IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)
An International Open Access, Peer-reviewed, Refereed Journal

COMPARATIVE STUDY OF HBRPC WITH SHUNT ACTIVE POWER FILTER FOR HIGH-SPEED RAILWAY TRACTION SUPPLY SYSTEM

[1]Mr. Shubham Sanjay Otari, [2]Mrs. Amaraja Dhamangaonkar

[1]Post Graduate Student, [2]Assistant Professor
[1]Department of Electrical Engineering,
[1]Walchand College of Engineering, Sangli, India

Abstract: With the rapid development of high-speed and high- power railway system, power quality issues such as the negative sequence current and harmonic current caused by electric locomotives becomes more and more critical.

The properties of locomotive load include high instantaneous power, high power factor, low harmonic components, and so on. High-speed locomotives with a high-power factor use four quadrant pulse width modulation (PWM), however they generate a lot of harmonic currents over a wide spectral range. Large amounts of harmonic current produced by the electric traction power supply system are injected into the power grid since most electric locomotives are single phase rectified loads with frequent random swings. As a result, the supply grid voltage and current are asymmetrical, and harmonic content increases, causing a slew of issues such as overheating, transformer service life shortening, and relay protection device mis-operation. These issues have a significant impact on the safe and stable operation of power systems.

This paper proposes a comparative study of Half Bridge Railway Power Conditioner (HBRPC) with Shunt active power filter STATCOM used to implement effective compensation of NSC and harmonic current

The comprehensive compensation for NSC and harmonic currents is implemented using STATic COMpensators (STATCOMs). Because distribution STATCOMs are frequently mounted on the three-phase side and carry high voltage, their cost and compensation capacity are usually high.

HBRPC is made up of two half-bridge converters connected in series by two capacitors. In comparison to the typical RPC, the HBRPC only requires two capacitors and two power switch legs. The HBRPC conditioner can decrease half of the power switches while still performing the same function as RPC, resulting in cheaper cost and hardware complexity.

Finally, MATLAB simulation and results have verified the proposed structure and its control method effectively.

***Index Terms* – HBRPC, STATCOM, NSC, Fuzzy, FFT Analysis, Compensation.**

I. INTRODUCTION

Power quality is becoming a major challenge for the traction power supply system due to the increasing growth of high-speed railways. High-speed locomotive loads differ from standard electrified railway locomotive loads in a few ways, including great instantaneous power, high power factor, low harmonic component, and high negative sequence components. A significant quantity of negative sequence current is injected into the grid, which has an adverse effect on the power system. For example, it increases motor vibration and excessive loss, lowers the output capacity of transformers, and disrupts relay protection. The traction supply system and power system for high-speed rail are at risk from these negative effects. As a result, steps must be taken to reduce harmonic and negative sequence current. A three-phase power grid can experience significant negative Sequence current (NSC) because to the electric traction system's ability to split a three-phase symmetrical supply into two separate single-phase sources. High-speed locomotives with a high-power factor use the four-quadrant pulse width modulation, but they also produce a lot of harmonic currents over a wide spectral range. These NSC and harmonic current would have a significant impact on the grid's capacity to operate reliably and efficiently, which might increase the traction system's power losses, shorten the traction transformer's lifespan and reliability, and cause sensitive equipment to malfunction.

The STATCOM shunt active filter is one of the most commonly utilized in mitigating power quality issues caused by harmonic currents. In this sort of filter, a current is introduced that, when combined with the supply current, causes the cancellation of current harmonics, leaving only the fundamental component of current needed to power the system. This scheme is used to balance out imbalanced currents, compensate for reactive losses, and eliminate harmonic current.

Two half bridge converters are connected in series by two capacitors to form the half-bridge railway power conditioner (HBRPC). The HBRPC only needs two capacitors and a pair of power switch legs in comparison to the conventional RPC. The proposed HBRPC conditioner can decrease half of the power switches while doing the same task as RPC, which can result in reduced costs and less complex hardware. For HBRPC, a balanced voltage (BV) control is proposed to mitigate the error of two capacitor voltages and ensure the device's normal operation. A double-loop control scheme is proposed to maintain the dc-link voltage constant and to achieve dynamic tracking of the current reference signals.

II. COMPENSATION BASED ON HALF BRIDGE RAILWAY POWER CONDITIONER

A railway static power conditioner (RPC) based on half-bridge converters (HBRPC) is made up of two half-bridge converter coupled by two capacitors in series. The HBRPC only needs two capacitors and a pair of power switch legs in comparison to the conventional RPC. This power conditioner can reduce the number of power switches in half while doing the same task as RPC, which lowers the cost and hardware complexity. For HBRPC, a balanced voltage control is suggested in order to reduce the error of two capacitor voltages and maintain proper operation. A double-loop control is also suggested to maintain the stability of the dc-link voltage and to achieve dynamic tracking of the current reference signal.

HBRPC is composed of two power switch legs and two dc link capacitor, with two switch legs coupled by two capacitors in series. A dynamical energy balance can be achieved by treating one half-bridge converter for rectification to absorb energy and to charge the dc-link capacitors and the other one for inversion to release energy and to discharge the dc-link capacitors. As a result, this power conditioner is essentially two half-bridge converters connected in back-to-back fashion. Thus, the traction power arms can receive active power from the HBRPC. It would be possible for HBRPC to transfer active power from one power arm to the other power arm, compensate for NSC, and suppress harmonic currents if it could implement a sensible control technique to modify the output voltage and current of two half bridge converters. This HBRPC topology can eliminate a pair of switch legs with four power switches as compared to RPC. Thus HBRPC can lower costs, hardware complexity, and power losses while performing the same task as RPC. Although the equivalent switching frequency would decrease by 50% and the switch voltage stress of the HBRPC would double, this could result in an increase in harmonic contents.

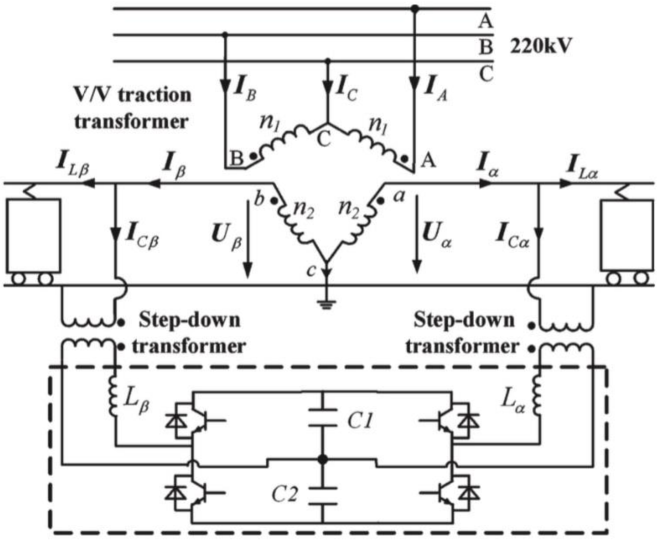

Fig. 1. Compensation system based on half-bridge converter.

For the high-speed railway's power quality, a comprehensive compensating system called HBRPC has been proposed. It is based on two half bridge converters. When compared to traditional RPC, there are reduced number power switches, which lowers the cost, power losses and hardware complexity. Fuzzy control is used to achieve quick monitoring of the current reference signal and enhance the performance of dynamic compensation in a real time reference detection approach for NSC and harmonic currents under V/V traction supply system. A BV control has been suggested to mitigate the unbalanced impact on system performance and eliminate the voltage imbalance by taking into account the dc-link voltage balance of two capacitors. Finally, simulation and experimental results have shown that HBRPC system has a significant impact on harmonic current suppression and NSC compensation. The HBRPC is a new approach to regulating the power quality of the railway system.

III. SIMULATION OF HBRPC

To validate the project, which is based on a half bridge converter and its control technique, a simulation model of HBRPC based on fuzzy logic is developed using MATLAB software. Assume that the power requirements for the 'a' and 'b' phase traction power arms are each supplied by a single phase at a different wattage. Here, R-L are used as a load model.

For compensated and uncompensated circuits, Ia and Ib stand for the a and b phase traction power currents. The voltages of two dc-link capacitors are Vdc and Vdc1. Two traction power currents that are not equal before adjustment contain a lot of harmonic and NSC currents. However, after switching to HBRPC at 0.3s, it can transfer a set amount of active power from 'b' phase traction power arm to the other and compensate the particular reactive power and harmonic current for two traction power arms correspondingly. Two traction power currents get balanced after adjustment. The harmonic currents are significantly reduced. Two capacitor voltages are out of balance prior to the HBRPC adjustment at 0.3s. After installing the HBRPC, the BV controller can internally enhance the time it takes for various power switches to conduct or shut down, increasing the amount of energy that can be used to discharge capacitors C1 and C2. Two capacitor voltages stabilize after some duration of adjustment. The voltage balance of the DC link is thus established.

Figure 3 depicts the load currents of two traction power arms prior to compensation, and Figure 5 depicts the traction currents of two traction power arms after compensation. With HBRPC's compensation, the harmonic components in the currents of two traction power arms are less than one of the two load currents. The harmonic currents of two traction power arm currents are considerably reduced, according to a specific harmonic current comparison of two traction power arm currents before and after compensation.

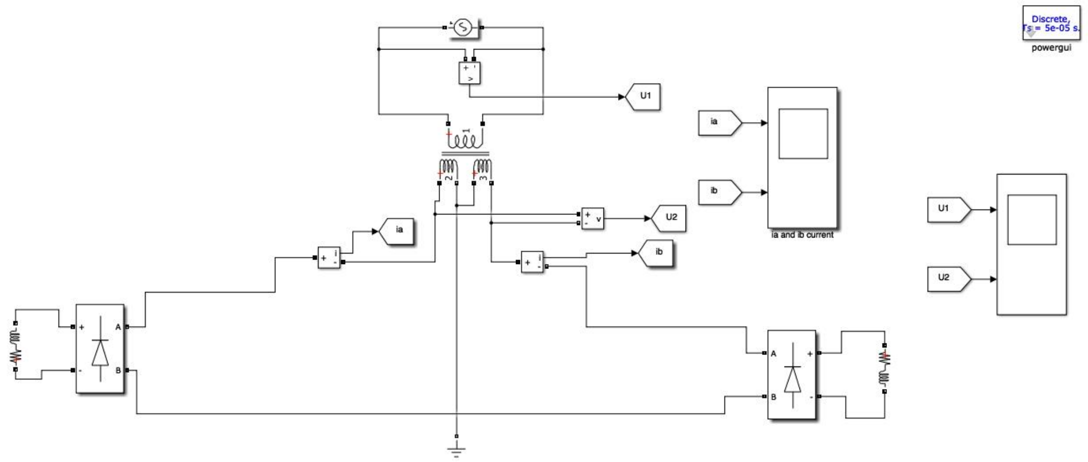

Fig. 2. Simulation model of uncompensated system.

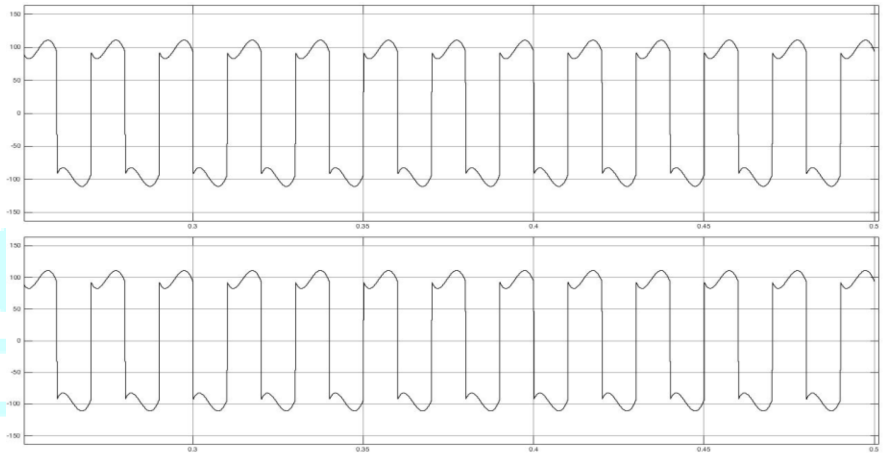

Fig. 3. Traction currents waveform before compensation.

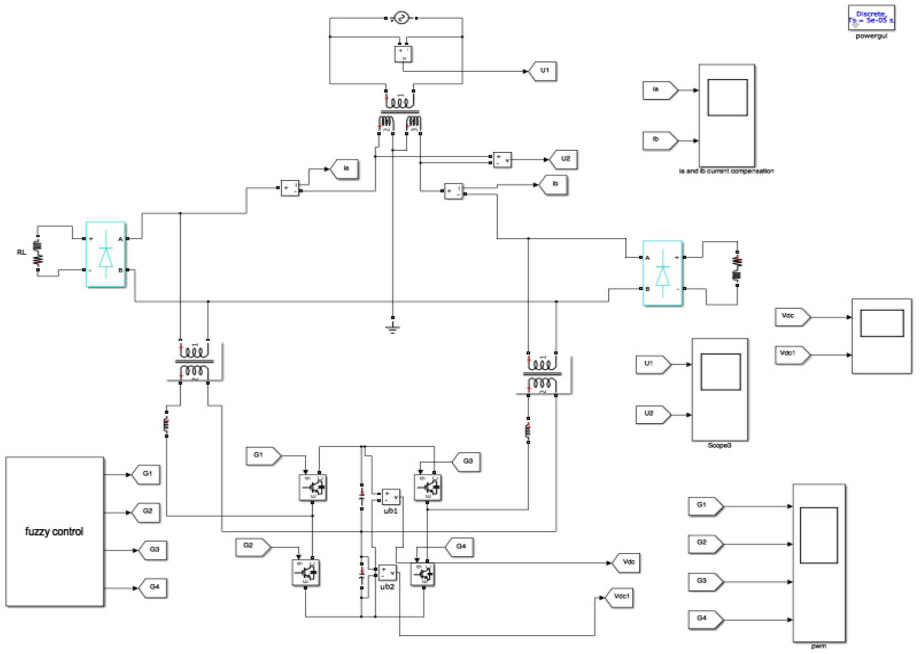

Fig. 4. Simulation model of compensated system.

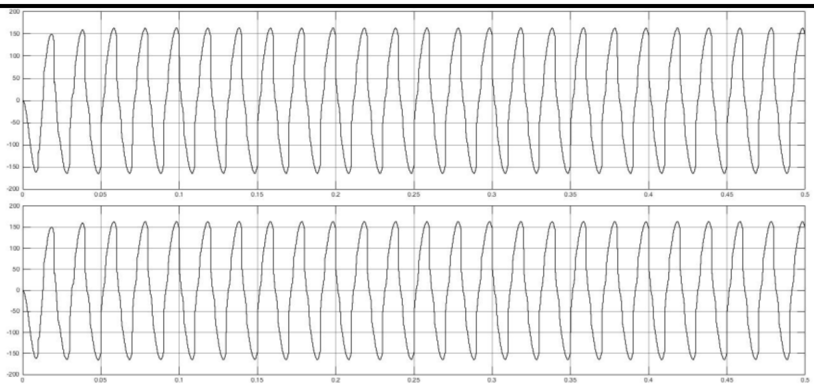

Fig. 5. Traction currents waveform after compensation.

By use of the FFT Analysis tool in MATLAB Total Harmonic Distortion (THD) of compensated and uncompensated circuits is calculated. The total harmonic distortion is reduced from 44.08 % to nearly 18%. So, the harmonic currents are effectively suppressed. FFT analysis also provides 3rd, 5th, 7th, 9th harmonics data of both circuits. It shows that the harmonics level is effectively reduced.

Table 1. Percentage of the significant current harmonics before compensation

Order of Harmonic Current	I-3rd %	I-5th %	I-7th %	I-9th %
Percentage	30.91	18.66	13.33	10.36

Table 2. Percentage of the significant current harmonics after compensation

Order of Harmonic Current	I-3rd %	I-5th %	I-7th %	I-9th %
Percentage	12.23	7.84	7.02	3.80

IV. COMPENSATION BASED ON SHUNT ACTIVE POWER FILTER

The shunt active power filter (SAPF) shown in Fig. 6 is a voltage source inverter (VSI) that is linked in parallel with the load. It is controlled in order to produce the load's necessary reactive and harmonic currents.

A current equal in size to the harmonic current but out of phase with it is injected by SAPF. In this scenario, the SAPF acts as an injector of current, phase-shifting by 180° the harmonic currents produced by the load. Any kind of load regarded as a harmonic source can be used according to this approach. Moreover, the SAPF can correct the load power factor with the right control strategy. The power distribution system perceives the nonlinear load and active power filter as perfect resistors in this manner. In order to cancel current harmonics on the AC side and bring the source current into phase with the source voltage, it is controlled to draw or supply a compensating current I from or to the utility.

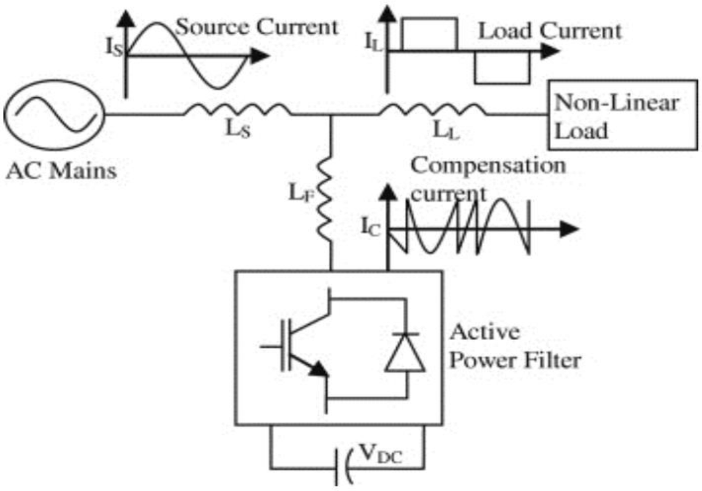

Fig. 6. Shunt active power filter.

V. SIMULATION OF SHUNT ACTIVE POWER FILTER

To validate the project, which is based on a shunt active power filter and its control technique, a simulation diagram of STATCOM based on d-q reference frame theory is developed using MATLAB software. Here, R-L are used as a load model.

Changing the a-b-c axes to the d-q-0 axes is referred to as reference frame transformation. the transition in coordinates from the three-phase a-b-c stationary coordinate system to the d-q-0 rotational coordinate system. In this case, the a-b-c coordinates are first transformed into alpha-beta coordinates, then into d-q-0 coordinates. It is necessary to have two separate transformation matrices: one for Clarks and one for parks transformation.

Integrators are employed in synchronous reference frame PI-based controllers to remove the steady state error of the DC components of the reference signals' 0–d–q coordinates. The current harmonics are represented as DC components in their associated reference frames in accordance with the 0-d-q frame theory, and the integrators remove the steady state error of each harmonic component. Using the Park transformation, reference signals are converted first into $0 - \alpha - \beta$ stationery frame, then into $0 - d - q$ rotating frame. In order to achieve the desired regulated reference signal, the steady state error is eliminated using the PI controller. The process is then advanced by converting the voltage reference signal from the 0–d–q spinning frame back to the a–b–c stationary frame, which will serve as the reference signal for the pulse width modulation (PWM).

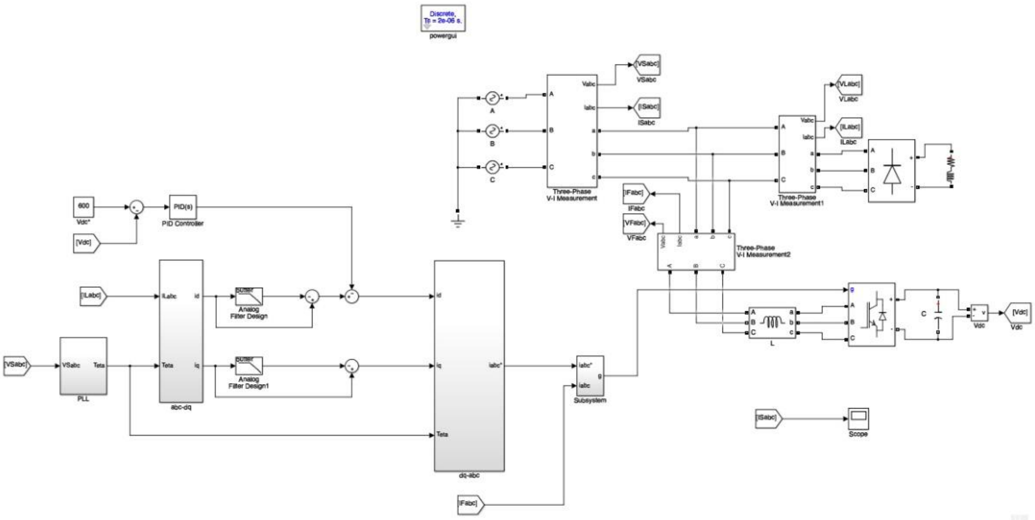

Fig. 7. Simulation model of shunt active power filter compensated system.

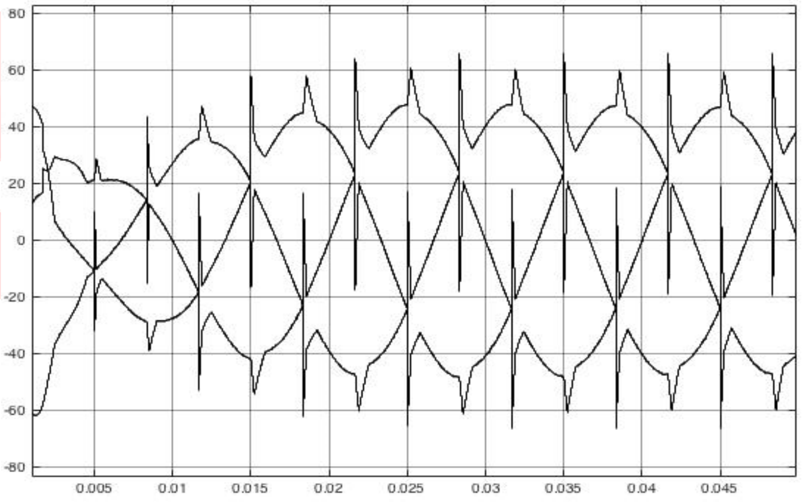

Fig. 8. Three phase current waveform after compensation.

By use of the FFT Analysis tool in MATLAB Total Harmonic Distortion (THD) of compensated and uncompensated circuits is calculated. The total harmonic distortion is reduced from 36.94 % to nearly 18 %.

VI. CONCLUSION

A comprehensive compensation systems HBRPC and Shunt active filter have been presented to improve power quality of the high-speed railway traction supply system, which is based on two half-bridge converters and STATCOM, in this paper. Comparative study can be effectively done on various aspects. HBRPC bears less voltage stress as it is installed on load side whereas Shunt active filter bears high voltage stress as it is source side compensation technique. Compared to the traditional RPC, HBRPC requires the less number of power switches, so the cost, power losses and hardware complexity are reduced correspondingly. While for shunt active filter compensation for railway traction power supply system requires large capacity rating devices and hence it is comparatively high-cost solution. As compared to Shunt active power filter, HBRPC is compact in design and less complex and hence HBRPC is more reliable compensation technique. Finally, MATLAB simulation and experiment results have confirmed that the proposed HBRPC compensation system has a good effect on negative sequence current compensation and harmonic current suppression. Even though the half bridge converter has some drawbacks, the proposed HBRPC provides a new attempt for managing the power quality of the high-speed railway traction supply system.

REFERENCES

[1] Hirofumi Akagi, "New Trends in Active filters in Power conditioning", IEEE TRANSACTIONS ON INDUSTRY APPLICATIONS, Volume 32, No.6, page 1312- 1322, November December 1996.

[2] Bueno, Jose M. Aller, Jose A. Restrepo, Ronald Harley, and Thomas G. Habetler, "Harmonic and Unbalance Compensation Based on Direct Power Control for Electric Railway Systems" IEEE TRANSACTIONS ON POWER ELECTRONICS, VOL. 28, NO. 12, Page 5823-5831, December 2013.

[3] Mingxing Tian, Yuqi Zhou and Hong Yan, "Comprehensive Compensation Method for Harmonics and Negative Sequence Current in High-speed Railway under Grid Voltage Distortion", International Journal of Control and Automation, Vol.7, No.7 Pages:191-202 (2014).

[4] Fujun Ma, An Luo, Xianyong Xu, Huagen Xiao, Chuanping Wu, and Wen Wang, "A Simplified Power Conditioner Based on Half-Bridge Converter for High-Speed Railway System", IEEE TRANSACTIONS ON INDUSTRIAL ELECTRONICS, VOL. 60, NO. 2, Page:728-738, FEBRUARY 2013.

[5] Natesan P, Madhusudanan G, "Compensation of Power Quality Problems in Traction Power System Using Direct Power Compensator", 2014 IEEE International Conference on Innovations in Engineering and Technology (ICIET'14), vol.3, Page 277-280, 3 march 2014.

[6] Bryan Klingenberg, "A Time-Varying Harmonic Distortion Diagnostic Methodology Using Fuzzy Logic".

[7] Chenmeng Zhang, Baichao Chen, Chao Cai, Mengkui Yue, Cuihua Tian, Bo Chen, Jiaxin Yuan, Jiabin Jia, "Novel Collaboration Compensation Strategy of Railway Power Conditioner for a High-Speed Railway Traction Power Supply System", UKACC International Conference on Control 2012 Cardiff, UK, 3-5, Page 731-736, September 2012.

[8] An Luo, Chuanping Wu, John Shen, Zhikang Shuai, Fujun Ma, "Railway Static Power Conditioners for High-speed Train Traction Power Supply Systems Using Three-phase V/V Transformers", IEEE TRANSACTIONS ON POWER ELECTRONICS, VOL. 26, NO. 10, Page 2844-2856, OCTOBER 2011.

[9] Karuppanan P and Kamala Kanta Mahapatra, "PI, PID and Fuzzy logic controller for Reactive Power and Harmonic Compensation", ACEEE Int. J. on Electrical and Power Engineering, Vol. 01, No. 03, Page 54-58, Dec 2010.

[10] Jin Li, Xiangzheng Xu, "Study on Harmonic Control for Electrified Railway", International Journal of Advancements in Computing Technology, Volume4, Number14, Page160-169, August 2012.

[11] Mridula sharma, Manish soni, "Review of Power quality issues for traction system", International Journal of Emerging Technology and Advanced Engineering,Volume 3, Issue 8, page 450-453, August 2013.

[12] B. Pakkiraiah, L. Raja, "Negative Sequence and Harmonic Currents Compensation in High-Speed Electric Railway", Journal of Environmental Science, Computer Science and & Technology Page 251-260 Vol.3. No. 1, December 2013-February 2014.

[13] Mihaela Popescu, Alexandru Bitoleanu, Mircea Dobriceanu, "Harmonic Current Reduction in Railway Systems", WSEAS TRANSACTIONS on SYSTEMS, Page 689-698 Issue 7, Volume 7, July 2008.

[14] M.Sunitha, B. N. Kartheek, "Elimination of Harmonics Using Active Power Filter Based on DQ Reference Frame Theory", International Journal of Engineering Trends and Technology (IJETT) - Volume4Issue4- April 2013.

[15] M. Rama Gopal, Sobharani Yarnagula, "Simulation and Analysis of Shunt Active Power Filter for Power Quality Improvement", International Journal of Advanced Trends in Computer Science and Engineering, Vol. 3, No.1, Pages: 26 - 31 (2014).

[16] Dr. Rama Rao, P.Devikiran and M. D. L. Saranya, "Modelling and Analysis of Controller for Three-Phase Shunt Active Power Filter", International Journal of Signal Processing, Image Processing and Pattern Recognition Vol.9, No.1 (2016), pp.103-110.