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Passive Filter For Harmonic Mitigation Of Power Diode Rectifier And SCR Rectifier Fed Loads

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Abstract— Power electronic devices find tremendous applications in industry as well as in domestic appliances. The excessive use of these devices causes major problems to the power system due to generation of current harmonics. These harmonic current pollute the power system and produce many adverse effect like malfunction of sensitive equipment, reduced power factor, overloading of capacitor, flickering lights, over heated equipments, reduced system capacity etc.

This work deals with the investigation of current harmonics mitigation by using passive filters. Passive filters provide low impedance path to divert harmonic current to the ground and thus clears harmonics from the circuit. The design and simulation of passive filters for diode rectifier and SCR rectifier fed loads is discussed in this paper. A comparison is also made between diode rectifier and SCR rectifier in six pulse and twelve pulse configuration. Simulation results are presented to prove that THD is reduced with the use of these filters, and in the twelve pulse configuration harmonics is reduced in both SCR and diode rectifier than the six pulse configuration. In the SCR rectifier, when firing angle is increased the THD is also increased.

Index Terms— Diode rectifier**,** Harmonics, Passive filter, SCR rectifier, Total harmonic distortion (THD)

1 INTRODUCTION

Modern consumers of power such as variable speed drives, switch mode power supplies in home electronics etc. significantly contribute to energy saving and more efficient use of electricity. The power handling capacity of modern power electronics devices such as power diodes, SCR, IGBT are very large. So such power electronic equipments are widely used in industry as well as in home appliances. However the nature of their operation will cause a non sinusoidal current flow from the supply. This current consists of fundamental wave and its integer multiples, called harmonics.

The main sources of the current harmonics are magnetic core equipments, power electronics devices and arc furnaces. Harmonic currents flow through such systems cause problems like reduction in equipment service life, function and reliability [1-2]. Harmonics have a serious impact; it will reduce system efficiency and waste precious energy. It also results in overloading and heating of electrical equipments, transformers, fuses and conductors. It will also cause derating of the equipment, overloading of the capacitor bank and causes malfunction in electronics control. Passive filters are the most effective and simple method to reduce the adverse effect of harmonics [3-7].

The paper is organized as follows: Section II presents the solutions for harmonic problems. Design of passive filter is discussed in Section III. The simulation results of how the passive filter alleviates the harmonic currents are provided in Section IV. Section V explains conclusion of this work.

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2 SOLUTIONS TO HARMONICS PROBLEMS

2.1 Line reactors

A Line Reactor (choke) is a 3-phase series inductance on the line side of a drive. Line reactors are available in various values of percent impedance, typically 1-1.5%, 3%, and 5%. The main advantages of line reactors are the low cost, it provide moderate reduction in voltage and current harmonics and input protection from line transients.

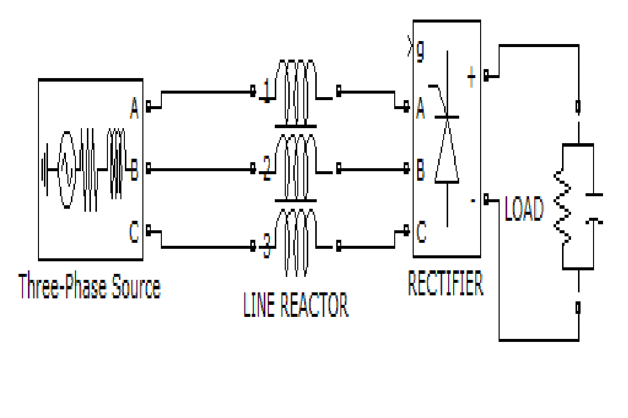

Figure 1. Line reactor

2.2 12 – Pulse converter

A 12 Pulse Converter consists of two separate input semiconductor bridges, which are fed from 30 degree phase shifted power sources with identical impedance. The two isolation

transformers, where one is a wye /delta design (which provides the phase shift) and the second a wye/wye design (which does not phase shift) which is fed to these two bridges.
It may also be a "three-winding" transformer with a primary wye winding, wye and delta are secondary windings. The 12-pulse arrangement allows certain harmonics (primarily 5th and 7th) from the first converter to cancel the harmonics of the second. Up to approximately 85% reduction of harmonic current and voltage distortion may be achieved (over standard 6-pulse converter). Advantage of 12- pulse converter is substantial reduction in voltage and current .

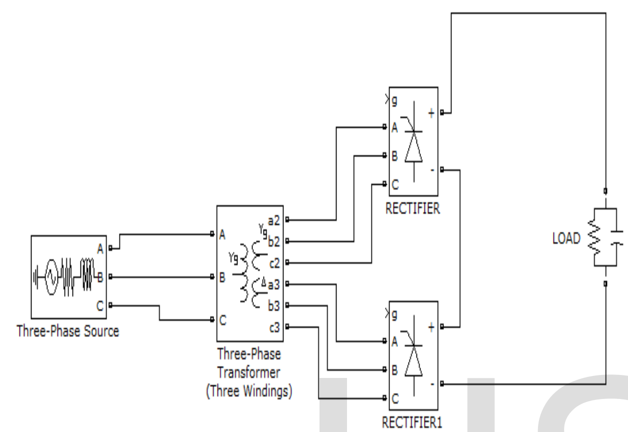

Figure 2. 12- Pulse rectifier

2.3 Passive filter

Tuned harmonic filters consist of the combination of an inductor, resistor and capacitor elements. It is sometimes desirable to have circuits capable of selectively filtering one frequency or range of frequencies out of a mix of different frequencies in a circuit. For mitigating the harmonic distortion passive filtering is the simplest conventional solution. The most commonly used passive filter is the single-tuned filter. This filter is simple and least expensive as compared with other means for mitigating the harmonic problems. Passive filter provide a low impedance path for harmonic current. These currents are then "sucked off" and the network is cleaned of damaging harmonic currents.
The different types of filters are Band-pass filters and High-pass filters. Band-pass filters, which are used to filter lowest order harmonics ,it can be tuned at a single frequency called single-tuned filter or at two frequencies called double-tuned filter. High-pass filters are used to filter high-order harmonics. One type of high-pass filters are the C-type high-pass filter, is used to filter low order harmonics and provide reactive power. C type filter avoids parallel resonance.

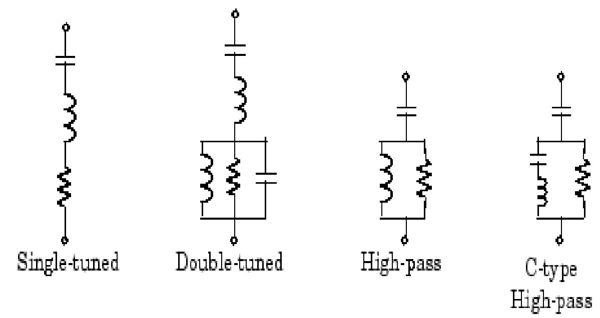

Figure 3. Passive filter

3 Design Of Passive Filter

The system considered here is ,input vltage VS = 415V, Reactive power = 168.62 kW, XC = (V2/ Q), XC = (1/2πFC), C = (1/2πF XC), L = (1/4Cπ2 F2). For the system according to these equations, the capacitance, inductance and resistance values are obtained are given in table 1.

TABLE 1

PASSIVE FILTERS FOR RECTIFIERS

FILTER	C(μF)	L(H)	R(Ω)
5TH	11.09	0.0365	0.54
7TH	11.09	0.0186	0.38
11TH	11.09	0.0075	0.24
13TH	11.09	0.0054	0.21
HIGH PASS FILTER	11.09	0.0031	49.66

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4 Simulation And Results

The system was simulated with the load fed by diode and SCR rectifier in a 6 pulses and 12 pulse configurations with and without passive filter. Figure 4 shows the circuit arrangement for 6- Pulse diode rectifier fed load without filter. A THD analysis was done and the result obtained is as shown in fig 5. Figure 6 shows the circuit arrangement for 6- pulse diode rectifier with tuned filter .The THD analysis of the system is given in the figure 7. The circuit arrangement with a 12- pulse diode rectifier is shown in figure 8 and THD analysis is shown in figure 9. Figure 10 and 11 shows the circuit arrangement for 12- pulse diode rectifier and THD analysis result with filter condition.

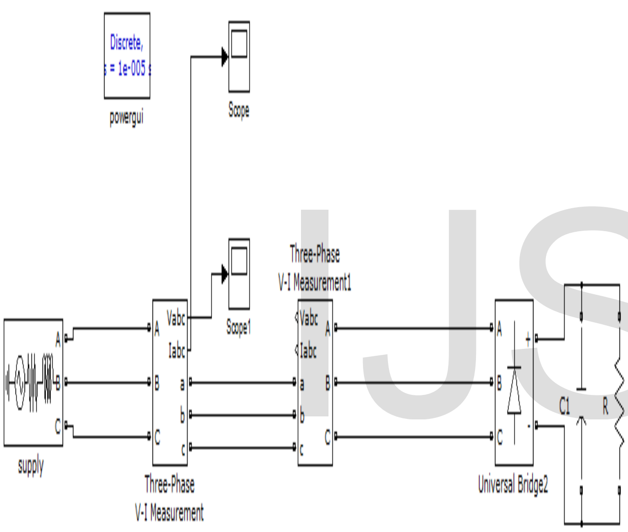

Figure 4. 6- Pulse diode rectifier without filter

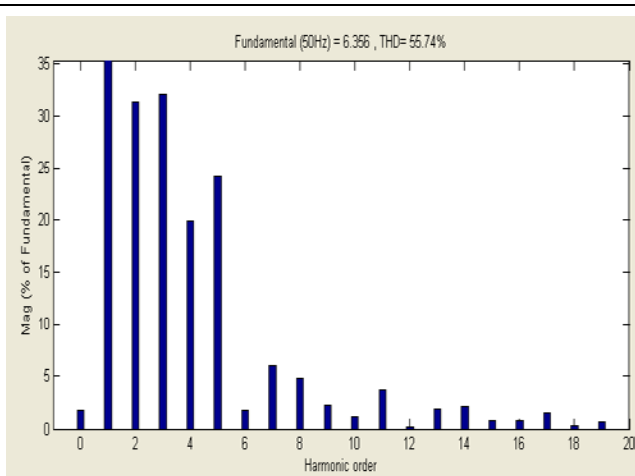

Figure 5. 6- Pulse diode rectifier without filter,THD = 55.74%

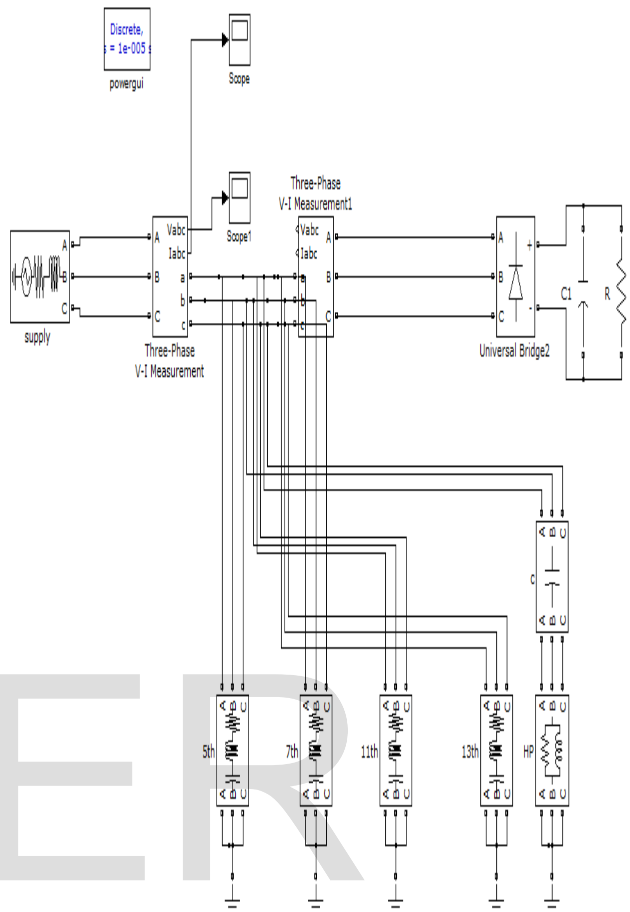

Figure 6. 6- Pulse diode rectifier with filter

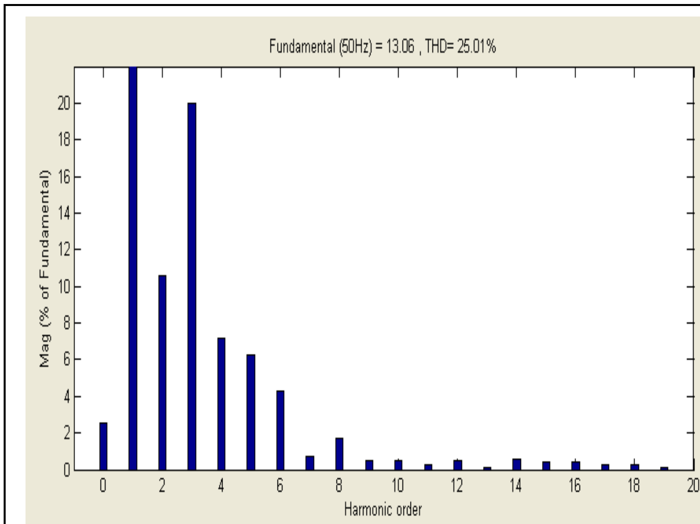

Figure 7. 6 pulse diode rectifier with filter,THD =25.01%

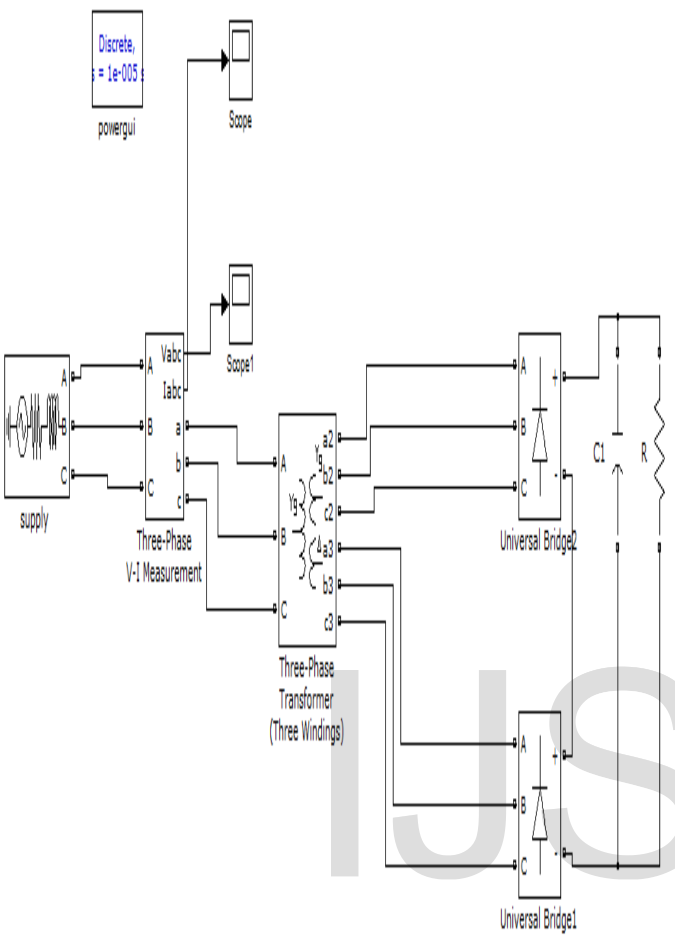

Figure 8. 12 pulse diode rectifier without filter

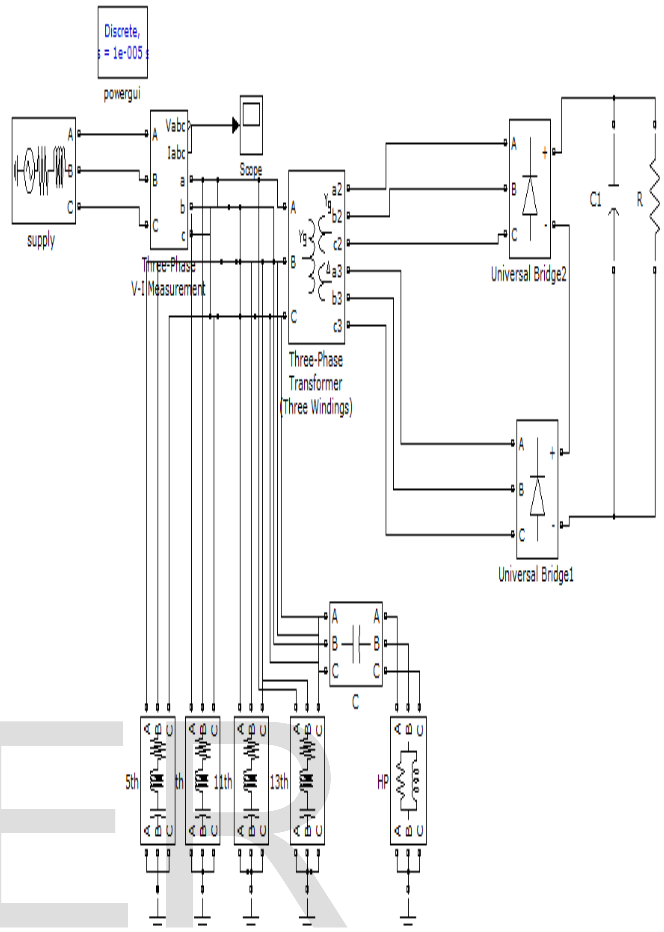

Figure 10. 12 Pulse diode rectifier with filter,

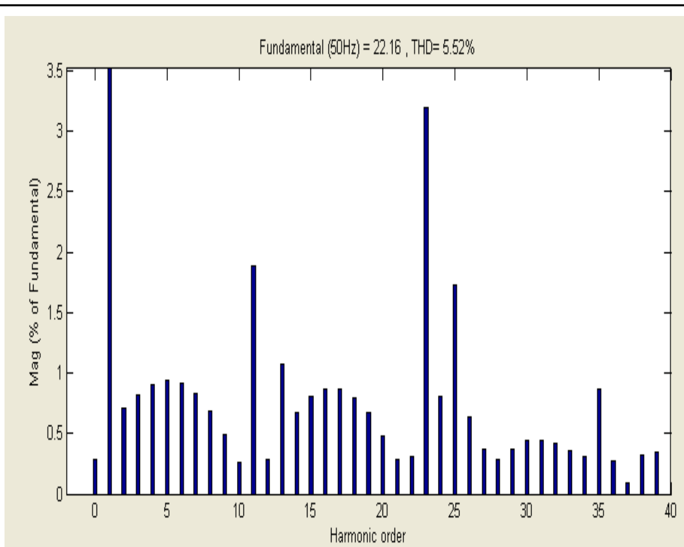

Figure 9. 12 Pulse diode rectifier without filter,THD =5.52%

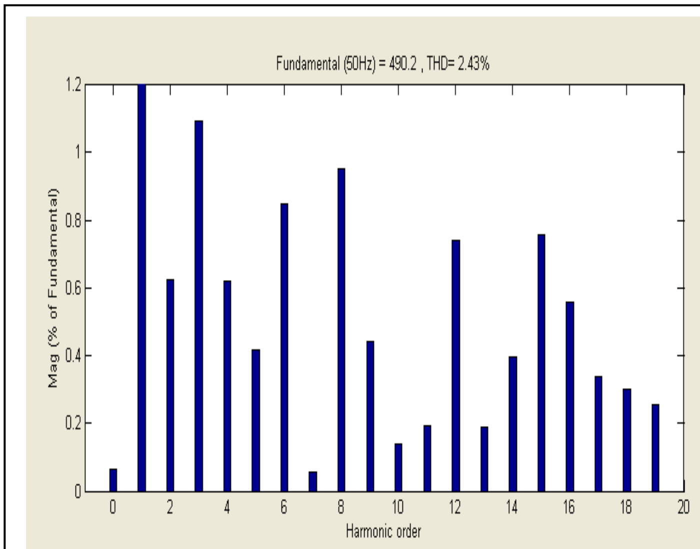

Figure 11. 12 Pulse diode rectifier with filter,THD =2.43%

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The diode rectifiers are replaced by controlled rectifier and analysis done. The circuit arrangement for a 6- Pulse SCR Rectifier without filter condition and its THD analysis are shown in figure 12 and 13. Tuned filter were connected to the circuit as in figure 14 and THD analysis done shown in figure 15. It is known that 12 pulse rectifier can result in substantial reduction in harmonics. Figure 16 and 17 shows the circuit arrangement for 12- pulse SCR rectifier without filter and its THD analysis result. The circuit arrangement for 12- pulse SCR rectifier with filter showed in figure 18 and its THD analysis shown in figure 19.

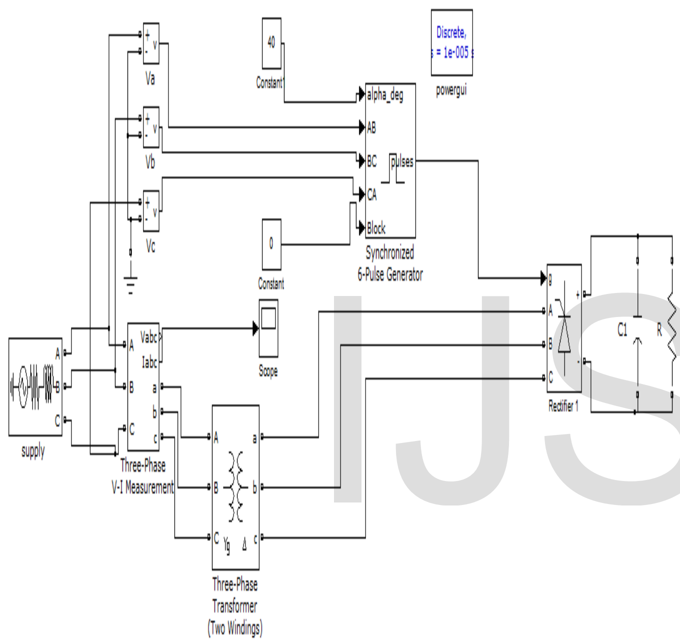

Figure 12. 6 Pulse SCR rectifier without filter

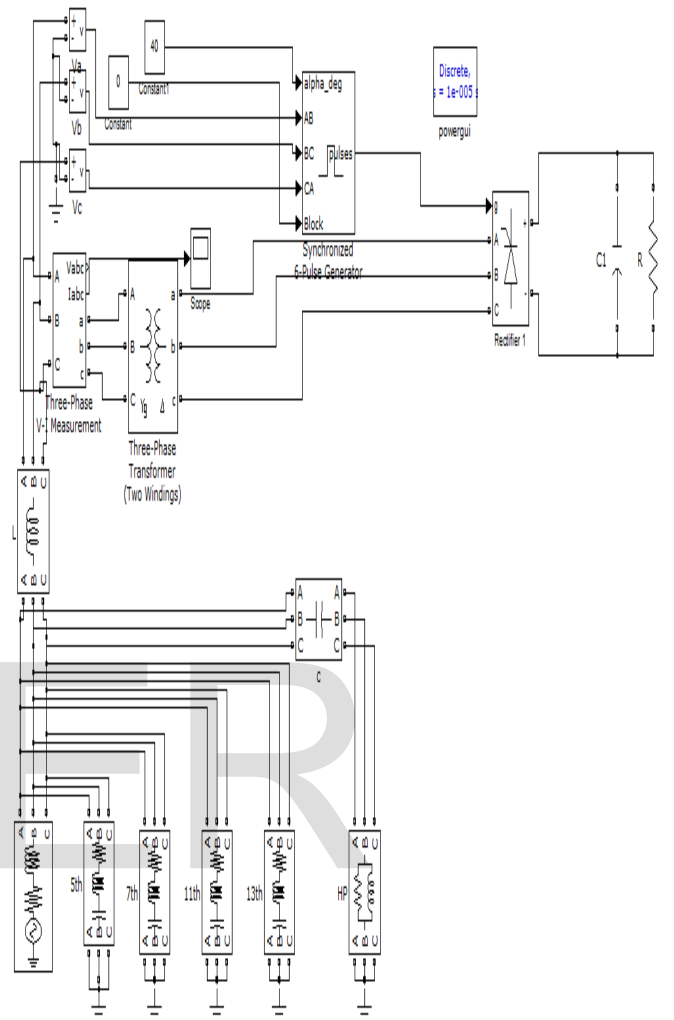

Figure 14. 6 Pulse SCR rectifier with filter

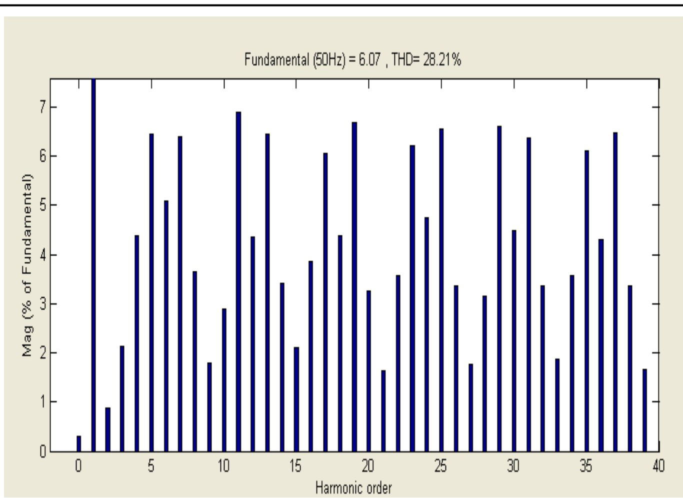

Figure 13. 6 Pulse SCR rectifier without filter,THD =28.21%

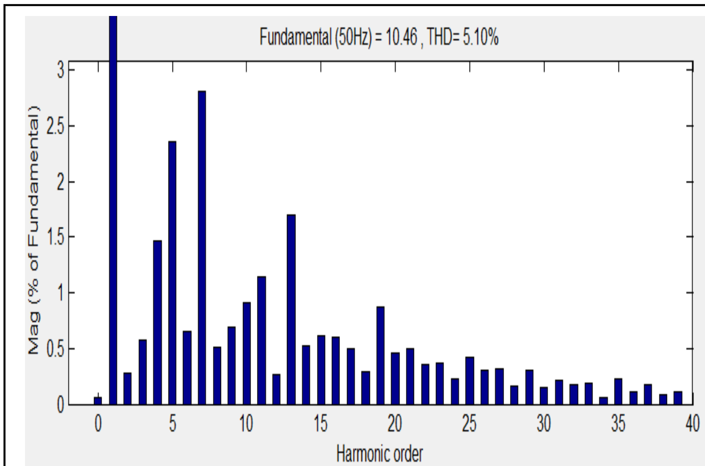

Figure 15. 6 Pulse SCR rectifier with filter,THD = 5.10%

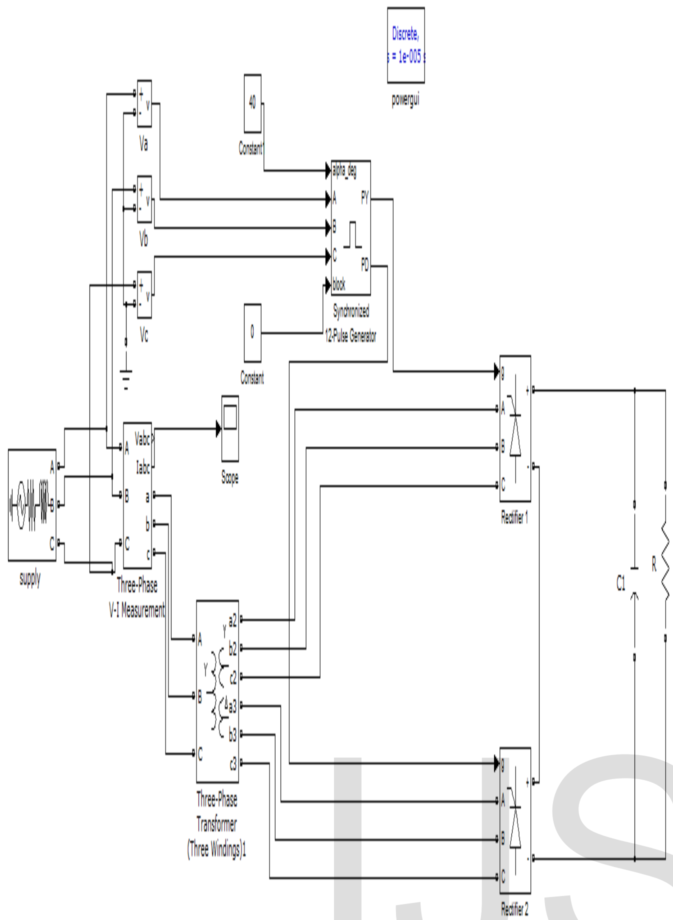

Figure 16. 12 Pulse SCR rectifier without filter

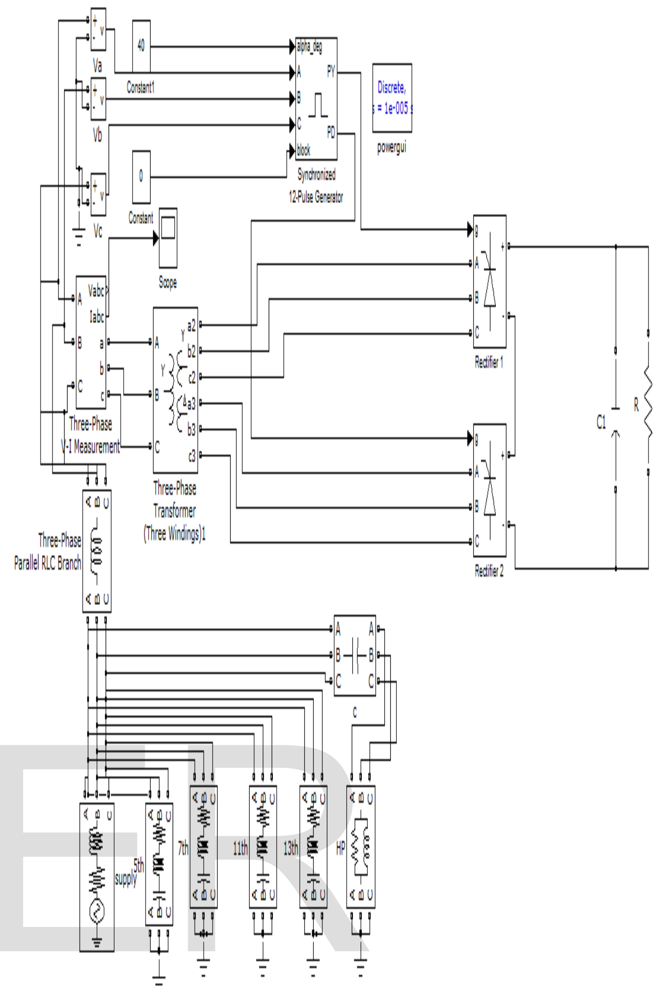

Figure 18. 12 Pulse SCR rectifier with filter

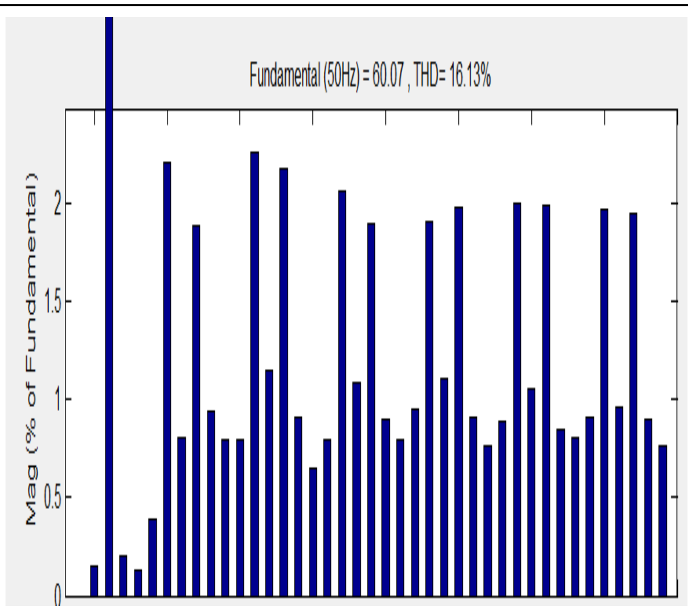

Figure 17. 12 Pulse SCR rectifier without filter,THD = 16.13%

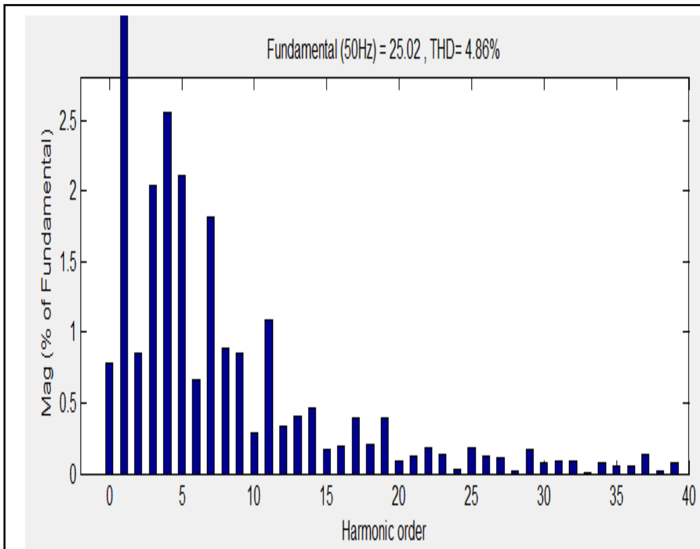

Figure 19. 12 Pulse SCR rectifier with filter,THD = 4.86%

A comparison of the different topology with and without filter is presented in table 2.

TABLE 2
COMAPARISON OF THD VALUES

Parameters	6-Pulse Diode Rectifier Without Filter	6-Pulse Diode Rectifier With Filter	12-Pulse Diode Rectifier Without Filter	12-Pulse Diode Rectifier With Filter
THD (%)	55.77	25.01	5.76	2.36

The effect of variation in firing angle on harmonics was studied.THD values are increases with increase in firing angle.

TABLE 3
THD VALUES OF A DIFFERENT FIRING ANGLES

	Firing Angle		
Types	10^0	40^0	50^0
6-Pulse SCR Rectifier Without Filter	49.80	54.19	72.87
6-Pulse SCR Rectifier With Filter	3.20	5.10	5.13
12-Pulse SCR Rectifier Without Filter	5.21	16.13	19.12
12-Pulse SCR Rectifier With Filter	1.41	4.86	5.21

The above result shows that a 12 pulse configuration can reduce current harmonics when compared to a 6 pulse configuration. There was about 89.6% reduction in harmonics for a 12 pulse diode rectifier when compared to 6 pulse diode rectifier. On addition of a filter there was a further reduction in harmonics, 95% reduction in harmonics was obtained on addition of tuned filter. In controlled rectifier THD increases with increase in firing angle.

5 Conclusion

Harmonics cause damage to electrical networks and can sometimes be dangerous. This result in overload, reduced lifespan and under some circumstances can even lead to premature failure of electrical and electronic equipments. The conventional method to mitigate the harmonics is by using passive filters. In this project, diode and SCR rectifier fed system are simulated in 6 pulse and 12 pulse configurations. From the simulation results, the use of a 12 pulse rectifier can results in substantial reduction in harmonics.

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