

# Application of Harmonic Mitigation Technique to a VSI fed by 12 pulse fully controlled rectifier circuit using passive filtering

Akash Deo, Deepanshu Sharma, Dipesh Kumar Meena, Devanshu Gupta, Dhananjay , Dharmesh Choudhary

*Asstt. Professor Dept. of Electrical Engineering Swami Keshvanand Institute of Technology, Management and Gramathan Jaipur, INDIA*

*Dept. of Electrical Engineering Swami Keshvanand Institute of Technology, Management and Gramathan Jaipur, INDIA*

*Dept. of Electrical Engineering Swami Keshvanand Institute of Technology, Management and Gramathan Jaipur, INDIA*

*Dept. of Electrical Engineering Swami Keshvanand Institute of Technology, Management and Gramathan Jaipur, INDIA*

*Dept. of Electrical Engineering Swami Keshvanand Institute of Technology, Management and Gramathan Jaipur, INDIA*

*Dept. of Electrical Engineering Swami Keshvanand Institute of Technology, Management and Gramathan Jaipur, INDIA*

Submitted: 01-08-2021

Revised: 07-08-2021

Accepted: 10-08-2021

**ABSTRACT** — This paper demonstrates the result of simulation when we induct a passive single tuned filter with a 12 pulse converter circuit. Harmonic occurrence is one of the major concern's in operation of these power electronic devices, research and studies have been made to bring down the harmonic distortion level. The upshot in the harmonic occurrence leads to overheating of devices, scaling down of efficiency of transformers and affecting efficacy of the power electronic devices thus leading to increased system cost and running cost. We depicted a model of rectifier circuit and a VSI model linked with passive tuned filter and in which a close to practical R L circuit has also been utilized. the output current increase due to harmonics have been tried to bring down to a satisfactory level and reducing the THD level we are targeting 5 th order harmonic as lower order ones are more dominant specifically 3rd order. The results have been found satisfactory and has been shown below for the same.

**Keywords**— Harmonic analysis, passive shunt filter

## I. INTRODUCTION

In today's world effective power transmission is one of the major challenges. A huge amount of power is transmitted over long distances. In the process of power transmission, there are

various issues which occur in the power system formulating power quality issues and from them, the major and more concerning is Harmonics. In HVDC transmission system, AC to DC conversion takes place at the sending end through rectifier and then DC to AC conversion takes place through inverter at the receiving end[5]. Major devices used in these converting stations are non-linear, power electronics devices. Causing harmonic current and voltage effect to some extent. These harmonics currents are small in magnitude but their combined effect leads to serious level harmonic distortion and problems like power loss, thermal stressing, loss of equipment life and in severe cases leads to collapse of power system.[6],[7]

To resolve these problems to some extent we use PWM based rectifier capable of controlling dc bus voltage, bi-directional flow of power, unity power factor and sinusoidal line current.

At the sending end, delivering 3-phase power we use rectifier of different pulse scheme like 6-pulse, 12-pulse, 36-pulse, etc. But, with the increase in no. of devices used so as the cost also increased. Therefore, for a most economical and effective system we usually prefer 12-pulse rectifier among all. In order to reduce the harmonic content several techniques like PWM, SUPWM are used [12],[13]. In this paper we have tried to design a shunt passive filter which further used to mitigate

the THD level in the circuit and compared the levels of THD with and without filter.

Harmonic are distorted electrical waveform that introduce in efficiency into our Electrical System. Harmonic current and voltages

are created by non-linear loads connected to power distribution system. It is a pollution for the electrical system causing issues in system if they sum up together and exceed above a certain unit.

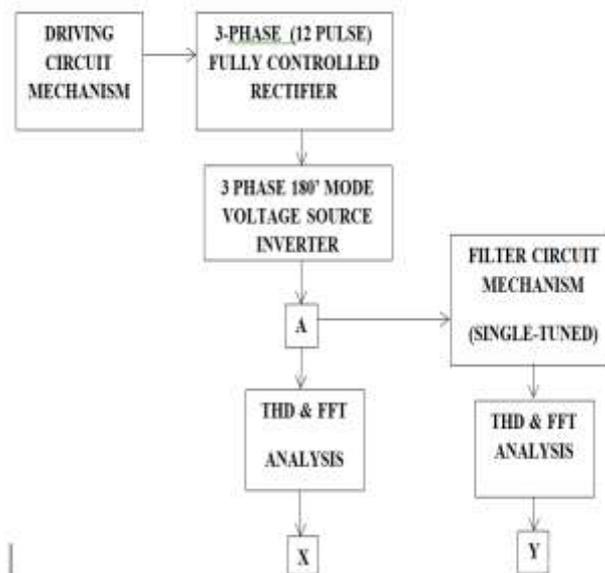


Fig.1 Basic block diagram

All power electronic devices used in different roles increase harmonic disturbances by injecting harmonic currents in line. Common non-linear loads including motor starters, variable speed drive electronic devices etc. These harmonics cause overheating of transformer, cable, motors, generators, capacitors and other devices connected to the same. It also causes electronic display and lightening to flicker, circuit breakers tripping and causing chances of system failure. These effects all together lead to financial and technical problems in system[3].

## II. METHODOLOGY

### A. Driving Circuit Mechanism

The depicted driving circuit model is designed with the help of MATLAB Simulink R2018a software. It acts as a triggering system for the main VSI module.

In the circuit we use a PWM based 12 pulse generator model which is used for the purpose of triggering i.e. giving 12 pulse to the system rectifier. The switching scheme is set in such a manner that every single SCR remain ON for 30° of a cycle.

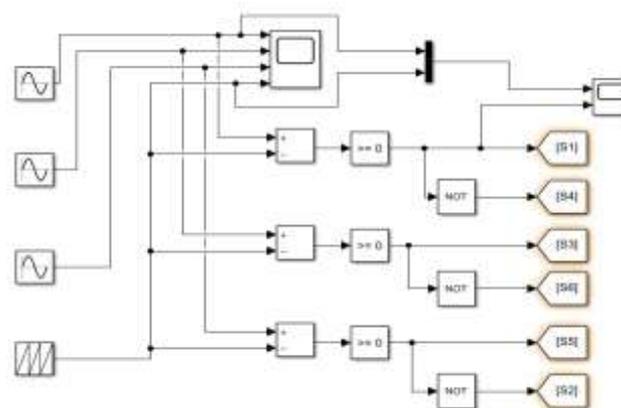


Fig 2

**B. Reactive Power and Inverter Circuit**

The layout of a 12 pulse VSC model is depicted in fig.2 the VSC model is 2 converter system i.e. one is rectifier and other is inverter. The reason for using VSC is as CSC based models have a high chances of commutation failure[2]. In the paper we present a 12 pulse converter configuration for a where our main of focus lies on VSI mode simulation. We investigate the THD percentage of in both the cases of with and without filter.

The main reason for having a 12 pulse configuration for the VSI model is due to lower switching count[2]. At the end we have 3 single phase voltage sources each having peak amplitude ( $V_M$ ) of 311V having  $120^\circ$  of phase shift from the other voltage source.

The 12 pulse bridge having 12 SCR switch getting triggered at different time. The DC line to line voltage 530 V is fed into the rectifier circuit as an input. So following the AC to DC conversion process further the output from rectifier is fed into the inverter and now DC to AC conversion is done and we get the output from the inverter as 311 V. In addition to this converter circuit we add a passive tuned filter with each phase and each branch of it carries value of Resistance (R) as 0.001 ohm, capacitor (C) as 1 micro-farad and Inductance (L) as 10 henry.

Also to calculate the real time performance we of the system we apply a load having Resistance of 50 ohm & Inductance of 1mH. The proposed system is analyzed under two conditions. First is without filter and the other is with filter on obtaining the results again perform a comparison of both THD percent under both the conditions. This 12-pulse converter generating a desired phase shift of angle  $30^\circ$  by using the formula of V (360/no. of pulses). To achieve this type of phase shifts configurations we can have star delta configuration or star zigzag configuration but we prefer star zigzag configuration as it provides a symmetrical system compared to another configuration. [26]

**C. Designing of Filter**

Passive tuned filters are considered a dual-purpose component in any transmission system as it serves both the purpose of current harmonic

compensation as well as the power factor correction. It is the most common method for harmonic elimination.

Designed on the concept of single tuned commonly referred as band pass technology, passive tuned filters have a higher value of quality factor (q). As we are using shunt passive filter it would be in parallel connection with rectifier circuit (load). Passive filters have been used in HVDC convertor system right from the beginning and continue to be used. Tuned filters are used filter out individual harmonics both characteristic frequency by offering low value of impedance. Serving the purpose of filtering of harmonic currents they have another tendency to be depicted in their design which is reactive factor to a suitable level.

To achieve a significant level of harmonics removal a number of filter banks are required to be connected in shunt. Most frequently used passive filters are tuned filters referred or band pass filter to deal with lower ordered harmonics of order  $5^{th}, 7^{th}, 11^{th}, 13^{th}$ .

As we use a single tuned passive filter it remains tuned to a single frequency level [8],[9]. In a single tuned passive filter reactances of both inductive and reactive loads should remains same. In an HVDC system only 36 pulse and above pulses are capable of supplying a pollution clean power with a 2 level converter system [11]. But higher pulses leads to cost inflation and complexity of system. So to serve our purpose and keeping system economical we use lower order pulse system. In operation of a 12 pulse convertor station, tuned AC filter are used for  $11^{th}$  and  $13^{th}$  harmonic in addition to  $3^{rd}$  harmonic which may be problematic. Passive filter in case of AC filter also act as a source of reactive power for required for line commutated converter (LCC).

The basic objective in designing the filter is to select the filter admittance ( $Y_{fn}$ ). The cost of reactor and capacitor which makes up the tuned filter are dependent on their respective ratings. For a single tuned passive filter, we define

$$\omega_r = \frac{1}{\sqrt{LC}}$$

As the resonance frequency,

$$X_C = \omega_r L = \frac{1}{\omega C}$$

As the reactance of inductor L at resonant frequency.

The impedance of the reactance becomes zero at  $h=h_r$  where  $h_r$  is order of harmonic for which filter is designed. We define sharpness of tuning in terms of q (quality factor). [1]

$$q = \frac{X_o}{R}$$

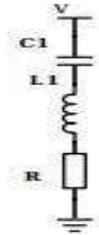


Fig. 3 Single tuned band pass filter

For tuned filter,

$$C_1 = \frac{Q}{2\pi fV^2} \left(1 - \frac{1}{n^2}\right) \quad (1)$$

$$L_1 = \frac{1}{(2\pi fn^2)C_1} \quad (2)$$

$$R = \frac{2\pi nL_1}{q} \quad (3)$$

Resonant frequency is  $f_o = \frac{1}{2\pi\sqrt{LC}}$

Where,

$f_o$  = resonant frequency

$L_1$  = Inductance of tuned filter

$C_1$  = Capacitance of tuned filter

$R$  = resistance of tuned filter

$Q$  = capacitive reactive power

$V$  = Line voltage

$n$  = order of the harmonic

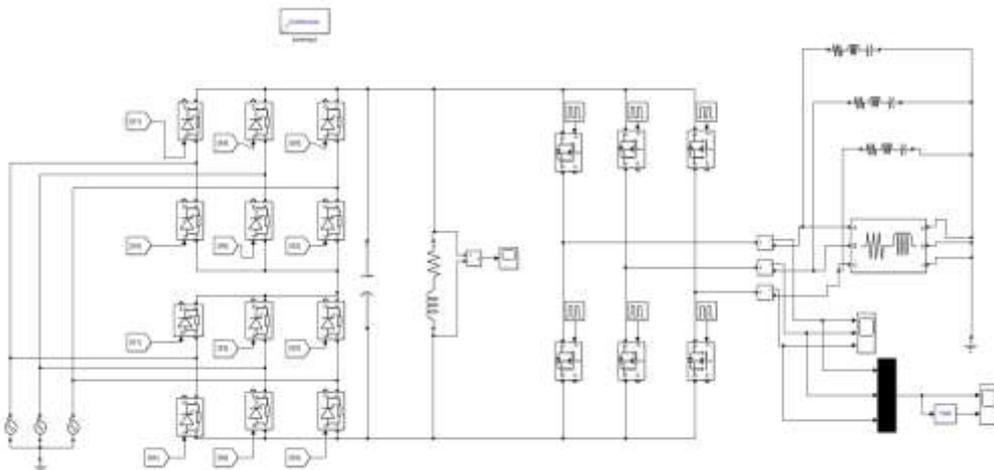


Fig. 4 Main circuit

#### IV. SIMULATION

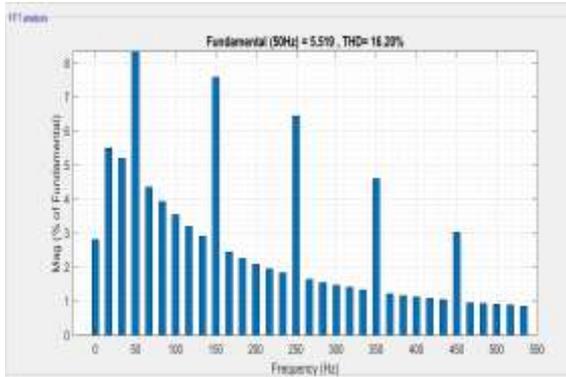


Fig. 5 FFT pattern (without filter)

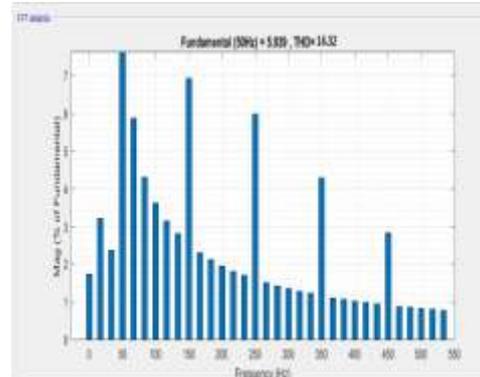
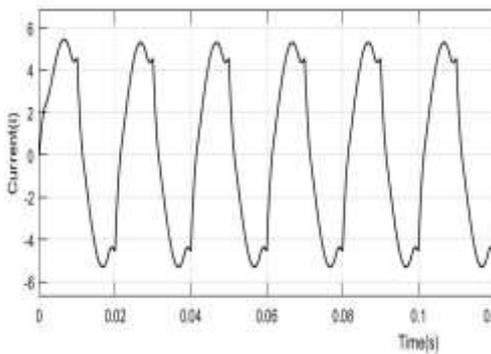
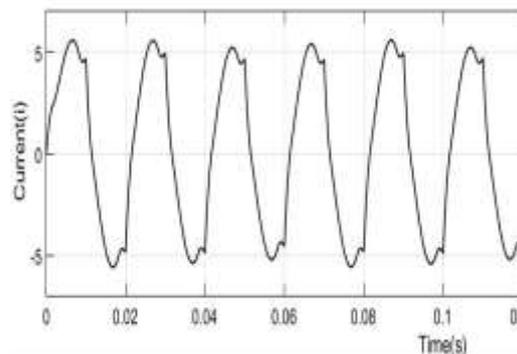


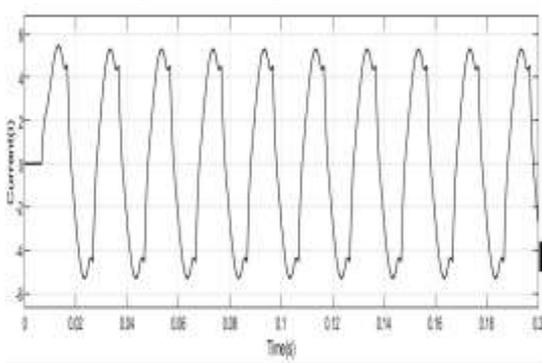
Fig. 6 FFT pattern (with filter)



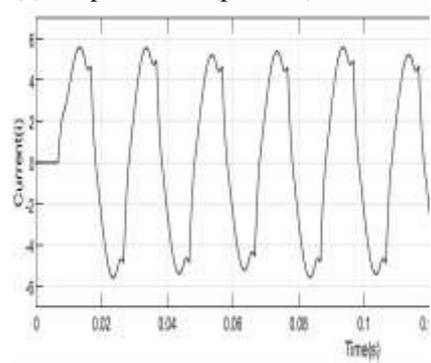
(a) Output current (phase A) without filter



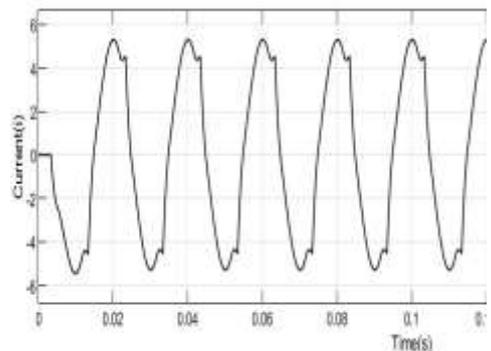
(d) Output current (phase A) with filter



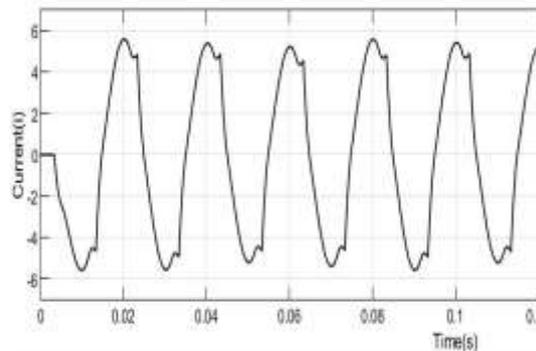
(b) Output current (phase B) without filter



(e) Output current (phase B) with filter



(c) Output current (phase C) without filter



(f) Output current (phase C) with filter

Fig. 7

## V. RESULT

Analyzing the above simulation results we found the THD level for the above depicted system without filter comes out to **16.20%** and with filter it comes out to be **14.32%** as same can be seen from Fig. 5 we can notice a significant scaling down in the occurrence of 5th harmonic from the above FFT pattern shown in Fig. 6.

## VI. CONCLUSION

On performing simulation of a 12 pulse converter system we witness an enhancement in the power quality parameters. Moreover when this system is operated with a passive tuned filter, it provides less polluted power. Based on simulation results of the proposed system we conclude that the operation of 12 pulse converter with passive tuned filter gives better results as compared to the one without filter & keeps the cost economical.

## REFERENCES

- [1]. A Gbadega Peter and K Akshay Saha, "Comparative study of Harmonic Reduction and Power Factor enhancement of Six and 12-pulses HVDC system using passive and shunt APFs Harmonic Filters" in International Conference on the Domestic Use of Energy (DUE), 1-10, 2018.
- [2]. R. Agarwal and S. Singh, "Harmonic Mitigation in Voltage Source Converter based HVDC systems Using 12-pulse AC-DC Converters", in Annual IEEE India Conference (INDICON), 2014.
- [3]. K. R. Padiyar, HVDC Power Transmission System, Technology and System Interaction, Wiley Eastern Limited, India, 1990.
- [4]. M. H. Rashid, Power electronics: circuits, devices and applications, Pearson Education, India, 2004.
- [5]. J. Arrillaga, Y. H. Liu and N. R. Waston, Flexible Power Transmission, The HVDC Option, John Wiley & Sons, Ltd, Chichester, UK, 2007.
- [6]. IEEE Recommended Practices and Requirement for Harmonics Control Electric power System, IEEE Std. 519, 1992.
- [7]. IEEE Recommended Practice for Monitoring Electric Power Quality, IEEE Standard 1159, 1995.
- [8]. C. Wong, N. Mohan, S. E. Wright, and K. N. Mortensen, "Feasibility study of AC, DC-side active filters for HVDC converter terminals," in IEEE Trans. Power Delivery, vol. 4, no. 4, pp.2067–2075, Oct. 1989.
- [9]. J. Nastran, R. Cajhen, M. Seliger and P. Jereb, "Active power filter for nonlinear AC loads," IEEE Trans Power Electron, vol.9, no.1, pp.92–96, 1994.
- [10]. B. Singh, S. Gairola, B.N. Singh, A. Chandra, K. Al-Haddad, "Multipulse AC–DC Converters for Improving Power Quality: A Review," IEEE Trans Power Electron, vol.23, no.1, pp.260-281, Jan. 2008.
- [11]. D. Madhan Mohan, B. Singh, B.K. Panigrahi, "Harmonic optimised 24-pulse voltage source converter for high voltage DC systems," IET Power Electronics, vol.2, no.5, pp.563-573, Sept. 2009.
- [12]. S. Fukuda, Y. Iwaji, H. Hasegawa, "PWM technique for inverter with sinusoidal output current," IEEE Trans Power Electron, vol.5, no.1, pp.54-61, Jan 1990.
- [13]. B.-T. Ooi, X. Wang, "Boost-type PWM HVDC transmission system," IEEE Trans. Power Delivery, vol.6, no.4, pp.1557-1563, 1991.
- [14]. L.C.G. de Freitas, M.G. Simoes, C.A. Canesin, L.C. de Freitas, "Programmable PFC based hybrid multipulse power rectifier for ultra clean power application," IEEE Trans Power Electron, vol.21, no.4, pp.959-966, July 2006.
- [15]. S. K. Nandi, R. R. Riadh, and S. Rahman, "Investigation of THD on a 12-pulse HVDC transmission network and mitigation of harmonic currents using passive filters," in Electrical Information and Communication Technology (EICT), 2015 2nd International Conference on, 2015, pp. 510-515.
- [16]. J. M. Mushagala, "Harmonic analysis and effectiveness of mitigation techniques applied to a bipolar HVDC system," Cape Peninsula University of Technology, 2017.
- [17]. K. Louie, P. Wilson, R. Wachal, A. Wang, and P. Buchanan, "HVDC power system harmonic analysis in the time and frequency domains," in Power System Technology, 2006. PowerCon 2006. International Conference on, 2006, pp. 1-8.
- [18]. M. Kale and E. Özdemir, "Harmonic and reactive power compensation with shunt active power filter under non-ideal mains voltage," in Electric Power Systems Research, vol. 74, pp. 363-370, 2005.
- [19]. S. Rahmani, N. Mendalek, and K. Al-Haddad, "Experimental design of a nonlinear control technique for three-phase shunt active power filter," IEEE Transactions on Industrial Electronics, vol. 57, pp. 3364-3375, 2010.
- [20]. A. Shah and N. Vaghela, "Shunt active power filter for power quality improvement in distribution systems," Int J Eng Dev Res, vol. 1, pp. 23-27, 2014.

- [21]. S. P. Diwan, H. Inamdar, and A. Vaidya, "Simulation Studies of Shunt Passive Harmonic Filters: Six Pulse Rectifier Load–Power Factor Improvement and Harmonic Control," *ACEEE International Journal on Electrical and Power Engineering*, vol. 2, pp. 1-6, 2011.
- [22]. H. A. Kazem, "Harmonic mitigation techniques applied to power distribution networks," *Advances in power electronics*, vol. 2013, 2013.
- [23]. D. A. Gonzalez and J. C. McCall, "Design of filters to reduce harmonic distortion in industrial power systems," *IEEE Transactions on Industry Applications*, pp. 504-511, 1987.
- [24]. J. L. Afonso, M. Aredes, E. Watanabe, and J. S. Martins, "Shunt active filter for power quality improvement," 2001.
- [25]. D. Kumar and F. Zare, "Analysis of harmonic mitigations using hybrid passive filters," in *Power Electronics and Motion Control Conference and Exposition (PEMC), 2014 16th International*, 2014, pp. 945-951.
- [26]. S. Singh, B. Singh, "Passive filter design for a 12-pulse converter fed LCI-synchronous motor drive," in *Proc. IEEE PEDES*, 2010, pp.1-8.