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Comparative Performance Analysis of 10-Pulse and 6-Pulse Converters for Flicker Mitigation

Akanksha Bhagat
Department of Electrical Engineering, GCET, Jammu, J&K, India-180001
akanksha126bhagat@gmail.com

***Abstract*—T**his paper presents the impact of using conventional 6-pulse and multi-pulse converter circuit configured D-STATCOM to mitigate voltage flicker. 6-pulse inverter has been used in industries, but is associated with large low-order harmonics. D-STATCOM is a shunt connected device for reactive power compensation, by absorbing or generating reactive power. Adjustment in output voltage of D-STATCOM is achieved to control power factor, stabilize power flow, regulate voltage and improve dynamic performance of the system. VSI (voltage source inverter) is an essential component of D-STATCOM, generating output voltage with required magnitude and phase angle synchronized with the system. A traditional two-level inverter can be used for low voltage applications. However, for high voltage, sinusoidal voltage with minimal distortion is required. Modern inverter topologies like multi-pulse inverter can be implemented for the purpose. Multi-pulse inverter requires the magnetic interface provided by complex zig-zag phase shifting transformers but provide lesser total harmonic distortion (THD). This paper discusses the performance of a conventional six-pulse and multi-pulse voltage source inverter in mitigating voltage flicker and their corresponding digital simulation using MATLAB/SIMULINK block set. The results are presented to validate the feasibility of proposed topology.

***Keywords*—**VSI; FACTS; Digital flicker meter; D-STATCOM; Programmable voltage source; THD and Harmonics.

I. INTRODUCTION

With the growth in industrial sector and improved standards of living, energy demand has increased drastically. The environment constraints and financial needs have forced to look for means to utilize available resources and look for the way to enhance performance of existing power system. FACTS devices are a modern world's solution for this which helps in distribution of electric energy in a way more economical manner providing better utilization of existing system and networks hence, reducing the need for extra transmission network [1].

Voltage source inverter (VSI) based FACTS device are quiet prominent owing to some advantages like high response speed, compact/small, and no harmonic contamination and cost effective. The role of VSI has been widely accepted as the next generation of reactive power controllers of power system to replace conventional VAR compensation [2]. Researchers are trying to apply FACTS in different domains to enhance power system operation. The major applications are: damping torsional oscillations, power system stability improvement, and power system voltage control and voltage stability enhancement. These applications can be implemented with a suitable control (voltage magnitude and phase angle control) [3-5].

Recently, Multi-pulse inverters have attracted the attention from researchers as well as scientists all over the world [6] and [7]. The output of a multi-pulse inverter is a staircase wave obtained by connecting identical inverter bridges through Phase shifting transformers (PST). Multi-pulse converters are designed for Total harmonic distortion (THD). Intensive amount of research has been put to reduce harmonic content in the utility line currents of converter [8]. Passive filters have been used with many configurations by researchers [9], but have certain disadvantages like heavy filter elements, bulky and resonance problem. Active filters have also been applied but, they suffer from high cost and complexity [10] and [11]. Hybrid combination of both active and passive filters is used for high power applications [12].

II. MULTI-PULSE METHOD

Flow of excessive harmonic current in a power system can lead to number of power quality problems like overheating, resonance and electromagnetic interference (EMI). Numbers of techniques have been made available for harmonic reduction including filters and multi-pulsing. Multi-pulsing is a very efficient way of decreasing harmonics. The basic principle is to displace power electronic device switching of two or more identical power modules, such that harmonics generated from switching of different modules can cancel [13].

Multi-pulse converters include multiple converters linked so that harmonics generated by one converter are cancelled by harmonics produced by other. By using this technique, particular harmonics related to number of converters are eliminated from power source [14]. In multi-pulse converters, reduction of input line current harmonics is important as regards to the impact the converter has on the power system [15]. Multi-pulse methods are characterized by the use of multiple converters or multiple semiconductor devices with a common load [16].

III. INVERTER TOPOLOGY

Voltage source inverter aims at generating AC output from the DC input. Thus, it is also called as DC to AC converter or inverter. VSI generates symmetrical AC voltage with required magnitude and frequency, which can be varied as per the requirements. The voltage source inverter is the basic part of any FACTS device like D-STACOM.

A traditional six-pulse inverter is also called 3-phase inverter, consisting of six asymmetric switching devices like GTO or IGBT with diodes connected in antiparallel forming six-pulse Graetz Bridge [17] as shown in Fig. 1. The firing signals are controlled such that each transistor conducts during 180° when

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resistive load is applied. The inverter is designed from three single-phase inverters, each phase providing a voltage shifted by phase angle of $\pm 120°$ with respect to other two.

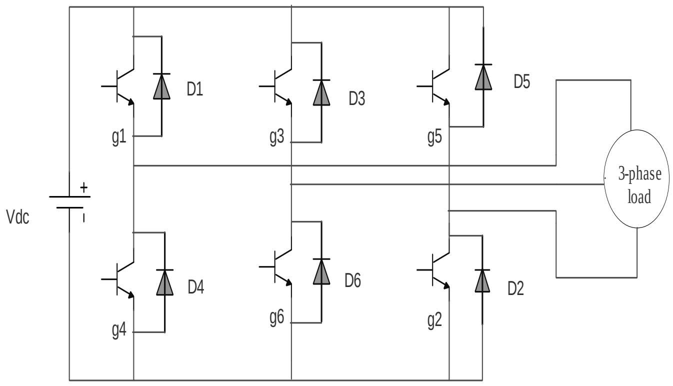

Fig. 1. Six-pulse Voltage Source Inverter

D-STATCOM is a device capable of generating and absorbing both active and reactive power, mostly used for reactive power exchange between system and compensator. Six-pulse configured VSI is the building block of a basic D-STATCOM. However for high power applications, it exhibits high harmonics thus, in high power applications 3-phase or six-pulse VSI fed D-STATCOM is not desirable for appropriate performance. Therefore for high power application multi-pulse inverter (more than six-pulse) is opted for. In this paper 10-pulse (non integral multiple of six) inverter has been used for the purpose.

IV. MODELLING OF SIX-PULSE INVERTER

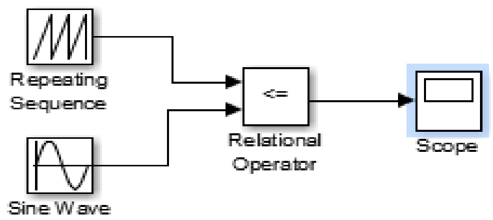

Fig. 2. SPWM Technique

Voltage source inverter is modelled in MATLAB/SIMULINK. Sinusoidal pulse width modulation (SPWM) is used to generate the pulses for power electronic switches like IGBT or GTO. In SPWM technique carrier wave is compared with the sine wave as shown in Fig. 2. The output of six-pulse and multi-pulse (ten) voltage source inverter is shown in Fig. 3 and Fig. 4.

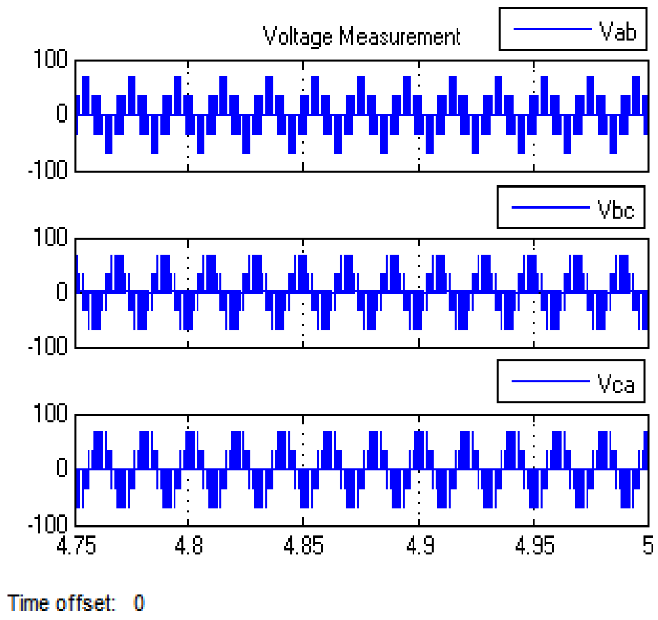

Fig. 3. Output Waveform of Six-Pulse Inverter

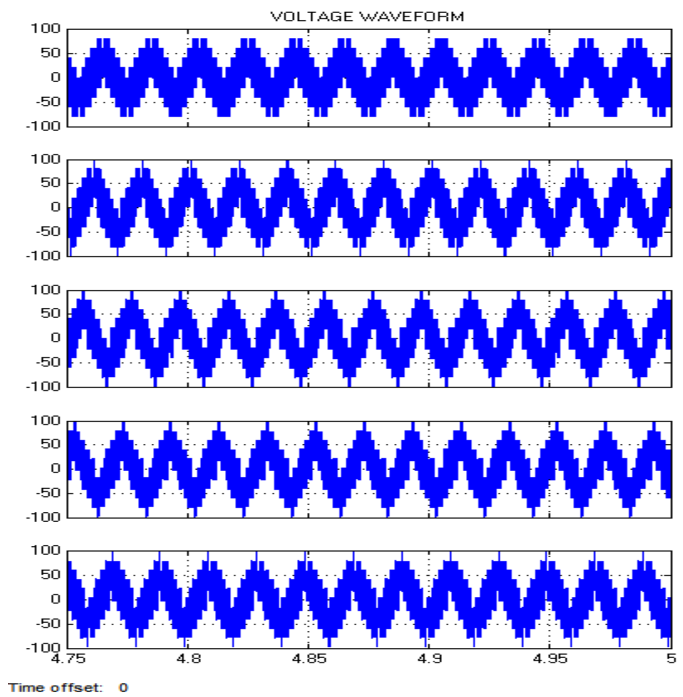

Fig. 4. Output Waveform of Ten-Pulse Inverter

V. VOLTAGE FLICKER MITIGATION

A lightning disturbance induced as a consequence to voltage fluctuation owing to presence of non-linear loads on the system like electric arc furnace is termed as voltage flicker. A two bus system is considered to investigate flicker.

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The flickered voltage is analysed using digital flicker meter block in MATLAB/SIMULINK [18]. The Input received by flicker meter is fluctuated voltage and gives instantaneous flicker level (IFL) as output. Fig. 5 illustrates the block diagram of test system. Voltage oscillations are produced by 3-phase programmable voltage source.

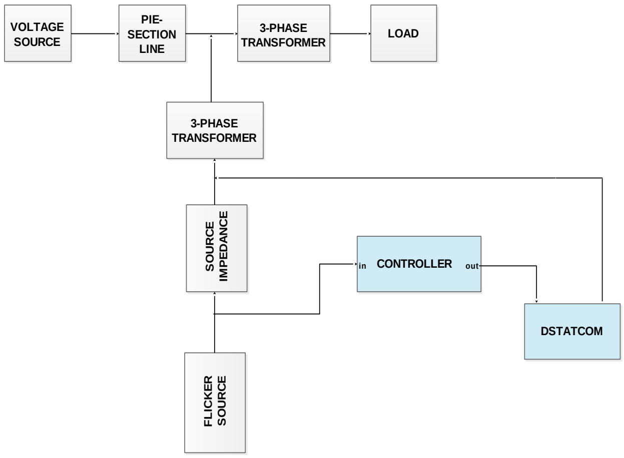

Fig. 5. Block Diagram of Studied Test System

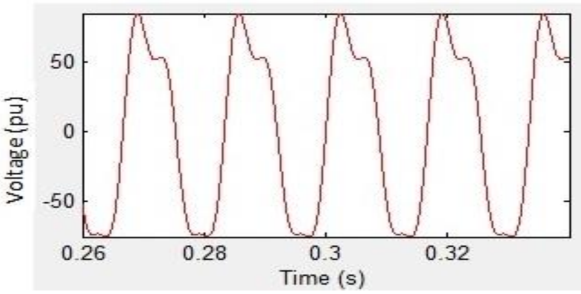

Fig. 6. Uncompensated Voltage Waveform

Owing to its fast response, D-STATCOM is an efficient tool for voltage flicker mitigation [19]. First voltage flicker mitigation is adopted using D-STATCOM with six-pulse VSI and then with ten-pulse VSI and the results are simulated in MATLAB. Uncompensated voltage is analysed using digital flicker meter as shown in Fig. 6 and 7 and FFT analysis of output voltage is provided in Fig. 8.

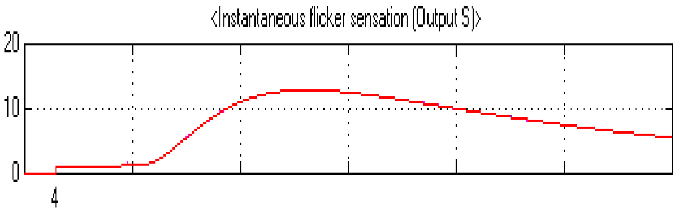

Fig. 7. Instantaneous Flicker Sensation

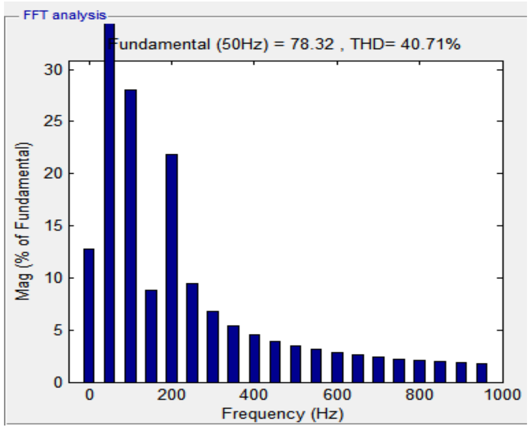

Fig. 8. FFT Analysis of Uncompensated Load Voltage

VI. SIMULATION RESULTS

The impact of using six-pulse and ten-pulse configured D-STATCOM has been investigated with the intentions of mitigating the voltage flicker. The output voltage of the test system for the two conditions with the associated IFL and THD is shown in Fig. 9 to Fig, 14. The various instantaneous flicker sensation levels are tabulated in Table .1.

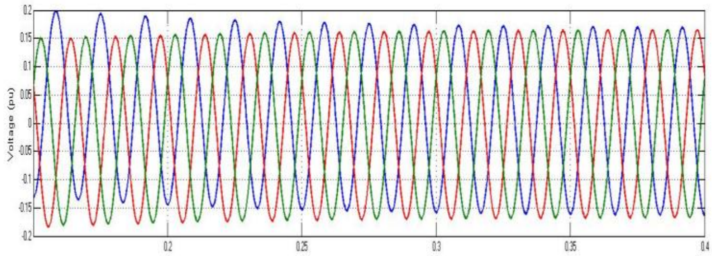

Fig. 9. Compensated Output Voltage by Six-Pulse Voltage Source Converter D- STATCOM

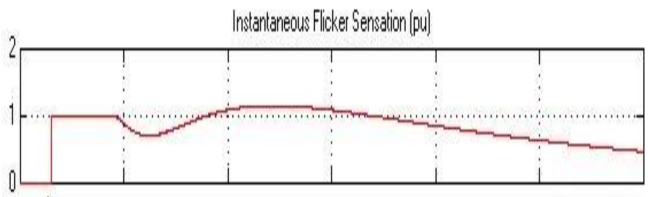

Fig. 10. Instantaneous Flicker Sensation Level with Six-Pulse Voltage Source Converter D- STATCOM

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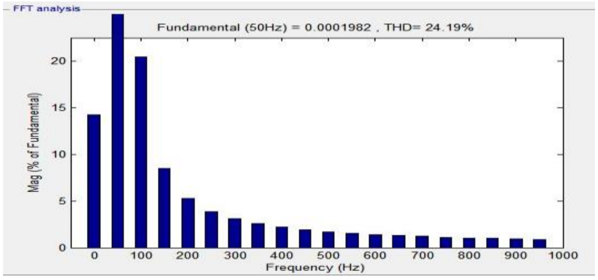

Fig. 11. FFT Analysis of Load Voltage with Six-Pulse Voltage Source Converter D- STATCOM

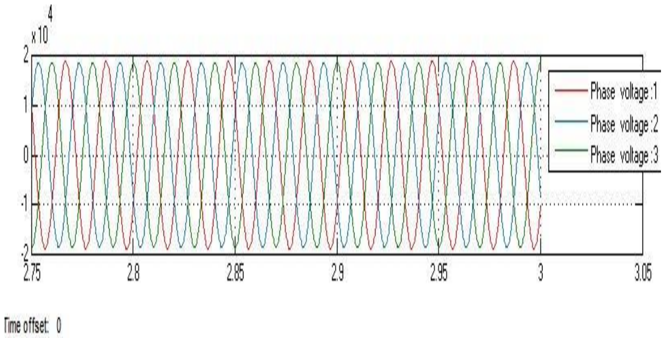

Fig. 12. Compensated Output Voltage by Ten-Pulse Voltage Source Converter D- STATCOM

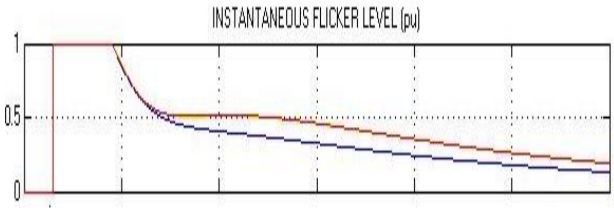

Fig. 13. Instantaneous Flicker Sensation with Ten-Pulse Voltage Source Converter D- STATCOM

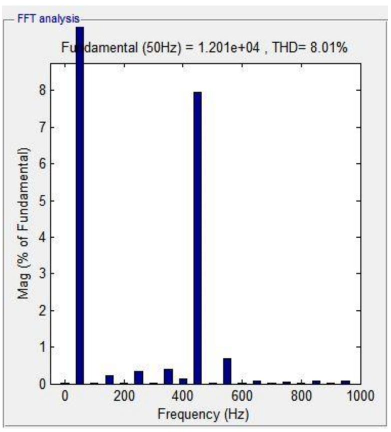

Fig. 14. FFT Analysis of Load Voltage with Ten-Pulse Voltage Source Converter D- STATCOM

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VII. SIMULATION ANALYSIS

The impact of using six-pulse and ten-pulse configured D-STATCOM has been investigated with the intentions of mitigating the voltage flicker. The output voltage of the test system for the two conditions with the associated IFL and THD is shown in Fig. 9 to Fig, 14.

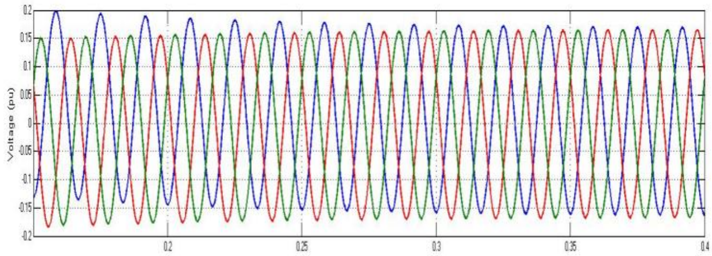

Fig. 15. Compensated Output Voltage by Six-Pulse Voltage Source Converter D- STATCOM

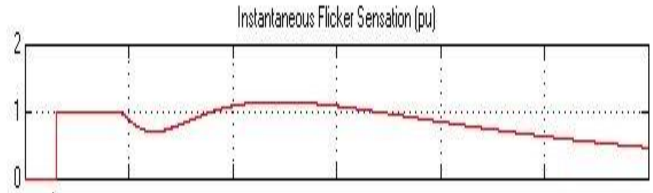

Fig. 16. Instantaneous Flicker Sensation Level with Six-Pulse Voltage Source Converter D- STATCOM

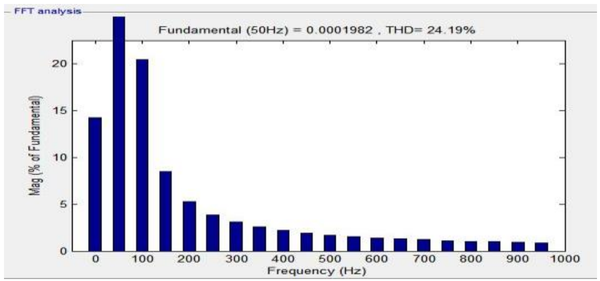

Fig. 17. FFT Analysis of Load Voltage with Six-Pulse Voltage Source Converter D- STATCOM

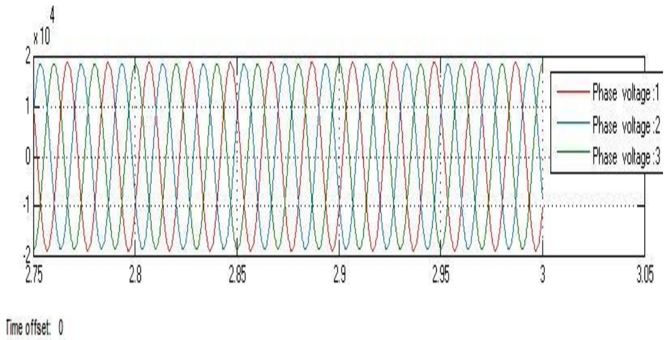

Fig. 18. Compensated Output Voltage by Ten-Pulse Voltage Source Converter D- STATCOM

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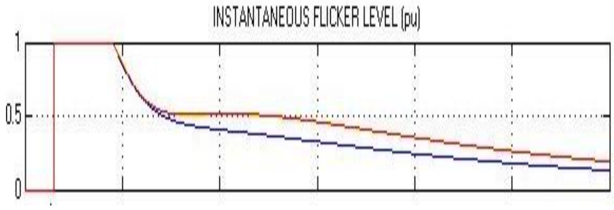

Fig. 19. Instantaneous Flicker Sensation with Ten-Pulse Voltage Source Converter D- STATCOM

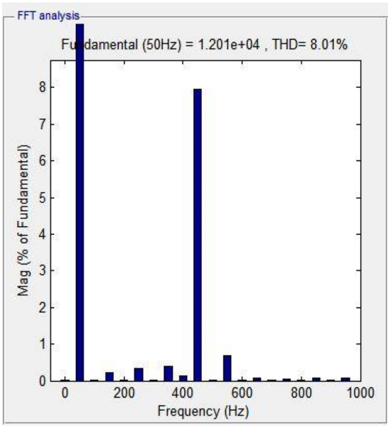

Fig. 20. FFT Analysis of Load Voltage with Ten-Pulse Voltage Source Converter D- STATCOM

VIII. SIMULATION RESULTS

A comparison is carried out between the Instantaneous flicker sensation values for the uncompensated system and the compensated system using six-pulse and ten-pulse voltage source converter for different time instances. As the numbers of pulses increase, the flicker sensation value sees a drop. Hence increasing the pulse number caused the better flicker mitigation with reduced THD levels. Based on this data, a graph is plotted indicating different harmonics for the system under different conditions as shown in Fig. 15.

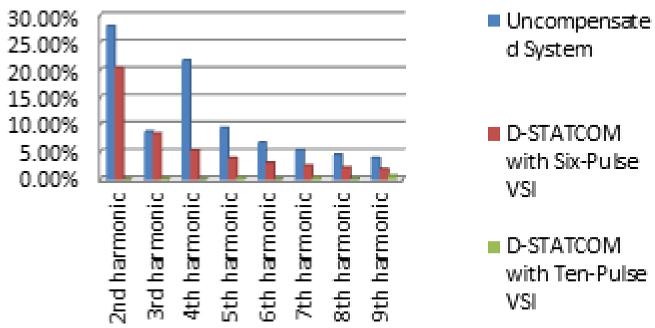

Fig. 21. Harmonic Analysis

IX. CONCLUSION

In this paper voltage flicker mitigation using voltage source inverter D-STATCOM has been investigated. The MATLAB/SIMULINK results indicate that six-pulse voltage source inverter is efficient in decreasing the voltage flicker by considerable amount. But the output load voltage has harmonic distortion of about 24% which can be reduced by increasing the pulse number of inverter. Using ten-pulse voltage source inverter D-STATCOM harmonic distortion is reduced to 8.01%. Also the data received from digital flicker meter indicates that as the number of pulses is increased; instantaneous flicker level can be reduced causing efficient flicker mitigation on the power system.

REFERENCES

[1] B. Geethalakshmi and P. Dananjayan, “A Combined Multipulse-Multilevel Inverter Based SSSC,” no. 58, pp. 25–30, 2009.

[2] J. M. Ramı and R. Da, “Three-phase multi-pulse converter StatCom analysis,” Elsevier, vol. 27, pp. 39–51, 2005.

[3] Yang Z, Shen C, Zang L. Integration of a StatCom and battery energy storage. IEEE Trans Power Syst 2001; 16(2):254–60.

[4] Chun L, Qirong J, Jianxin X, Investigation of voltage regulation stability of static synchronous compensator in power system. IEEE Power Engineering Society, Proceedings of the Winter Meeting 2000, IEEE vol. 4, 2642–7.

[5] Wang HF. Applications of damping torque analysis to StatCom control.Elsevier, Electric Power Energy Syst 2000; 22:197–204.

[6] Bhim Singh, G. Bhuvaneswari and Vipin Garg, “Harmonic mitigation using 12-pulse ac-dc converter in Vector Controlled Induction Motor Drives”, IEEE Transactions on Power Delivery, vol.21, no.3, pp.1483-1492, 2006.

[7] Ricardo Davalos M., Juan M. Ramirez and O. Ruben Tapia, “Three-phase multi-pulse converter STATCOM analysis”, Electric Power and Energy Systems, vol.27, pp.39-51, 2005.

[8] H. A. Pacheco, G. Jimenez, and J. Arau, “Optimization method to design filters for harmonic current reduction in a three phase rectifier,” in Proc. IEEE Conf. CIEP, Puebla, Mexico, Aug. 1994, pp. 138–144.

[9] S. Bhattacharya, D. M. Divan, and B. B. Banerjee, “Control and reduction of terminal voltage harmonic distortion (THD) in hybrid series active and parallel passive filter system,” in Proc. IEEE PESC, Seattle, WA, Jun. 1993, pp. 779–786.

[10] J. Ortega, M. Esteve, M. Payán, and A. Gómez, “Reference current com- putation methods for active power filters: Accuracy assessment in the frequency domain,” IEEE Trans. Power Electron., vol. 20, no. 2, pp. 446– 456, Mar. 2005.

[11] B. Lin and Y. Ou, “Active power filter based on three- phase two-leg switch-clamped inverter,” Electr. Power Syst. Res., vol. 72, no. 1, pp. 63– 72, Nov. 2004.

[12] S. Bhattacharya, P. Cheng, and D. M. Divan, “Hybrid solutions for im- proving passive filter performance in high power applications,” IEEE Trans. Ind. Appl., vol. 33, no. 3, pp. 732–747, May/Jun. 1997.

[13] F. Wang,“System Harmonics Reduction Using Multipulse AC Fed PWM Voltage Source Inverters,” pp. 1265–1268, 1998.

[14] D. Singh, H. Mahala, and P. Kaur, “Modeling & Simulation of Multi - Pulse Converters for Harmonic Reduction,” no. 3, 2012.

[15] B.Singh, S.Gairola, B.N.Singh, A.Chandra, and K.A.Haddad, “Multi-pulse AC-DC Converter for Improving Power Quality: A Review” IEEE Transactions, On Power Delivery, Vol.23 No.1 January 2008.

[16] G.K.Dubey, S.R.Doradla, A.Joshi, R.M.K.Sinha, “Thyristorised Power Controllers”, New Age International publishers, July 1996.

[17] Song YH, Johns AT. Flexible ac transmission systems FACTS. IEE Power Energy Ser 1999; 30.

[18] MATLAB The Language Of Technical Computing, SIMULINK Software, Version R2014a.

[19] Hingorani NG, Gyugyi L. Understanding FACTS. IEEE Press; 2000.

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