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Harmonic Reduction in Power System

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***Abstract*—Harmonics is one of the attributes which lead to deterioration of power quality. Poor power quality has many adverse effects on the power system. The main source of harmonics in power system is nonlinear loads.**
Harmonic frequencies are the integral multiple of fundamental frequency of the system. The harmonics is the cause of many adverse effects on the system as well as on the power system equipment.
These effects are increase of heating in the equipment as well as in the conductors i.e., I2R losses, Maloperations of power electronics devices available in the Adjustable Speed drive circuitry, fluctuations in torques of the motors etc. mitigation of harmonics is possible with the help of different types of filters such as Passive filters, Active filters, Hybrid power filters.
This paper mostly focuses on the analysis as well as the study of effects of harmonics on the power system and the calculation of Total harmonic distortion by using FFT analysis. It also shows effects of different types of filters on total harmonic distortion of the system. The analysis of power system is carried out with the help of MATLAB/Simulink Library.

***Index Terms*— Harmonics, Harmonic reduction, Passive Filters, FFT analysis.**

I. INTRODUCTION

An alternator always generates sinusoidal voltage and current waveforms when the load is linear.
Now a days with increasing use of nonlinear loads increased in industry as well as in domestic applications like Adjustable Speed drives, personal computers, blast furnaces, power electronic devices led to the flow of nonlinear current in the system which also distort sinusoidal voltage, as a consequences odd harmonic come into picture [1].
The current and voltage in the system have distortion because of harmonics known as Harmonic distortion. Harmonics are sinusoidal waveforms of voltages and current with the multiple of integer of fundamental frequency i.e., multiple of 50 in India generally this distortion is due to the nonlinear loads which disturb the current waveform first and this current led to the distortion of voltage in the system.
The typical industrial loads such as arc furnaces, lightning discharge also cause distortion in the harmonics and effects include data loss, heating in the equipment, multiple frequencies can cause interference in the telecommunication system as well [9].
To avoid and control above problems, mitigation of harmonics is necessary in the power system. There are multiple ways to eliminate the harmonics.
This paper focuses on filtering techniques. There various types of filters such as Passive filters, Active filters, Hybrid power filters. This paper makes use of Passive filters i.e. Shunt passive filter to mitigate harmonics [2] [10].

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II. HARMONIC FILTERING TECHNIQUES

A. Active filtering Technique

Active filters are used to mitigate the harmonics in the system. They are generally FACTS devices and power electronics-based devices to reduce the harmonics. These devices are generally connected near to load. Active filters are of two types i.e., Series and shunt. These filters are composed of active components like amplifiers which are used to improve the performance of filters which eventually increases the cost of the equipment. [2][4][5] [14].

B. Passive Filtering techniques

Conventionally this method is used for mitigation of harmonics in the system. These techniques used passive filters to mitigate the harmonics which include R, L, C parameters which makes these filters less costly than Active filters. Continuously development has been going on for the betterment of this technique. The optimization in terms of reduction in rating and equipment cost to be used is possible with active filters.
This paper focuses on passive filters such as single tuned, Double tuned, High pass C-type filters which consist of reactor and capacitor as shown in Fig.1 [3] [4][9] [10] [14].

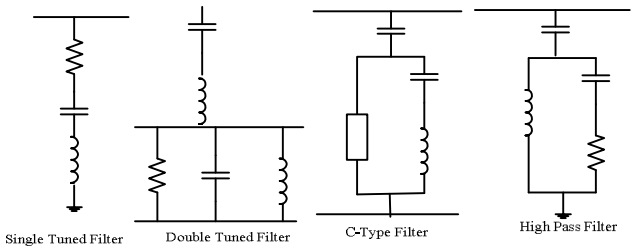

Fig.1 Different types of passive filters

Passive filters can be implemented with the help of using resistors (R), inductors (L)and capacitors (C) in various combinations. They are known as passive filters, because they do not require power supply from an external source and also, they are not designed with active components like transistors and SCRs. [3]

III. SOURCES OF HARMONICS

The following are the main sources of harmonics in the modern power system.

- Transformers with magnetization nonlinearities
- Rotating machines such as induction motors with VFD
- Arcing devices
- Power supplies using semiconductors
- Industrial A.C drives fed with inverters
- Industrial reactor with thyristerised control
- Controllers used for phase modification

IV. THE POWER SYSTEM MODEL

The single line diagram of power system model is shown in Fig.2.The simulation is carried out using MATLAB Simulink model to study the effect of various passive filters on system harmonics created due to nonlinear load.

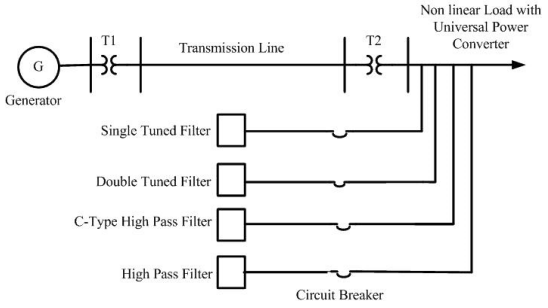

Fig.2. The model of power system

The Power System Data:
Generator:11 Kv,50 Hz,250 Mw
Transformers T1 and T2: 250 MVA,33 Kv/11 Kv
Transmission Line:300 Km,33 Kv, R=0, L=0.97x10-3H/Km, C=11.5x10-9 F/Km
Load: Nonlinear load 1000 Mw, Universal Power Converter, Power Electronic device used as thyristor

V. SIMULATION & RESULTS

In this paper the power system is first simulated without filter and the voltage and current THD % present in the system are noted. Total harmonic distortion is reduced by using passive filters [4], [14]. Motive of the model in this paper is to reduce the harmonics within their permissible range or minimize as much as possible. For this various passive shunt filters used to reduce the percentage THD. In the Simulink model, provision is made to apply the type of the filter. A comparison of THD level before and after application of various filters is studied.Fig.3 shows the output waveforms obtained without using any filter. The B1 and B2 represents the sending and receiving ends of transmission line respectively. From Fig. 4 and Fig.5, it can be seen that before using filter the voltage THD is 27.18% and 13.27% Current THD is 13.27 % Fig.6 depicts the output waveforms after the application of filter. Fig.7 and Fig 8 shows the results after using filter in the system for mitigation of harmonics. It reduces the Voltage THD up to 1.28 % and Current THD up to 0.84% by using single tuned filter. The simulation results as obtained by using different filters such as c-Type filters, high pass and double tuned passive filters are tabulated below with their comparison for effect on particular harmonic order. In the simulation model, provision is made to connect the single filter or multiple filters for reduction of harmonics. Also, the filters can be tuned to reduce a particular harmonic frequency. The voltage and current THD levels after application of filter is found to be within limit as per the IEEE 519-2014 standard for harmonics. [15].

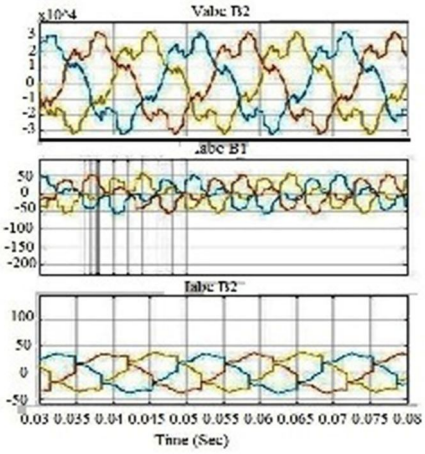

Fig.3. output without filters

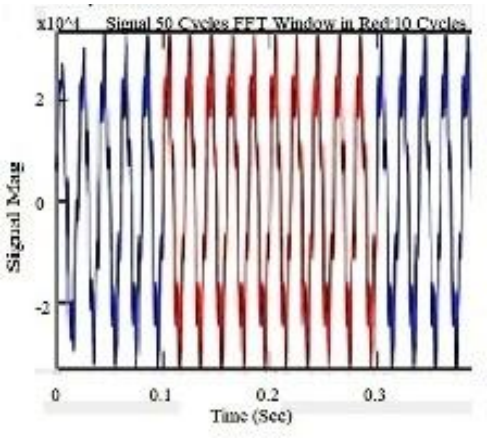

Fig.4(a) Voltage THD before using filter

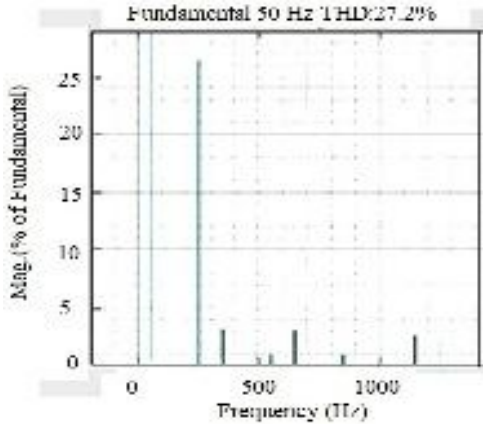

Fig.4 (b) Voltage THD before using filter

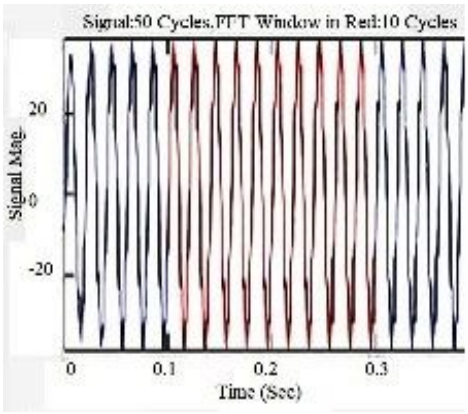

Fig.5(a) Current THD before using filter

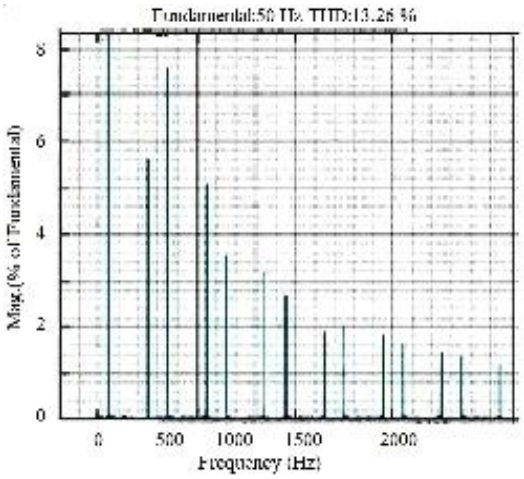

Fig.5(b) Current THD before using filter

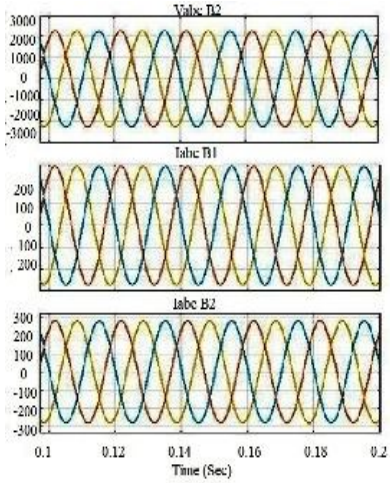

Fig.6. output with single tuned filters

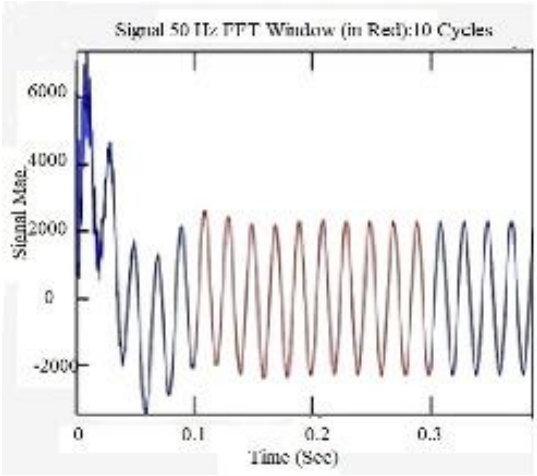

Fig.7(a) voltage THD after using Filter

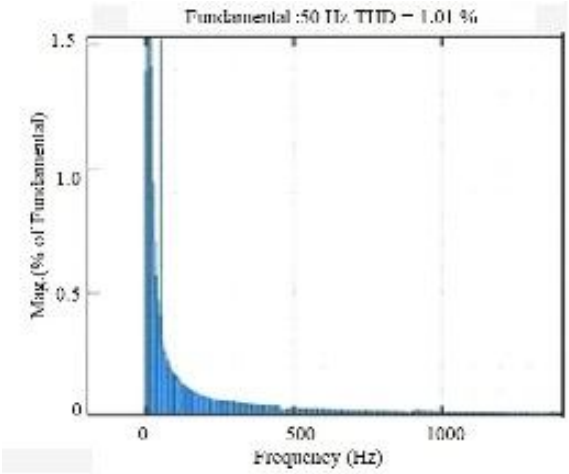

Fig.7(b) voltage THD after using Filter

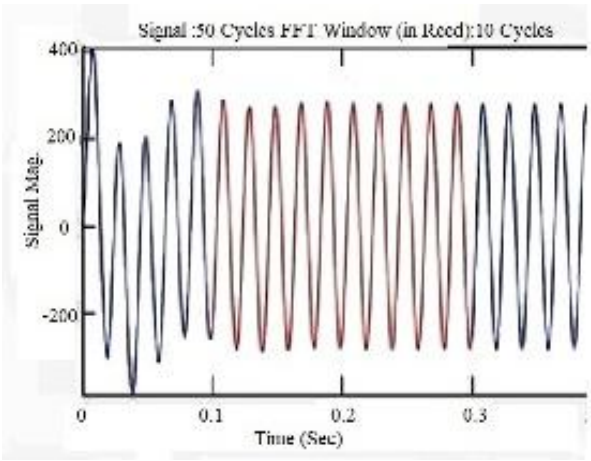

Fig.8(a) Current THD after using filter

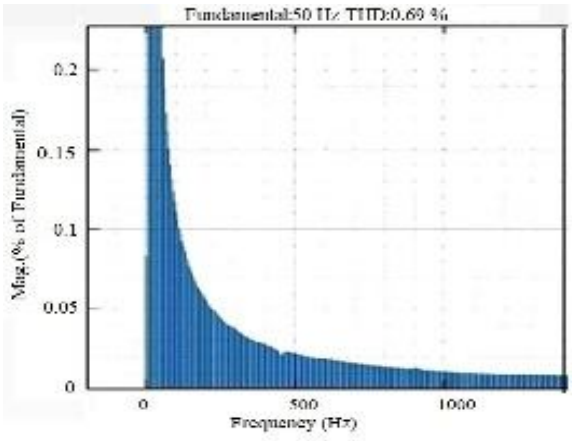

Fig.8(b) Current THD after using filter

THD shown in the table 1, table 2, table 3 calculated with the help of Fast Fourier Transform in which staring time is 0.1, number of cycles are 5 at 50 Hz frequency.
Values can vary slightly if starting time and number of cycles changed while doing fast Fourier Transform (FFT) Analysis

TABLE I. EFFECTS OF PASSIVE FILTERS ON OVERALL AND 5TH ORDER THD

Types of Filters	%THD		5th order	
	Voltage	Current	Voltage	Current
No Filter	27.2	13.26	26.29	5.59
Single Tuned Filter	1.28	0.84	0.04	0.09
Double Tuned Filter	1.20	0.92	0.05	0.06
C-type High Pass	1.26	0.84	0.05	0.06
High Pass	1.32	0.92	0.04	0.04

TABLE II. EFFECTS OF PASSIVE FILTERS ON OVERALL AND 7TH ORDER THD

Types of Filters	%THD		7th order	
	Voltage	Current	Voltage	Current
No Filter	27.2	13.26	3.24	7.61
Single Tuned Filter	1.15	0.91	0.08	0.06
Double Tuned Filter	1.12	0.93	0.07	0.05
C-type High Pass	1.16	0.9	0.08	0.06
High Pass	1.18	0.92	0.08	0.06

TABLE III. EFFECTS OF PASSIVE FILTERS ON OVERALL AND 11TH ORDER THD%

Types of Filters	%THD		11th	
	Voltage	Current	Voltage	Current
No Filter	27.2	13.26	1.03	5.08
Single Tuned Filter	1.01	0.93	0.04	0.04
Double Tuned Filter	1.08	0.94	0.04	0.03
C-type High Pass	1.1	0.93	0.04	0.04
High Pass	1.09	0.94	0.04	0.04

VI. CONCLUSION

Shunt filters reduce the harmonic in power system and they can also inject the Reactive power in the system which is consumed by the converters which eventually saves the cost as compared to active filters. The adverse effect of harmonics on power system includes the distortion of power quality. Harmonic is one of the attributes which is responsible poor power quality.Total Harmonic distortion is successfully reduced by using passive shunt filters. This paper can also help to find which type of filter is most efficient for mitigation of a particular harmonic order. Although, the effect of passive filters on mitigation of harmonics is established for a sample power system, it can be applied to any practical system.

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