Electric Power Quality Enhancement by Reduced Harmonic Distortion

Dr. Suad Ibrahim Shahl

Abstract— A different type of load draws non-sinusoidal current from the mains, leading to deterioration the power quality by causing harmonic distortion. These nonlinear loads seem to be prime sources of harmonic distortion in a power system. Furthermore, the harmonics produced by nonlinear loads can react negatively with a wide range of power system apparatus, most especially capacitors, transformers, and motors, causing additional losses, overheating, overloading and interference. The aim of this paper is to study power quality /harmonics problem and review a passive power filters that commonly used to mitigate harmonics within an acceptable range.

Index Terms— Power Quality, Harmonic, passive power filters, Total harmonic distortion

1 INTRODUCTION

In recent years, there has been an increased emphasis on the quality of power delivered to factories, commercial establishments, and residences. This is due in part to the prevalence of harmonic-creating systems in use. Such harmonic generating equipment contributes to the harmonic burden the system must accommodate. Furthermore, utility switching and fault clearing produce disturbances that affect the power quality. One of the biggest problems in power quality manifestation is the harmonics content in the power system. Generally, harmonics may be divided into two types: voltage harmonics and current harmonics. Current harmonics is usually created by harmonics located in voltage source and depends on the nature of load like resistive, capacitive and inductive, voltage and current harmonics can be generated by either the source side or the load side [1], [2].

Harmonics created by load are resulting from nonlinear devices such as power converters. Load harmonics can lead to the overheating in the magnetic cores of transformers and motors. Moreover source harmonics are mainly created by electric power supply with non-sinusoidal voltage waveform. Voltage and current source harmonics imply power losses, electromagnetic interference and pulsating torque in AC motor drives [3].

A lot of the devices in use today is susceptible to damage or service interruption during poor power-quality events. Everyone with a computer has experiment a computer shutdown and reboot with a loss of work resulting. Mostly this is caused by poor power quality on the power line. Bad power quality also affects the efficiency and operation of electric equipments in factories and offices.

IEEE Standard 1100 (IEEE 1999) defines power quality as the concept of powering and grounding sensitive electric devices in a method suitable for the devices. There are a lot of Electrical apparatus susceptible to power quality or more appropriately to lack of power quality. All electrical apparatus are susceptible to failure or malfunction when exposed to one or more power quality problems. The electrical apparatus might be an electric motor, a transformer, a generator, a computer, a printer, communication equipment, or a household appliance. All of these apparatus and others react negatively to power quality problems, depending on the severity of problems [4].

2 POWER SYSTEM HARMONICS

Harmonics are voltages waves or currents waves with frequencies that are integer multiples of the primary electrical power frequency. Harmonics are created by non-linear loads that draw current in sudden pulses rather than in a sleek sinusoidal manner. Electrical power system voltage and currents are sinusoidal waves as shown in Figure1a. Harmonics are sinusoidal components of a cyclic wave that are integral multiples of the power frequency (50Hz or 60Hz). Superposition of harmonics with fundamental will distort the original waveform as shown in Figure 1b [5].

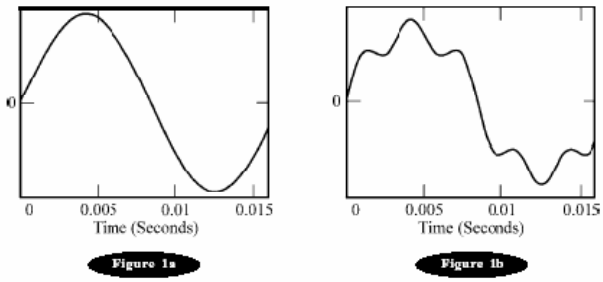

Fig.1. Fundamental and waveforms containing harmonics
(a) Normal fundamental 50Hz Waveform.
(b) Waveform containing the fundamental plus third and fifth harmonics.

Distorted waveforms can be decomposed into the sum of the fundamental frequency and the harmonic components. Harmonic distortion levels are described by the complete

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harmonic spectrum with magnitudes and phase angles for each individual harmonic component. It is common for measure of the effective value of harmonic distortion is use the single quantity, Total Harmonic Distortion (THD). Harmonic distortion originates in the nonlinear characteristics of devices and loads in the power system. Typical harmonic sources are variable speed drives and other power electronics based equipment. One of the major problems related to harmonic disturbances is harmonic resonance. The resonance can magnify harmonic distortions to a level that can damage the equipment or cause equipment malfunction. Power factor correction capacitors in distribution system are the main cause of harmonic resonance. Other effects of harmonics are equipment overloading, increased losses and sometimes equipment malfunction [6-8].

The most commonly used harmonics index is:-

$$THD_V = \frac{\sqrt{\sum_{k=2}^{\infty} V_k^2}}{V_1} * 100\% \quad and \quad THD_I = \frac{\sqrt{\sum_{k=2}^{\infty} I_k^2}}{I_1} * 100\% \qquad (1)$$

This is defined as the ratio of the rms value of the harmonic components to the rms value of the fundamental component and usually expressed in percent. This index is used to measure the deviation of a periodic waveform containing harmonics from a perfect sine wave. For a perfect sine wave at fundamental frequency, the THD is zero. Similarly, the measures of individual harmonic distortion for voltage and current at hth order are defined as V_h/V_1 and I_h/I_1, respectively. Harmonics are created in electrical power systems by [9], [10]:

• Arcing Devices - tools that make arcs as part of normal operation, such as electric arc welders.

• Magnetic Circuits - Magnetic devices such as transformers, produce distorted wave shapes when they are operated in their nonlinear regions.

• Power Electronics - The switching of such apparatuses as Silicon Controlled Rectifiers and thyristors produce electrical wave shapes that are not sinusoidal in kind.

3 RESULTS AND DISCUSSION

In this paper, a three phase power system model has been simulated with and without passive filters using MATLAB/SIMULINK environment. This system is analyzed without and with passive filters using Total Harmonic Distortion (THD) as an index. The schematic of the system is shown in the Figure 2.

Case Study One

The system without filter in Figure 2 has many distortions which are blamed for many power quality disturbances with high frequency component. Figure 3 shows the voltage and current wave simulation result without filter.

The limits of allowable voltage harmonic distortion set by ANSI/IEEE 519 voltage distortion limits. Without passive filters the THD of the current is above the range specified by the power quality standards. To follow the recommended ANSI/IEEE 519 the Voltage THD must be less than 1.5% as shown in Table 1.

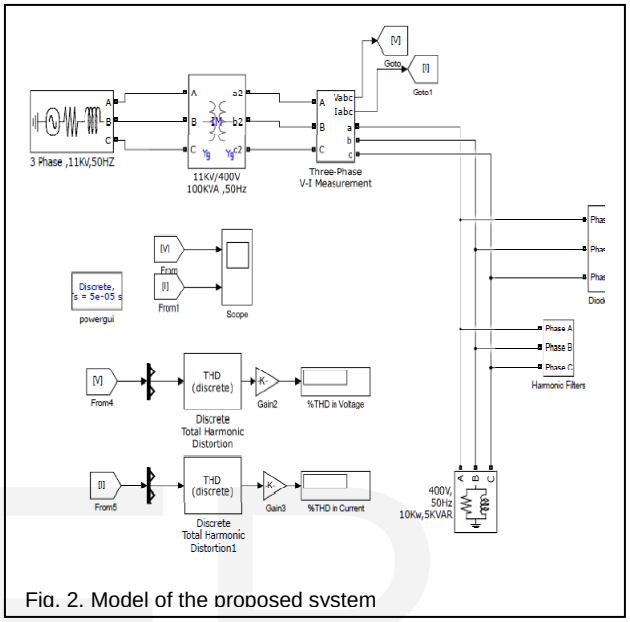

Fig. 2. Model of the proposed system

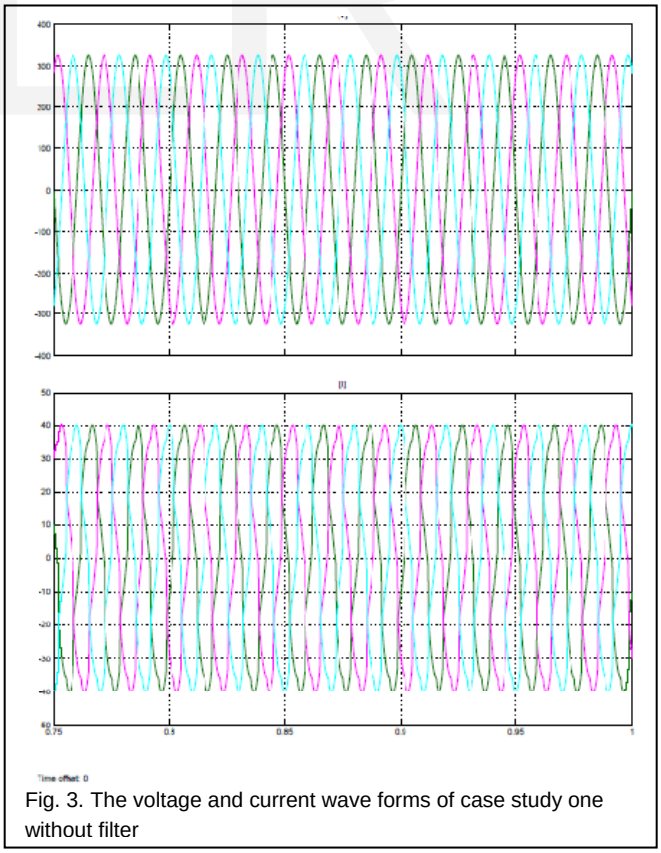

Fig. 3. The voltage and current wave forms of case study one without filter

Case Study Two

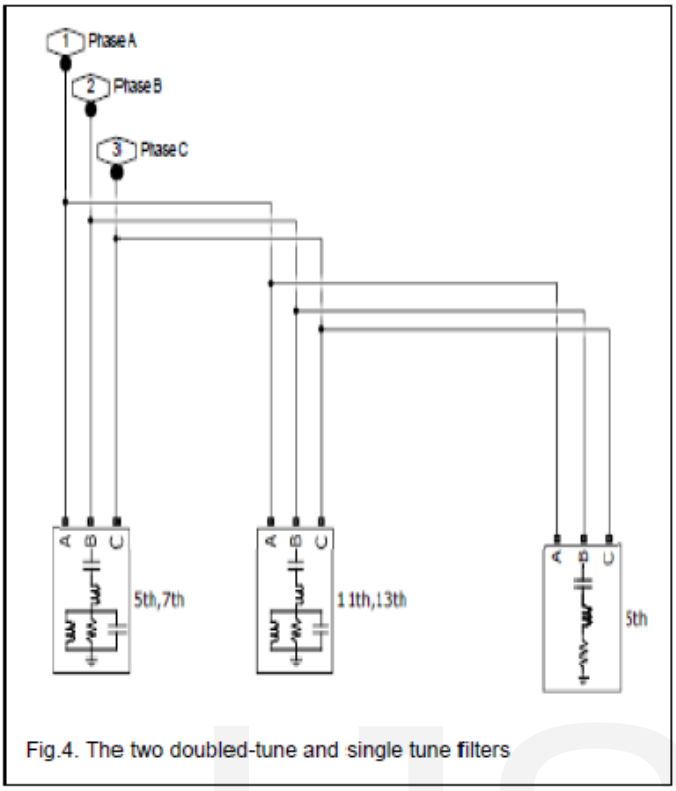

Fig.4. The two doubled-tune and single tune filters

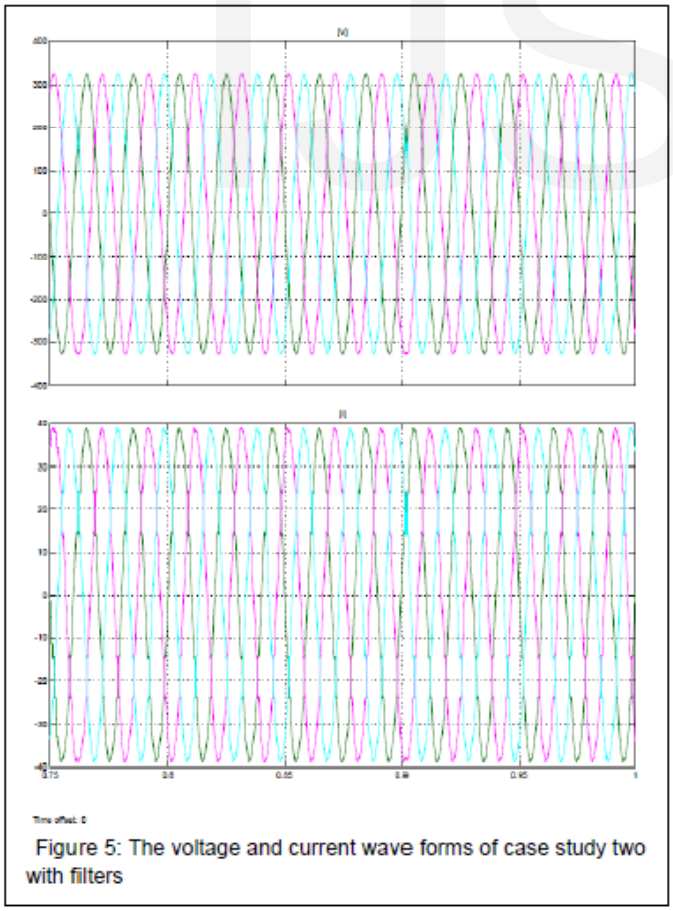

Figure 5: The voltage and current wave forms of case study two with filters

Case Study Three

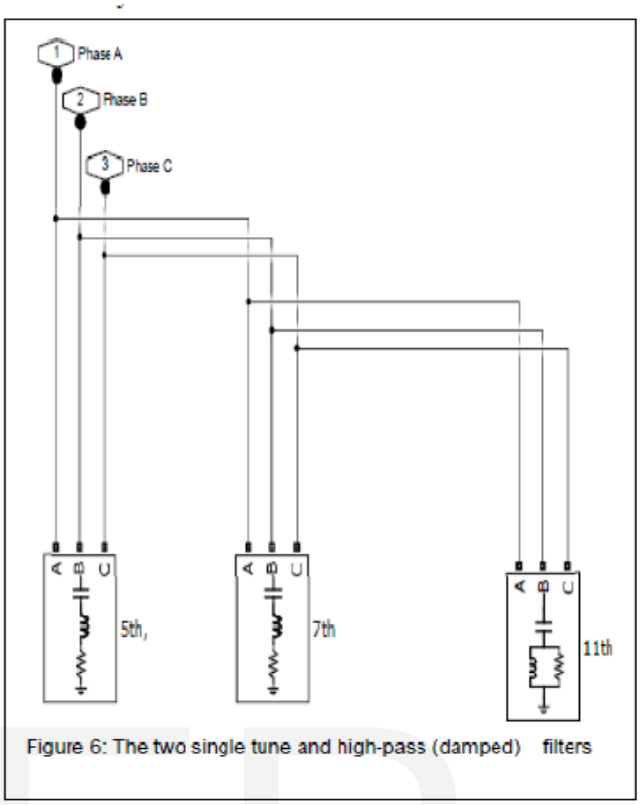

Figure 6: The two single tune and high-pass (damped) filters

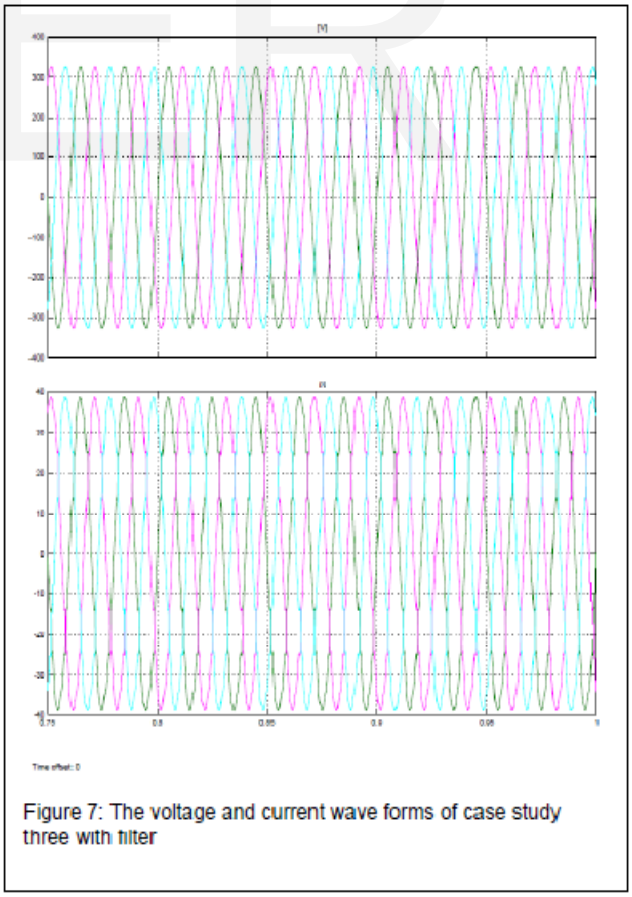

Figure 7: The voltage and current wave forms of case study three with filter

Case Study Four

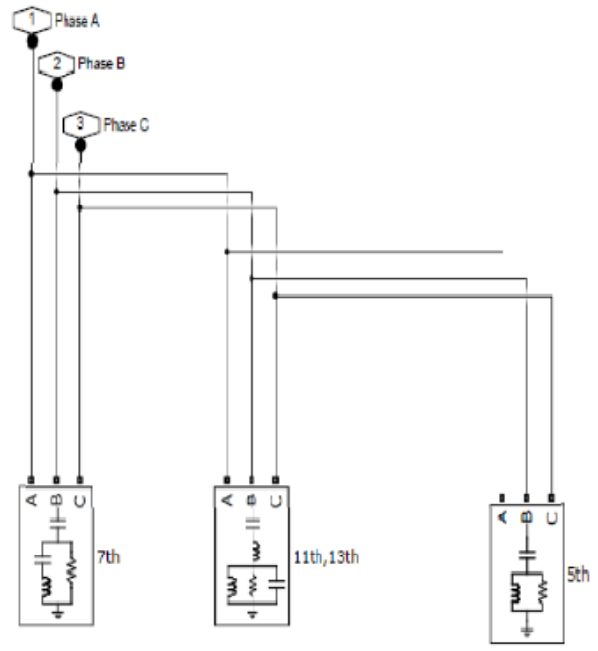

Figure 8: The C-type high-pass, doubled-tune and high-pass filters

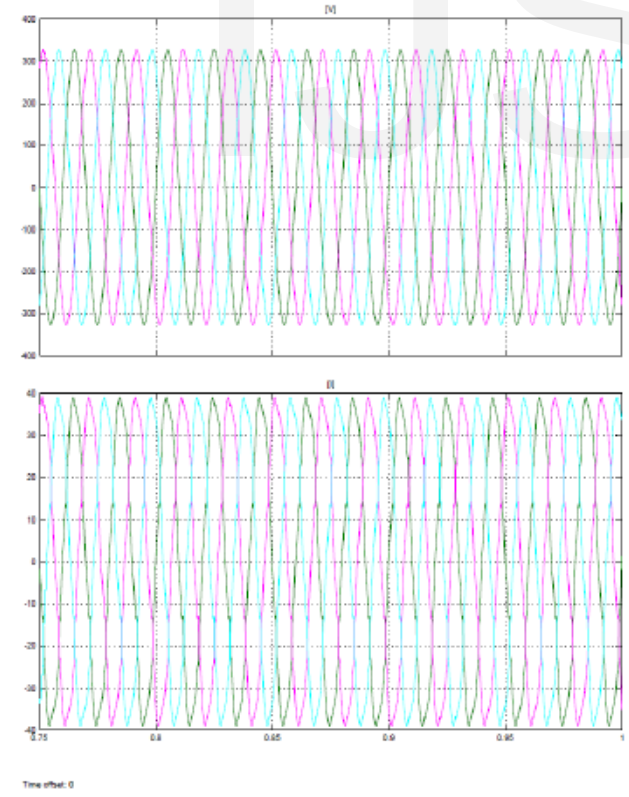

Figure 9: The voltage and current wave forms of case study four with filter

Case Study Five

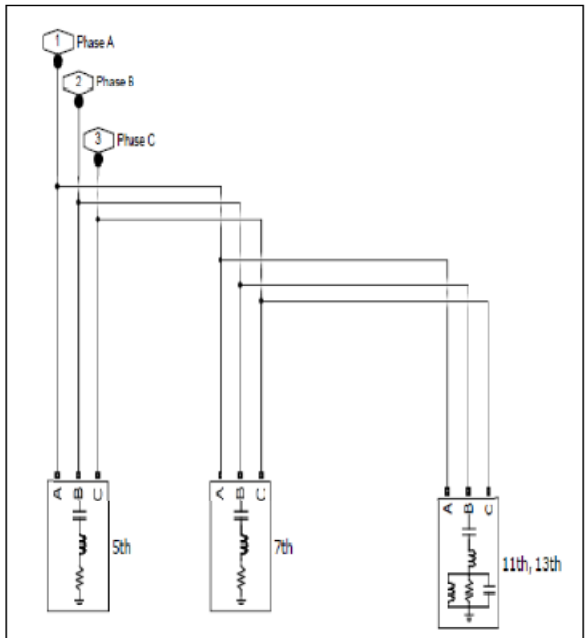

Figure 10: The two single tune and doubled-tune filters

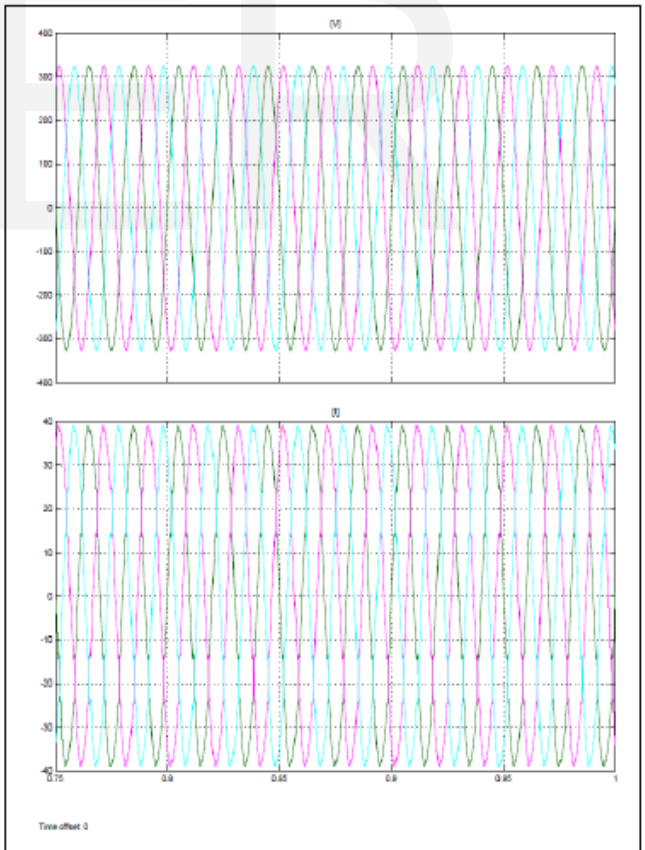

Figure 11: The voltage and current wave forms of case study five with filter

After comparing the different simulation results, we conclude that the circuit with the Figure 4 is much betters then the remaining circuit as shown in Figure 5 and the results in Table1. Because in that given circuit there is two double tune filters, which is dealing with two frequencies component and to remove the harmonics with two different frequency ranges.

TABLE 1
COMPARISON TABLE FOR VOLTAGE AND CURRENT HARMONICS DISTORTION

Circuit	Voltage THD , %	Current THD , %
Case Study one	1.789	13.14
Case Study Two	1.299	4.251
Case Study Three	1.375	5.414
Case Study Four	1.313	6.558
Case Study Five	1.342	4.965

4 CONCLUSION

In this paper, different types of passive filters are used in the proposal power system, in order to achieve an acceptable distortion. A power system model in MATLAB/ SIMULINK is used with different passive filter banks to reduce the distortion and to increase the power quality of the system. After comparing the different passive filters simulation results, it is found that the high pass with double tune filter is used mostly to achieve the acceptable distortion level. The results show that this filter has to remove the high frequency harmonics component as well as to remove the low frequency component. From the above result we conclude that above filter can be used to suppress to harmonics at different frequency levels.

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