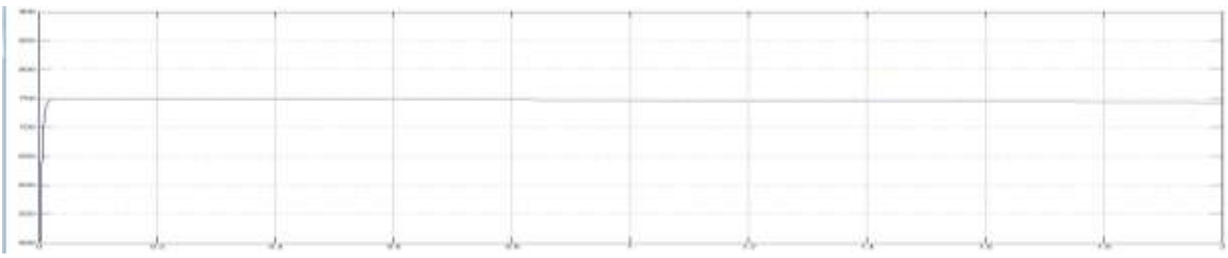

Fig 21: output voltage without load

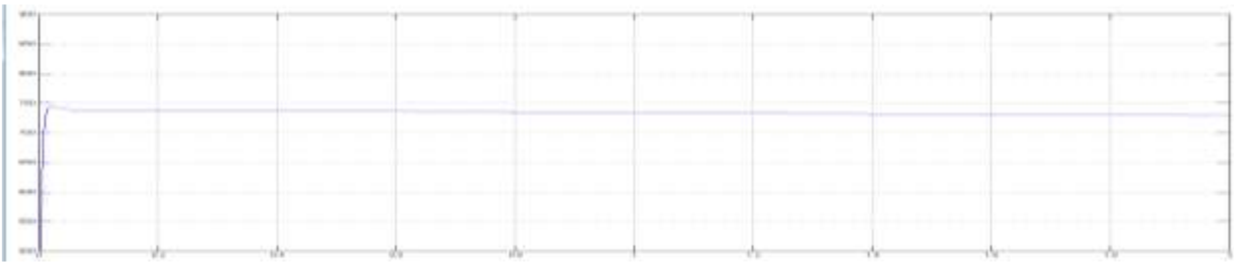

Fig 22: output voltage no load torque

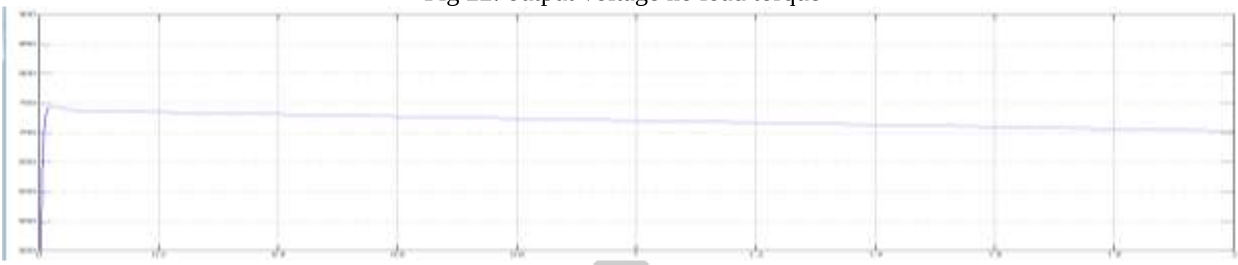

Fig 23: output voltage at fill load torque

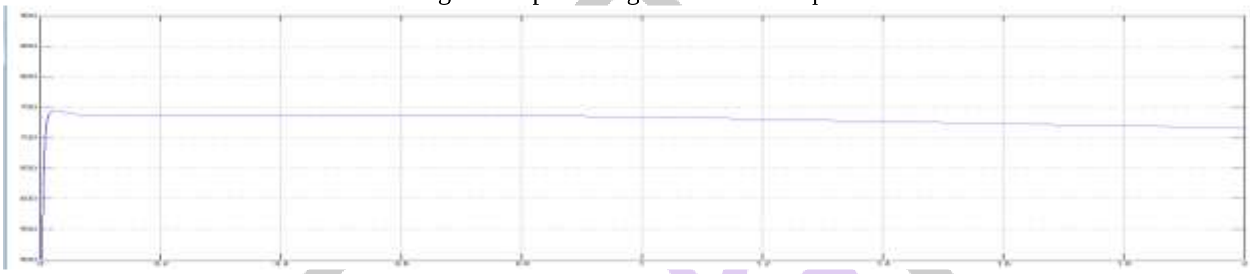

Fig 24: output voltage at step load torque

6.3.2 Speed

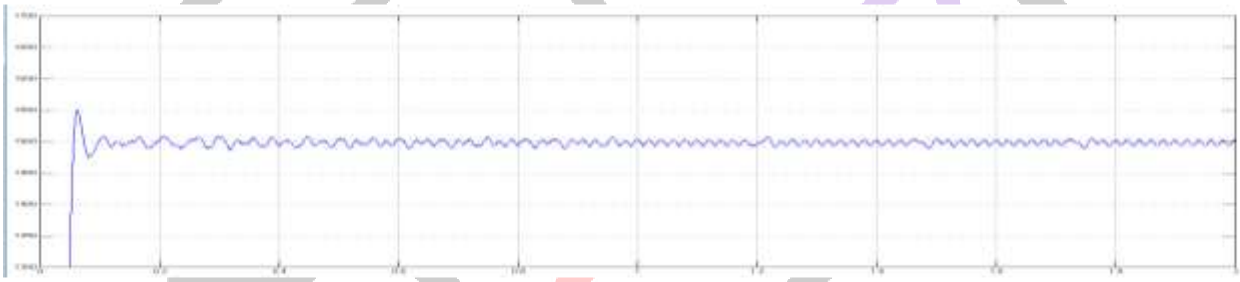

Fig 25: speed at no load

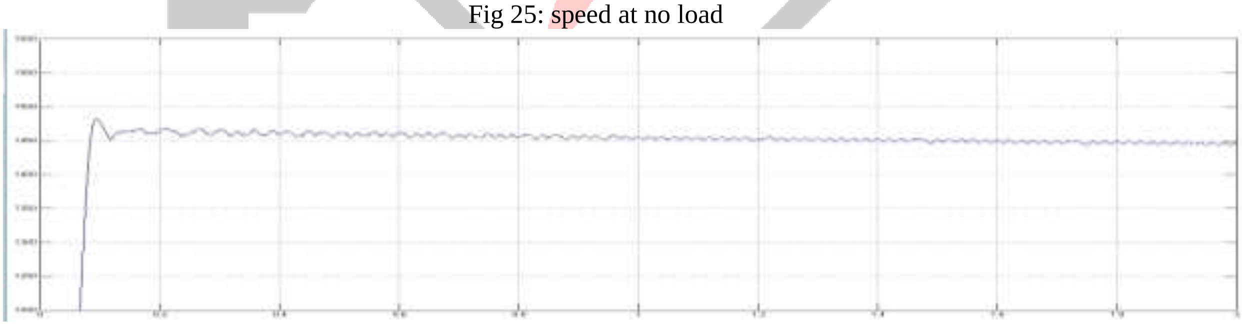

Fig 26: speed at full load torque

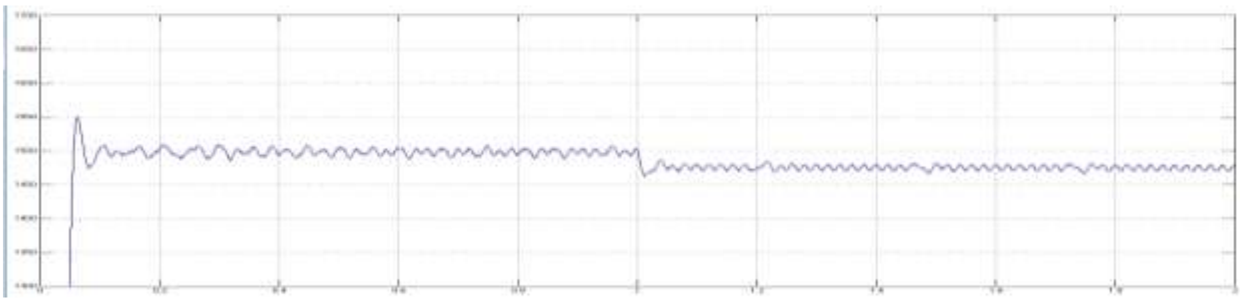

Fig 27: speed at step load torque

6.4 Active Powers

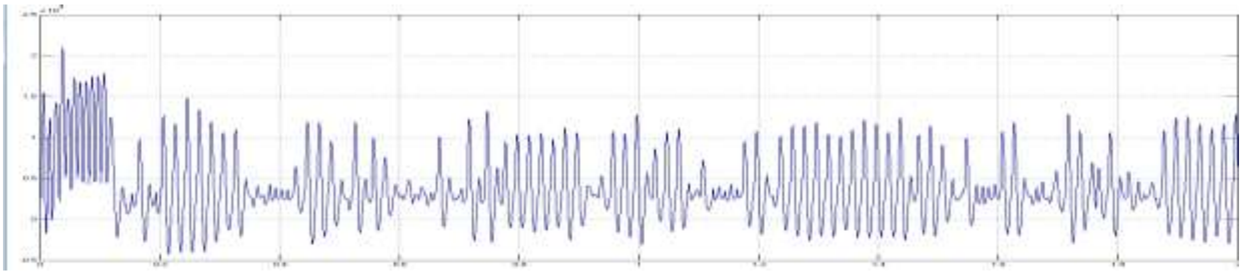

Fig 28: Active power from Hysteresis control

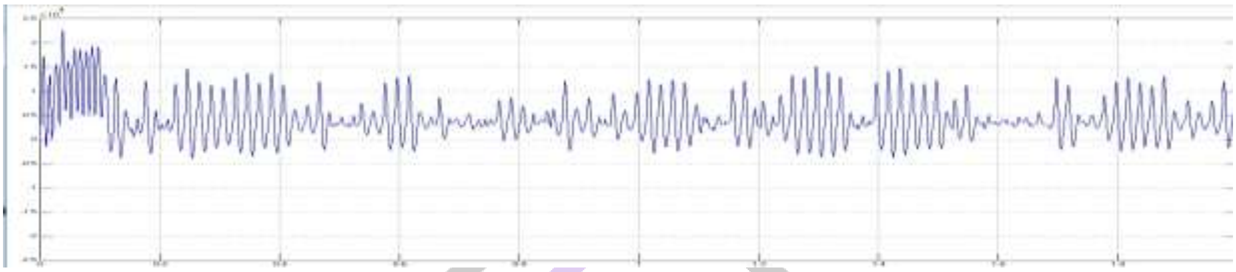

Fig 29: Active power from SPWM control

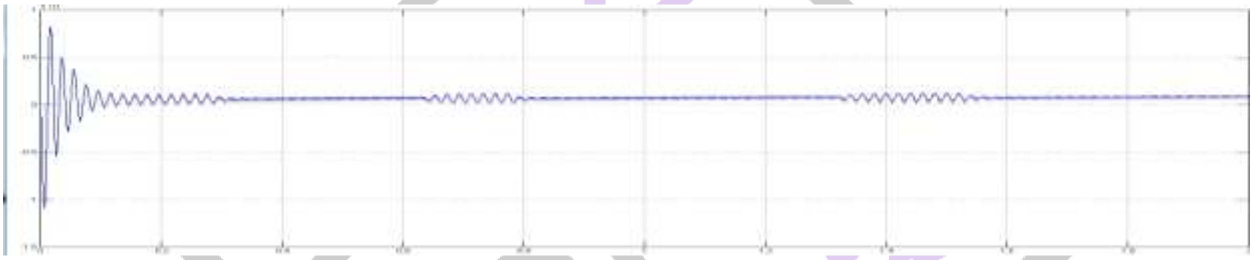

Fig 30: Active power from UTT control

7 COMPARISON TABLE

VSR Voltage controlled using unit vector template technique	VSR Current controlled using SPWM technique	VSR Current controlled using hysteresis band technique
- It doesn't contain dc link harmonics.	- It has lower dc link harmonics.	- It has comparatively large dc link harmonics.
- The output voltage is maintained to a constant value instantly.	- The output voltage is taking comparatively more time than VSR Voltage controlled.	- The output voltage is taking more time than the other two methods.
- Speed at no load and full load has fine value as compared to other two methods.	- Speed at no load and full load both have little variation compare to the VSR Voltage control.	-Speed at no load and full load has greater variation than the other two.
- It has good active power which indicates unity power factor.	- Its active power shows that it is nearly unity power factor.	- Its active power shows that its power factor is also nearly unity.

8 CONCLUSION

The PWM rectifiers pays a special attention to the controlling of electrical machine with lesser harmonics content and good power factor. This dissertation work is the comparative analysis of different kinds of the voltage source rectifiers and it also shows that VSR is preferred for the high power applications because of its controlling. Controlling output dc voltage with unity power factor and making output voltage constant is the major problem for the conventional rectifier, but with the introduction of the PWM rectifiers this problem is eliminated. All these studies have be done in closed loop analysis and results are verified using the simulation work done on MATLAB. PWM techniques as explained in previous chapters for the voltage source rectifiers are UTT, SPWM and hysteresis band PWM. All these methods are used to generate the PWM pulses for the switching of rectifier switches. Switches are also capable of flowing current in both direction and therefore the converter can be used for regeneration. Power factor at unity obtainable. Further the PWM rectifier is connected with the inverter and asynchronous machine to check the feasibility of converter circuit. Speed regulation is least and Power quality is also improved with the higher efficiency using PWM techniques. For the regeneration work VSR is as efficient as VSI. Therefore, PWM rectifiers are an efficient converter with the unity power factor and regeneration capability, which can enhance performance and efficiency.

REFERENCES

[1] Koray Sepetci and Bunyamin Tamyurek," Design and Simulation of a High Power Quality Regenerative PWM Rectifier System for 1 MW Electric Locomotives, 2013 3rd International Conference on Electric Power and Energy Conversion Systems, Yildiz Teclmical University, Istanbul, Turkey, October 2-4,2013.
[2] Anirudh Acharya. B, Vinod John," Common Mode DC Bus Filter for Active Front-End Converter", www.peg.ee.iisc.ernet.in
[3] José R. Rodríguez, Juan W. Dixon, José R. Espinoza, Jorge Pontt and Pablo Lezana, "PWM Regenerative Rectifiers: State of the Art", IEEE Trans. On Industrial Electronics, Vol. 52, No. 1, February 2005.
[4] P.S. Bhimbrah, Power Electronics.
[5] M. H. Rashid, Ed.," Handbook of Power Electronics", New York: Academic, 2001, Ch. 25, pp. 599–627.
[6] HVIGBT modules, (2013, June 15). Available: http://www.mitsubishielectric. com/semi con ductors/products/po wermod/hvigbtmodl.
[7] Amruta Pattnaik1, Haymang Ahuja1, Shubham Mittal, Nisha Kothari, Tushar harma, "Design and Implementation of SPWM and Hysteresis based VSI Fed Induction Motor".
[8] Zhenyu Yu, Arefeen Mohammed and Issa Panahi, "A Review of Three PWM Techniques", Albuquerque, New Mexico June 1997.
[9] Mahasweta Bhattacharya," Improvement of Power Quality Using PWM Rectifiers", International Journal of Scientific and Research Publications, Volume 4, Issue 7, July 2014.
[10] Hui Wang and Hui Qi, "Study of Control Strategies for Voltage-Source PWM Rectifier", Proceedings of the 2nd International Conference on Computer Science and Electronics Engineering (ICCSEE 2013).