An Active Filter and Passive Filter Techniques Analysis of Harmonic Mitigation Using PSIM Software

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Abstract—**Active power filters and Passive power filter have been broadly used for harmonic elimination. This paper presents an active filter and passive filter connected in parallel with three phase 12Pulse AC/DC converter to mitigate the harmonics generated. The simulation presented in PSIM computer simulation software. The results show that the circuits with filter perform better than the original circuit and satisfy the harmonic limitations with respect to the objective of minimizing the total demand distortion of harmonic currents and total harmonic distortion (THD) of voltages. It has been also established that the power filter overcomes supply system disturbance while maintaining an acceptable level of system power supply. The effective operation of both filter are demonstrated and the potentials are illustrated with a case study.**

Keywords-Active filter, passive filter, total harmonic distortion (THD), harmonic mitigation.

I. INTRODUCTION

Power quality is an important measure of an electrical power system. The term power quality means to maintain purely sinusoidal current waveform with purely sinusoidal voltage waveform. Power supply normally produces a clean and purely sinusoidal current waveform in nature. This sinusoidal waveform is regarded a pure form of the AC voltage and any deviation from it is described as distortion. More and more types of load absorb non-sinusoidal from the power system. These nonlinear loads draw non-sinusoidal current from the sources, causing non-sinusoidal voltage drops across the system [1].

Figure 1 show how harmonics produce in the power converter system. The total current is the sum of fundamental and 5th harmonic [9]. Harmonic distortion is caused by nonlinear devices in power system (current is not proportional to voltage), the apply voltage is sinusoidal but current is not. [3].

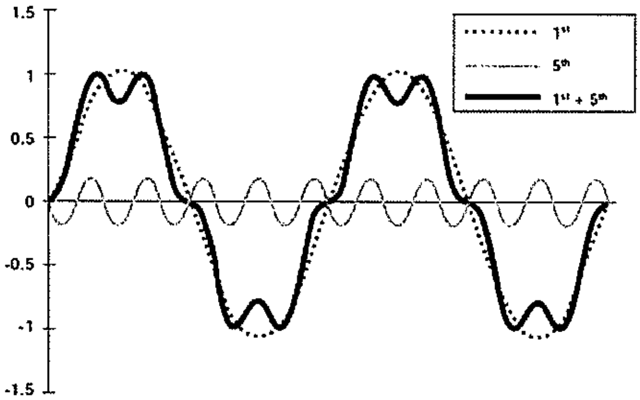

Figure 1. Harmonic phenomena.

Harmonic can adversely affect the operation of cables, capacitors, metering, and protective relays. As the harmonic present at equipments, it can cause the equipment malfunction, overheating, and installation breakdown. Consequently harmonic is affecting the quality of the power supply system [3, 9].

TABLE1. Harmonics different factors and their effects in AC drive system.

THE CAUSE	THE EFFECT
The larger the DC or AC inductance	The lower the current harmonics
The higher the number of pulse in the rectifier	The lower the current harmonics
The larger the transformer	The lower the voltage harmonics
The lower the transformer impedance	The lower the voltage harmonics
The higher the short circuit capacity of the supply	The lower the voltage harmonics

Various harmonic-mitigation techniques have been proposed and applied in recent years. Harmonics reduction can be done either by structural modifications in the drive system or by using external filtering. It is well known that the harmonic distortion can be reduced with the installation of a power system filter. The structural modifications can be strengthening the supply, to use 12 or more pulse drive, to use a controlled rectifier or to improve the internal filtering in the drive. In this contribution, an active power filter and passive power filter is proposed for the determination of the filtering currents for harmonic mitigation [2, 9].

The purpose of this project was to determine the filtering currents for harmonic mitigation in three phase 12Pulse AC/DC converter by using an active power filter and passive power filter. The operations and performance of the active power filter and passive power filter is verified with the digital implementation in PSIM software. The PSIM software was chosen for the simulation because PSIM provided a great simulation and design environment for switch mode power supply. PSIM was also been chosen because many of power quality work is implemented in MATLAB software. With fast simulation and friendly user interface, PSIM software was the advantages of the used techniques [7].

A. Three phase 12pulse AC/DC converter

Figure 2 shows three phase two way 12pulse AC/DC converter. The 12-pulse rectifier was formed by connecting two 6-pulse rectifiers in parallel to feed a common DC-bus. The input to the rectifiers is provided with one three-winding transformer. The transformer secondary are in 30° phase shift. A three-phase transformer with tapped wye-connected primary winding isolated delta-connected secondary and wye-connected secondary winding were used to power two 6-pulse converter bridges connected in series to give 12-pulse operation The benefit with this arrangement is that in the supply side some of the harmonics are in opposite phase and thus eliminated [9].

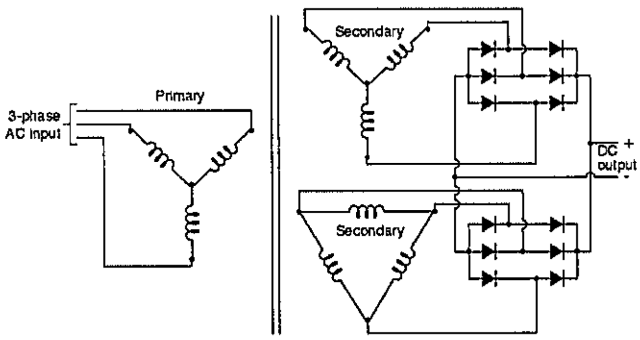

Figure 1. Three phase two way 12pulse AC/DC converter

B. Shunt active filter

An active filter is the power electronics components used to actively inject harmonics to cancel harmonics in the line current. This method has been used in the past in lower power electronics applications. Figure 3 shows shunt active filter connected to the power converter. In this work shunt active filter was implemented to the AC/DC converter circuit. Note that the nonlinear load draws harmonic current, from the power source. The active compensator senses the harmonic current and injects a compensation current, which cancels the harmonic current. The net supply current, contains only the fundamental. The compensator switches at a very high frequency compared to the fundamental frequency— hence, the VA rating of the energy storage devices in the compensator can be minimized [2].

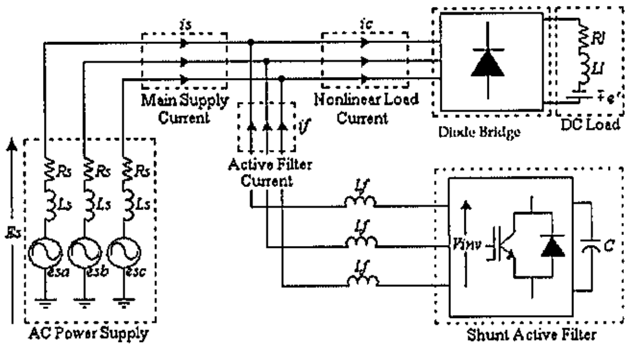

Figure 3. Shunt Active Filter configuration.

C. Shunt passive filter

Figure 4 shows the types of passive filter. The installation of the shunt passive filter is the most common method for controlling harmonic currents. Passive filters, as the name implies, use passive components such as resistors, inductors, and capacitors. A combination of passive components is tuned to the harmonic frequency that is to be filtered. The values of the inductor and the capacitor are chosen to present low impedance to the harmonic frequency that is to be filtered out. Due to the lower impedance of the filter in comparison to the impedance of the source, the harmonic frequency current will circulate between the load and the filter. This keeps the harmonic current of the desired frequency away from the source and other loads in the power system. If other harmonic frequencies are to be filtered out, additional tuned filters are applied in parallel.

Applying harmonic filters requires careful consideration. Series-tuned filters appear to be of low impedance to harmonic currents but they also form a parallel resonance circuit with the source impedance. In some instances, a situation can be created that is worse than the condition being corrected [2, 3].

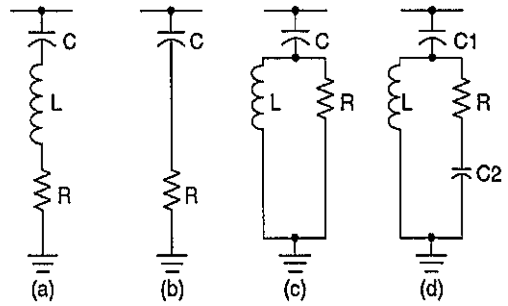

Figure 4. Type of Shunt Passive filter

(a) Single-tuned filter
(b) First order high-pass filter
(c) Second order high-pass filter
(d) Third order high-pass filter

D. Distortion Factor

Ratio of the RMS of the harmonic content of a periodic wave to the RMS of the fundamental content of the wave, expressed as a percent. This is also known as the total harmonic distortion (THD). Total harmonic distortion (THD) is a term used to describe the net deviation of a nonlinear waveform from ideal sine waveform characteristics. Total harmonic distortion is the ratio between the RMS value of the harmonics and the RMS value of the fundamental. For example, if a nonlinear current has a fundamental component of $I1$ and harmonic components of I_2, I_3, I_4, I_5, I_6, I_7, ..., then the RMS value of the harmonics is [3]:

$$I_H = \sqrt{(I_2^2 + I_3^2 + I_4^2 + I_5^2 + I_6^2 + I_7^2 + ..)} \quad (1)$$

$$\text{THD} = \left(\frac{I_H}{I_1}\right) \text{x } 100\% \quad (2)$$

The results are not altered by using either the magnitude of the RMS quantities or the individual harmonic distortion values. The individual harmonic distortion indicates the contribution of each harmonic frequency to the distorted waveform, and the total harmonic distortion describes the net deviation due to all the harmonics. These are both important parameters. In order to solve harmonic problems, we require information on the composition of the individual distortions so that any treatment may be tailored to suit the problem. The total harmonic distortion, while conveying no information on the harmonic makeup, is used to describe the degree of pollution of the power system as far as harmonics are concerned. Defining the individual and total harmonic distortions will be helpful as we look at some typical nonlinear waveforms and their harmonic frequency characteristics [3].

E. Harmonic voltage and current limitation

It is important, therefore, that attempts be made to limit the harmonic distortion that a resource might produce. There are two reasons for this. First, the lower the harmonic currents produced in an electrical system, the better the equipment within the confinement of the system will perform. Also, lower harmonic currents produce less impact on other power users sharing the same power lines of the harmonic generating power system. The IEEE 519 standard provides guidelines for harmonic current limits at the point of common coupling (PCC) between the resource and the utility. Table 2 (per IEEE 519) lists harmonic current limits based on the size of the power user [3].

TABLE 2. Harmonic Current Limits for General Distribution Systems (120-69,000V)

I_{SC}/I_L	h <11	$11 \leq h <$ 17	$17 \leq h <$ 23	$23 \leq h <$ 35 3	$35 \leq h$	THD
<20	4.0	2.0	1.5	0.6	0.3	5.0
20-50	7.0	3.5	2.5	1.0	0.5	8.0
50-100	10.0	4.5	4.0	1.5	0.7	12.0
100-1000	12.0	5.5	5.0	2.0	1.0	15.0
>1000	15.0	7.0	6.0	2.5	1.4	20.0

As the ratio between the maximum available short circuit current at the PCC and the maximum demand load current increases, the percentage of the harmonic currents that are allowed also increases. This means that larger power users are allowed to inject into the system only a minimal amount of harmonic current (as a percentage of the fundamental current). Such a scheme tends to equalize the amounts of harmonic currents that large and small users of power are allowed to inject into the power system at the PCC. Table 3 show guidelines for maximum voltage distortion at the PCC. Limiting the voltage distortion at the PCC is the concern of the utility. It can be expected that as long as a facility's harmonic current contribution is within the IEEE 519 limits the voltage distortion at the PCC will also be within the specified limits [3].

TABLE 3.Voltage Harmonic Distortion Limits

Bus Voltage at PCC	Individual Voltage Distortion (%)	Total Voltage Distortion (%)
69kV and below	3.0	5.0
69.001kV through 161kV	1.5	2.5
161.001kV and above	1.0	1.5

II. RESEARCH METHODOLOGY

In this work, PSIM software was used to perform the circuit simulation. A simulation model of three phases 12 Pulse AC/DC Converter without filter, with active filter and with passive filter was build. In order to build the understanding upon this project, many journals and books regarding power electronic have been read regularly and almost everyday. Thus, three type of circuit were modeled.

Two type of filters were designed which work as harmonic mitigation for the AC/DC Converter circuits. By using PSIM software three types of result which were phase source current (red, yellow and blue), harmonics component and Total Harmonic distortion with three difference circuits were presented. Those data were collected because it was the major component of harmonics distortion related to this work. All the data were collected by run the simulation in the PSIM software. The results were analyzed by comparing the data of circuit before adding filters and after adding filters.

From figure 4, parallel conditioner is also called shunt conditioners. They are connected in parallel with the AC line and need to be sized only for the harmonic current drawn by the non-linear load(s). The shunt filters were connected in parallel with the supply, and constantly injects harmonic currents that precisely correspond to the harmonic components drawn by the load. The result is that the current supplied by the power source remains sinusoidal [2].

The shunt Active filter works by short-circuiting harmonic currents as close to the source of distortion as practical. This keeps the currents out of the supply system. This is the most common type of filtering applied because of economics and because it also tends to correct the load power factor as well as remove the harmonic current. The shunt Passive filter eliminates one or more harmonics. The most common variety is simply an inductor in series with a shunt capacitor, which short-circuits the major distorting harmonic component from the system [3].

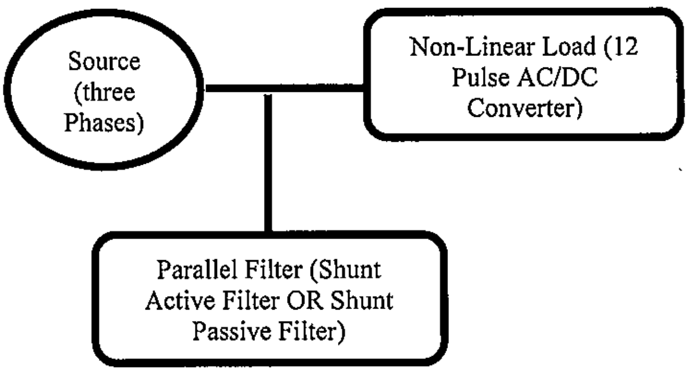

Figure 4. Parallel conditioner of filter used.

TABLE 4. Simulation Parameter

Element	Note
Supply Voltage	Three phase Sinusoidal (415V,50Hz)
Transformer	Three phase two way 12Pulse wye/wye/delta
THD block	VTHD(fundamental 50Hz,passing band frequency 20Hz)
AC/DC Converter	Diode
Active filter	Parallel active filter(IGBT) connnect with control circuit
Parallel Passive filter	Capcitor, Inductor and resistor connect in parallel
Simulation Control	Print Time 0.06s

The tuning characteristic of the filter is described by its quality factor Q. Q is a measure of the sharpness of tuning and, for series filter resistance, is defined as

$$Q = \frac{nX_L}{R}$$

Where
R = series resistance of filter elements
n = tuning harmonic
XL= reactance of filter reactor at fundamental frequency

The filter reactor size is computed from the equivalent capacitive reactance, determined follows:

$$X_L = \frac{X_{cap}}{h^2}$$

Where
XL= reactance of filter reactor at fundamental frequency
$Xcap$=capacitance reactance
h= no of harmonic

TABLE 5. Parameter of Active and Passive Power Filter

Type of Filters	Component	Value
Shunt Passive Filter	Capacitors, C_P	0.1F
	Inducors, I_P	0.321H
	Resistors, R_P	97Ω
Shunt Active Filter	Capacitors, C_A	0.2F
	Inducors, I_A	0.445H
	Resistors, R_A	88 Ω
	Source resistor R_S	10 Ω
	Source inductor, I_S	0.11H
	Load resistor, R_L	100Ω
	Load inductor, I_L	0.145H

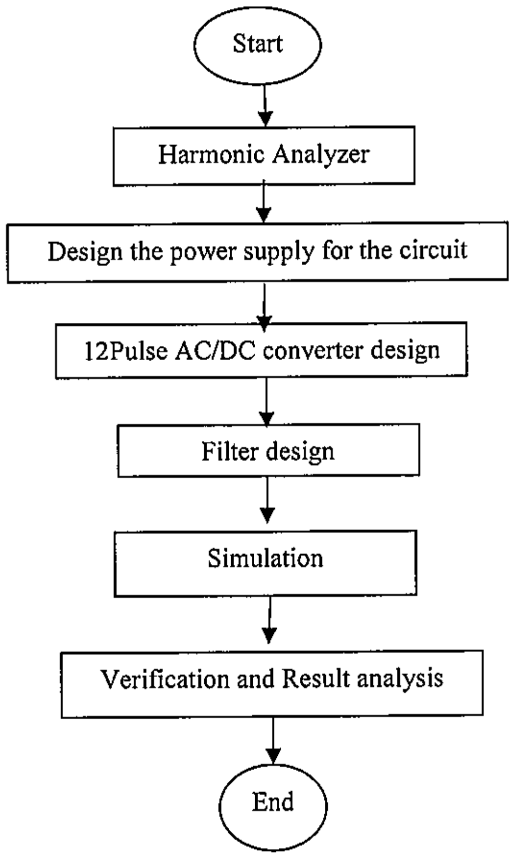

Figure 5. Flowchart of Three Phase 12Pulse AC/DC Converter with Filter design.

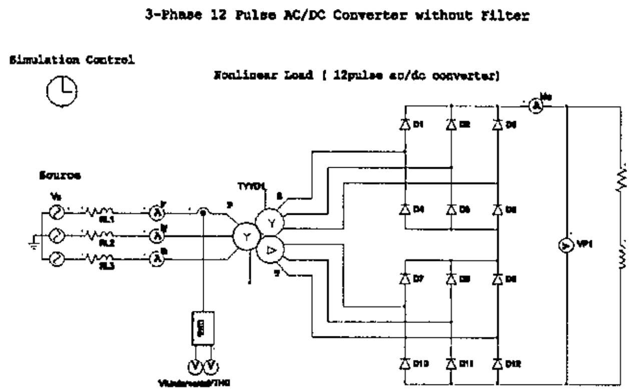

Figure 6. Three Phase 12pulse AC/DC without filter.

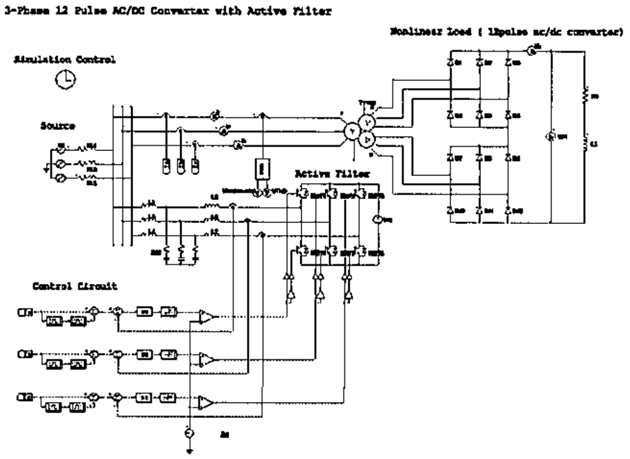

Figure 7. Three Phase 12pulse AC/DC with Active filter.

From figure 7, the Control Circuit used to maintain the capacitor voltage constant and to determine the amplitude of the mains currents required in Active Filter system. The control circuit was connected to the Active Filter constructed by IGBT.

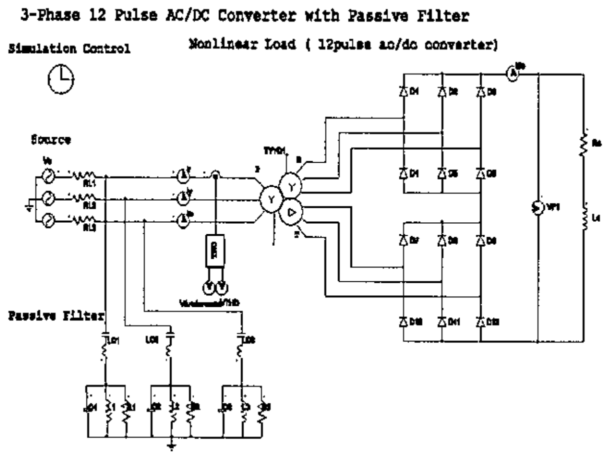

Figure 8. Three Phase 12pulse AC/DC with Passive filter

III. RESULT AND DISCUSSION

The results were observed and discussed in this session. Figure 2.1, 2.2, 2.3, 2.4, 2.5, 2.6, 2.7, 2.8, and 2.9 illustrated the simulation done by PSIM software.

Form figure 2.1 the x-axis shows the time in millisecond and y-axis show the magnitude of the currents. The harmonic presented in the current waveforms. There were slight distortions on the supply current. The phase currents deviate strongly from the sinusoidal current waveform. This event occurs because of the load was injecting current harmonics into the supply system. In figure 2.2, after adding Active filter the waveform has turn to sinusoidal waveform. The harmonics have been cancelled. While in figure 2.3 phase current (red, yellow and blue) after adding passive power filter, not all of harmonic have been canceled. By comparing both results between adding active filter and passive filter, active filter was better on harmonics improvement. It works by electronically supplying the harmonic component of the current into a nonlinear load and subsequently removes the harmonics currents. In Passive filter harmonic currents are diverted from their normal flow path on the line through the filter.

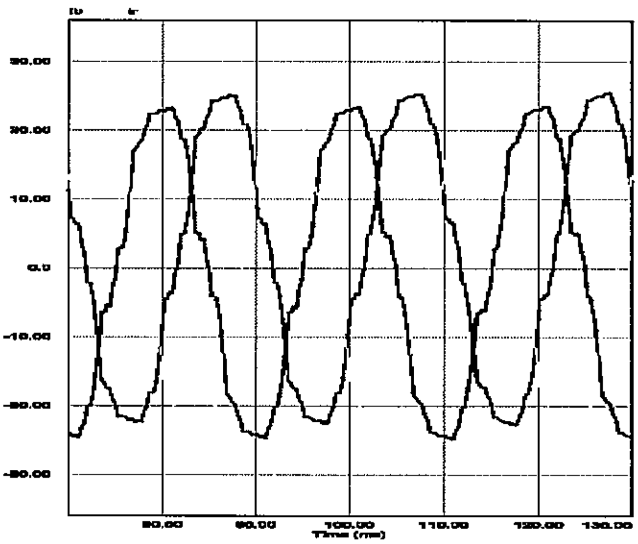

Figure 2.1. Phase Current (red, yellow and blue) before adding filter.

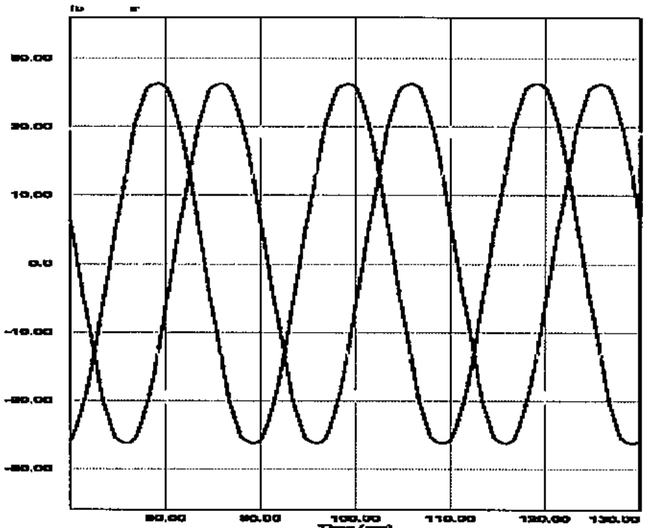

Figure 2.2. Phase Current (red, yellow and blue) after adding active filter.

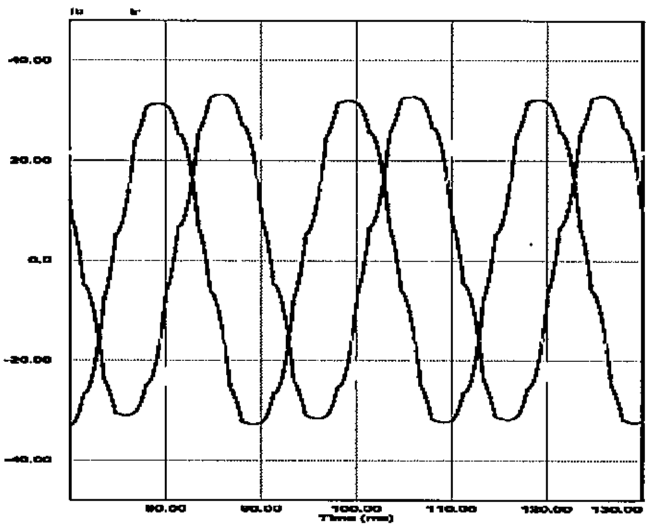

Figure 2.3. Phase Current (red, yellow and blue) after adding passive filter.

Figure 2.4, 2.5, and 2.6 show the harmonics component from the phase currents of the ac side. The x-axis shows the frequency and y-axis shows the magnitude of the currents.The harmonics component is shown by running the FFT on PSIM software. Harmonic component have been presented by time domain waveform, it was easier and most common to represent the harmonics by means of the current spectrum. The spectrum shows for each harmoic component present in the current analysed. Possibly, the magnitude of the harmonic components is expressed as a percentage of the magnitude of the fundamental component. The horizontal axis shows generally the harmonic order, which is given by the ratio of the harmonic frequency over the fundamental frequency. The quality of phase current red, yellow and blue on ac side consists of harmonic components as shown in Figure 2.4 [8].

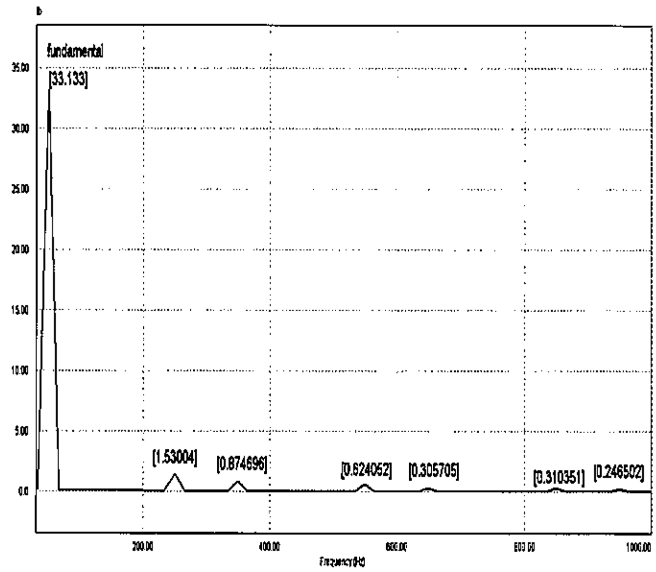

Figure 2.4. Harmonics component of circuit without filters.

From figure 2.5 the active filtered have filter the selected harmonics until their magnitudes are close to zero. The active filter have perform the maximum filtering. While in figure 2.6 the passive filter have filtered the selected harmonics until their magnitudes reach the prescribed level. The passive filter filtering the curve of the graph. The current was reduced to the residual level [8].

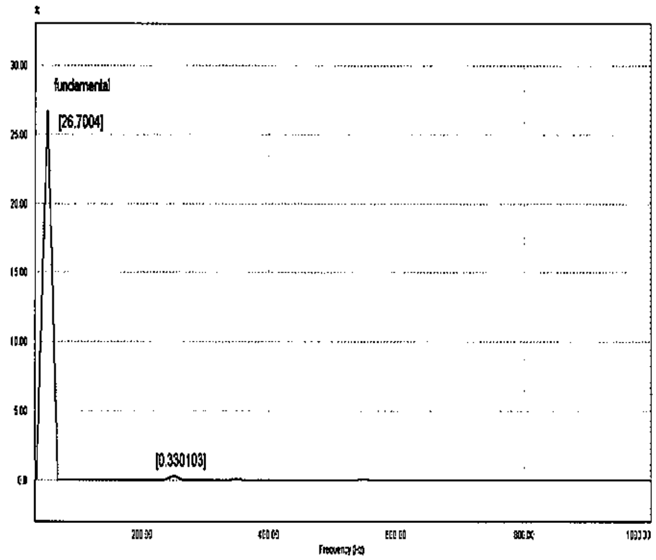

Figure 2.5. Harmonics component of circuit with Active Power Filters.

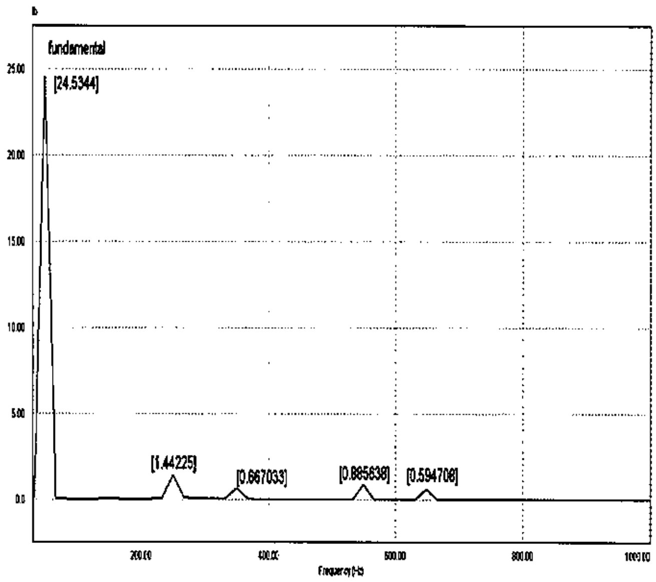

Figure 2.6. Harmonics component of circuit with Passive Power Filters.

TABLE 6. Harmonic component present in the current magnitude analysis without filter and with both filters.

	Harmonic Order (odd)	Current Magnitude (Ampere)
Without filter	1st	31.133A
	5rd	1.53004A
	7th	0.874696A
	11th	0.624052A
	13th	0.305705A
	17th	0.310351A
	19th	0.246502A
After adding with active filter	1st	26.7004A
	5rd	0.330103A
After adding with passive filter	1st	24.5244A
	5rd	1.44225A
	7th	1.33866A
	11th	0.667033A
	13th	0.885638A
	17th	0.594708A

Table 7 illustrated the Total Harmonic Distortion without adding filter and after adding filter. It was found that by comparing all the result, the Total Harmonic Distortion without adding both filters was higher than Total Harmonic Distortion after adding filter. Adding Active filter to the system created less Total Harmonic Distortion than Passive filter. Active filter performed better than Passive filter on mitigated the harmonic produced by the system.

TABLE 7. Total Harmonic Distortion

	Total Harmonic Distortion, %
Without filter	7.80092
After adding active filter	1.23632
After adding passive filter	6.21682

IV. CONCLUSION

This contribution has demonstrated the effective operation of the harmonic mitigation in three phase 12Pulse AC/DC converter by using an active power filter and passive power filter. The active and passive filters were efficient and enable effective harmonic mitigation in three phase 12Pulse AC/DC converter and subsequently improved the quality of the system. Form result obtained, harmonic presented at phase current red, yellow and blue phase current, have been reduced. In addition, Total harmonic distortions have been decreased by adding both filters. Designing of component parameters for harmonic filter and three phase 12Pulse AC/DC converter can be made quick and easy with the help of PSIM software. For the future research the successful operation and simulation can be demonstrated in the realistically and practically with the Active filter and Passive filter. Furthermore the total harmonic distortion should be decreased more than this work for future work.

V. REFERENCE

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