Experimental Analysis of Harmonic Mitigation Effects on Three Phase Six Pulse Converter by Using Shunt Passive Filter

ZUBAIR AHMED MEMON*, MUHAMMAD ASLAM UQAILI**, AND MANSOOR AHMED SOOMRO***

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ABSTRACT

Power quality is the regulation and stability in power in terms of current, voltage and frequency so as to keep these parameters under defined limits of use to satisfy the demand of electrical utility. Harmonic is one of the power quality problems which are because of distortions in sinusoidal supply voltage at the fundamental frequency. Harmonics cause significant effects at all levels of electrical utility i.e. domestic loads, commercial and industrial loads and control devices. These effects can be minimized with harmonic mitigation techniques. In this regard, shunt passive filter provides reliable, economic and cost effective solution when used with three phase converters. Moreover, six pulse converter circuit is used in conjunction with shunt passive filter which eliminates 3rd harmonics and reduces 5th and 7th harmonics as dominant harmonic levels. This work focuses on harmonic mitigation of three phase six pulse converter circuits by using shunt passive filters. In this context, hardware model is designed and its results are analyzed by using PQA (Power Quality Analyzer).

Key Words: **Power Quality, Stability, Harmonics, Shunt Passive Filter, Six Pulse Converter, Power Quality Analyzer.**

1. INTRODUCTION

The switching characteristics of power electronic devices allow the use of power electronic converters to figure the input power of one form to the output power of another form [1-2]. The power electronic converters when used with power electronic devices energized with either single phase or three phase supply are severely affected by non linear loads. These nonlinear loads cause the power quality problems [2-3].

Power quality is the systematic regulation and stability in power (e.g. current, voltage or frequency) under definite circumstances which satisfy the demands of electrical utility. Harmonics is one of the power quality problems that exist mainly in power electronic devices due to nonlinear loads. These harmonics can appear either in odd or in even form. The odd harmonics are severe and create heating and insulation problems. In these cases, the third harmonic is most significant and needs attention with sophisticated design and manufacturing of electrical and power electronic devices as they emerge as the major source of nonlinear loads.

A pure supply voltage or sine wave does not appear with distortion and hence no harmonics are developed

*Assistant Professor, **Professor, and ***Lecturer,
Department of Electrical Engineering, Mehran University of Engineering & Technology, Jamshoro.

but the non-sinusoidal wave results in distortion and hence harmonics are produced in it. To measure the distortion developed due to the existence of non linear loads, THD (Total Harmonic Distortion) is used [4]. It is the specification that determines the amount of unwanted harmonic frequencies when the signal is passed through any component or device. The higher the value of THD is undesirable therefore it is enviable to keep THD value 8% when applied with variable or continuously changing load and up to 5% when applied with full load [5] as per IEEE 519-1992 standards [2,6]. In context to these effects, harmonics appear with their maximum effect during the early hours of the day when the electrical system is lightly loaded and the supply voltages are relatively higher [7].

Various harmonic mitigation techniques have been applied to reduce the THD. These techniques include increasing the pulse number, shunt passive filter, an active filter and hybrid topologies which is combination of shunt passive filter and series active filter [7-8]. The efficient use phase multiplication technique in six pulse converter circuits eliminates 3rd harmonic frequencies and reduces the magnitude of current [9]. This effect is numerically given as:

$$h = kp \pm 1 \quad (1)$$

$$I_h = I_1/h \quad (2)$$

Where, 'h' is harmonic order, 'k' is integer constant, 'p' is number of pulses, I_h is the amplitude of harmonic current and I_1 is the amplitude of fundamental current.

To overcome the harmonic problems in three phase six pulse converters and improve the quality of power supply in commercial and industrial electrical utility, passive filter provides a simple, rugged, reliable, highly efficient and cost effective solution [10].

2. SPECIFIC RESEARCH WORK DONE ON HARMONIC FILTER MODEL

The objective of this research work is to develop an experimental model with three phase six pulse converter which eleminates the 3rd harmonic effects caused by nonlinear behavior of power electronic devices and therefore use shunt passive filter to reduce THD less than 5% as per IEEE 519-1992 standards.

3. RESEARCH METHODOLOGY

The methodology of this research work is based on analysis and experimental approach.

In this research work the fundamental steps that have been followed are given as follows:

(a) Fabrications of an experimental model by using three phase six pulse converter.

(b) Analysis of the effects of harmonics on six pulse converter before and after the application of shunt passive filter.

(c) Use PQA to obtain the results of current and voltage waveforms and spectrographs for determining the percentage of THD.

(d) Compare the waveforms and spectrographs before and after the application of shunt passive filter.

(e) Validate the results obtained after the use of passive filter from IEEE 519-1992 standards.

4. HARMONIC FILTER MODEL

In order to determine the effectiveness of three phase six pulse converter used with passive filter to mitigate the harmonic produced by the nonlinear behavior of power electronic converters, the hardware model experimentation has been performed. The results are taken from PQA before and after the application of shunt passive filter Fig. 1.

4.1 Behavior of Harmonics Before the Application of Passive Filter

The following waveforms describe supply voltage and supply current when taken before the application of three phase passive harmonic filter. The supply voltage obtained is 261.5V and supply current of 2.95A as shown in Fig. 2.

Fig. 2 shows that the voltage waveform is purely sinusoidal having no significant effect by the application of power electronic devices whereas the current waveform is considerably distorted wave because of nonlinear behavior of power electronic devices.

Since, the current harmonics are causing major damage to the electrical and power electronic devices like electromagnetic interference in motor windings and heating losses like (i.e. copper losses, iron losses and dielectric losses) through electrical equipments like cables, circuit breakers and switchgears.

The spectrum of supply current suggests that the dominant harmonic orders to six pulse converter i.e. 5th and 7th harmonics were resulting in 26.9% THD of current harmonics and the current was observed to be 2.94A, through it. These results obtained from spectrograph describing THD are shown in Fig. 3.

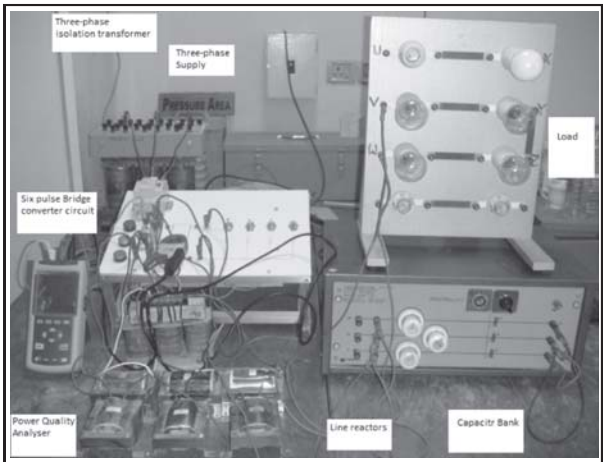

FIG. 1. EXPERIMENTAL MODEL OF SIX PULSE RECTIFIER SYSTEM USING PASSIVE FILTERS

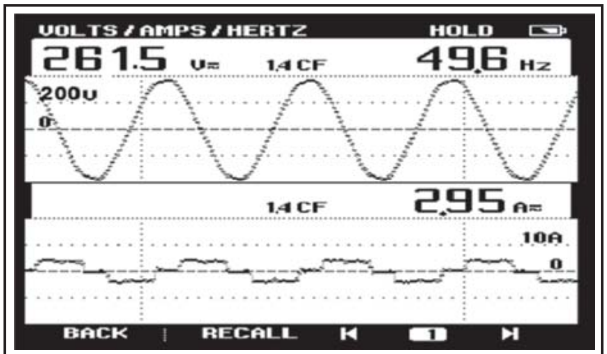

FIG. 2. SUPPLY VOLTAGE AND SUPPLY CURRENT BEFORE FILTERING

4.2 Behavior of Harmonics After the Application of Passive Filter

The application of six pulse converter with passive filter has this tendency that it eliminates the 3rd harmonic level and reduces 5th and 7th harmonics which are the most dominant in all levels of harmonics. Furthermore, the passive filter is providing simple circuitry, reliability and cost effective solution while filtering power system harmonics.

The introduction of passive filter resulted in shaping both supply voltage and supply current waveforms sinusoidal. It indicates that the losses are minimized and thus reliability and proper operation of the machines and equipments are maintained.

The following waveforms show that the supply voltage and supply current obtained is 281.2V and 2.48A respectively as shown in Fig. 4.

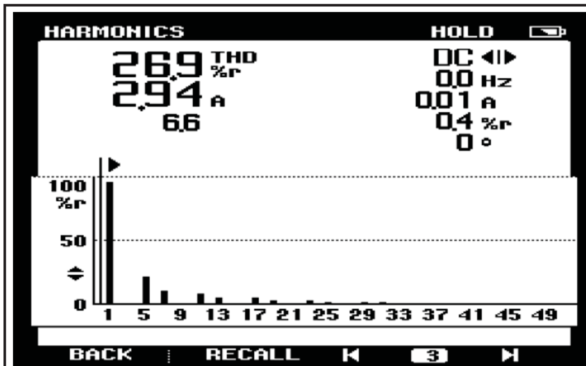

FIG. 3. SPECTRUM OF SUPPLY CURRENT BEFORE FILTERING

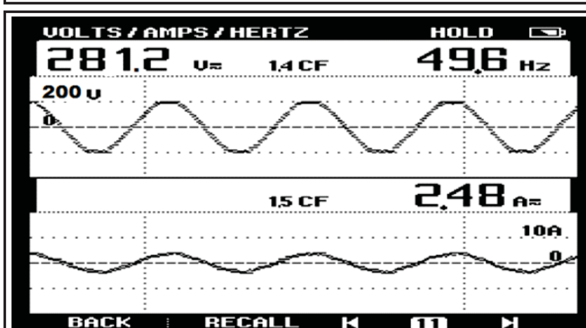

FIG. 4. SUPPLY VOLTAGE AND SUPPLY CURRENT AFTER FILTERING

Fig. 5 shows that supply voltage and supply current is sinusoidal. It suggests that the system performance can be optimized whereas the THD is under the standards limits i.e. THD is 5% or below when used with full load and up to 8% when used with continuously changing load.

The spectrograph shows that result obtained from six pulse converter of passive filter for THD of current harmonics is 4.8% at a current of 2.46 A. It indicates that this system is so effective that it can be reliably used with the application of three phase power electronic converters without considerable damage to their subsequent parts.

5. CONCLUSION

Harmonics of three phase six pulse converter using passive filter was analyzed by using PQA for the experimental model. The current and voltage waveforms and their corresponding line spectrums before and after filtering were validated and it was observed that these values are under defined limits of use. The six pulse rectifier was used in harmonic mitigation in which 5th and 7th harmonics respectively were dominant harmonic levels along with fundamental frequency while neglecting other harmonic levels. The THD for the experimental model was 26.9% when experimented without using passive filter. The THD is 5% when applied with full load, therefore by using passive filters of six pulse converter circuit it was experimentally analyzed that result was less than 5% of THD. Harmonic mitigation can be applied to various fields of electrical engineering like drives system, power electronic circuits, power distribution system, power quality, power system protection, etc. Moreover, it is also used in electronic and telecommunication networks.

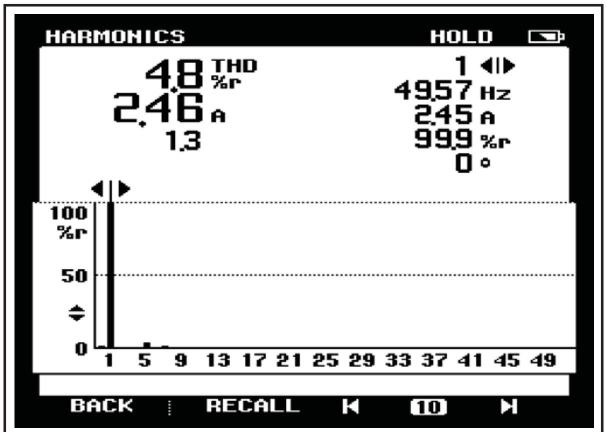

FIG. 5. SPECTRUM OF SUPPLY CURRENT AFTER FILTERING

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