Efficient Hybrid Shunt Active Power Filter for Improvement of Power Factor and Harmonic Suppression using MATLAB

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ABSTRACT

Power quality management is the main problem that the industry is facing today. This is mainly affected by the generation of harmonics. The growing use of electronic equipment produces a large amount of harmonics in distribution systems because of non-sinusoidal currents consumed by non-linear loads. As we know for the better quality of power, the voltage and current waveforms should be sinusoidal, but in actual practice it is somewhat disturbed and this phenomenon is called “Harmonic Distortion”. Voltage harmonics are generally present in supply of power from utility. Even though electronic and non-linear devices are flexible, economical and energy efficient, they may degrade power quality by creating harmonic currents and consuming excessive reactive power.

The two approaches using which the harmonic distortions can be suppressed are passive and active filtering. The passive filtering is the simplest conventional solution to mitigate the harmonic distortion. Although simple, the use of passive element do not always responds correctly to the dynamics of the power distribution systems. Active filters can be applied to a single non-linear load or many. They provide controlled current injection to remove harmonic current from the source side of electric system and also can improve the power factor.

This work presents a method capable of designing power filters to reduce harmonic distortion and correct the power factor by which the power quality of a distribution system can be improved. The simulation results of the non- linear systems have been carried out with MATLAB 7.6.

Key Words: *Harmonic suppression, Hybrid Filter, MATLAB 7.6, Power Quality, Shunt Active Power Filter,TotalHarmonicDistortion,.*

1. INTRODUCTION

Harmonic pollution is not a new phenomenon, issues of harmonic components of voltage and / or current curves occurred early in the industrial use of electricity, the first mention regarding to the use of harmonic analysis as a way of solving a practical electrical engineering problem, was made in 1893 by Steinmetz.

Nowadays, in modern industry, about 50% of receivers an industrial customer are supplied using frequency converters (AC and DC adjustable drives), switching mode power supply (for powering computer systems or process controllers) and electronic ballasts. Due to the nonlinear characteristics of these receivers (using diodes, thyristors or transistors to convert AC voltage in DC voltage and DC voltage in AC voltage or DC voltage in DC voltage), in industrial distribution systems harmonic currents occur. These, harmonic currents, leads to the distortion of the voltage curve at the point of common coupling (and in other parts of the distribution system), so are affected and other customers, non-harmonic polluting. Resonance phenomena can increase the harmonic components of voltage that will lead to increase the voltage in different parts of the electricity supply system, overloading of transformers and, in particular capacitor. Also, can causing losses increasing in overhead electric lines, cable, transformers and capacitor banks, leading to acceleration of insulation aging and reduction life. In four wire systems, harmonic current with frequency multiple by three will be add up in the neutral conductor, so the current through this reaches high values. Given the negative consequences of harmonic distortion the measures must be taken that would lead to limitation of harmonic pollution in power networks. Measures can be undertaken involving: reduce harmonic currents from customers, changing the resonance frequency and filtering of the harmonic distortion using passive, active or hybrid systems.

The filter design has become essential for distribution systems. This work examines the feasibility of designing a filter size such that the total investment cost, (in which unacceptable voltage profiles must be correct and harmonic must be reduced within the permissible maximal value e.g. IEEE Std. 519 [4]), is keep at a minimum.

Designing a harmonic filter has conventionally been by a trial and error approach. Various formulations for a more systematic approach to design harmonic filters have been developed in the decade [1-3,5-7]. Although effective in eliminating the harmonic, some of these methods did not consider the cost of filter elements. Moreover, other related investigation did not address whether or not the issue of the filters can adhere to the industrial specifications. The harmonic filter design problem has a partially discrete, partially continuous formulation with a non-differentiable nonlinear objective function. The non-differentiable nature, originating from a circumstance in which the cost of capacitors is step-wise, makes most nonlinear optimization techniques difficult to apply. This type of problems has generally been tackled by heuristic or approximate techniques. Simulation results have been shown in this paper.

2. CONFIGURATION OF THE SYSTEM

Fig.1 shows a proposed system consisting of a Shunt active power filter and Passive filter. The purpose of using this combined system is to reduce the harmonics effectively. The power factor also improved by using the combined System.

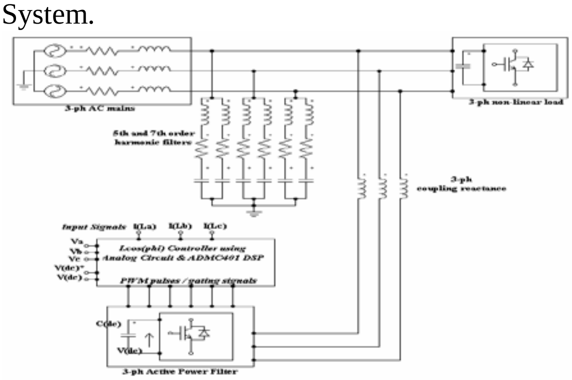

Figure 1 Combination of shunt active filter and passive Filter.

3. SIMULATION RESULTS

The simulation results are compared with the control method of Passive Power Filter, Active Power Filter and the combination of Passive Power Filter and Active Power Filter.

3.1 Results For passive Power Filter

The following figure is the simulation diagram with Passive Power Filter. The diagram consists of the source, non-linear load and Passive Power Filter.

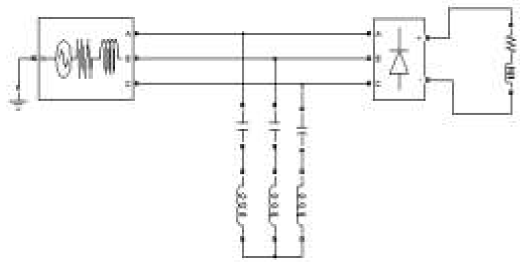

Figure 2 Simulation diagram with PPF

Figure 3 shows the waveform of supply current before compensation. It consist of fundamental current as well as the harmonic current due to the non-linear load.

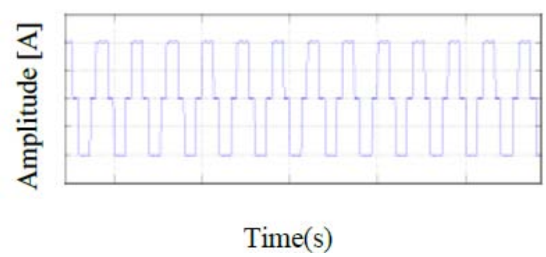

Figure 3 Supply current waveform –before Compensation

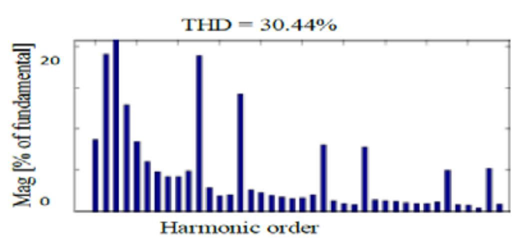

Figure 4 Spectrum analysis of supply current-Before Compensation

Fig.4 shows the spectrum analysis of supply current before compensation. The Total harmonic Distortion of the supply current is 30.44%. Figure 5 shows the waveform of supply current after compensation. It consist of fundamental current only. The harmonic current

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present in the supply current is eliminated by using the Passive Power Filter.

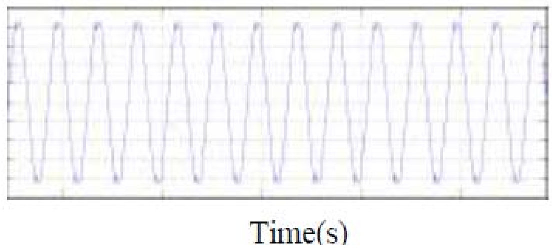

Figure 5 Supply current waveform –after compensation using PPF

Figure 6 shows the spectrum analysis of supply current after compensation. The Total Harmonic Distortion of the supply current is reduced to 4.10% from 30.44%.

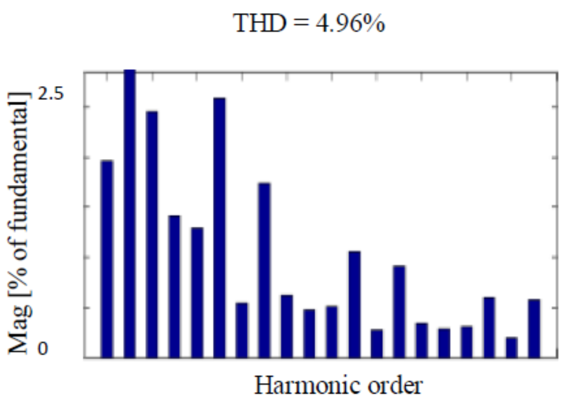

Figure 6 Spectrum analysis of supply current- after compensation using PPF.

3.2 Results For Shunt Active Power Filter

The general representation of shunt active power filtering is shown in figure 7.Figure 8 will represents the block diagram of control of an APF using Hysteresis current control and the simulation diagram with shunt Active Power Filter is shown in Figure 9. The diagram consists of the source, non-linear load, shunt Active Power Filter and its control circuit.

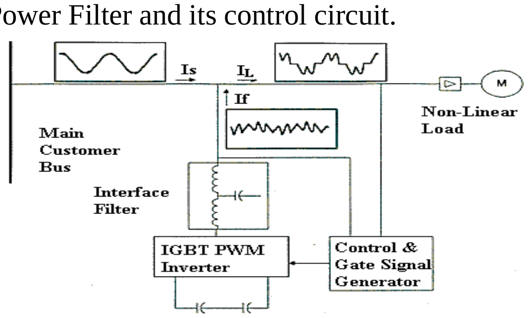

Figure 7:Shunt Active Power Filtering

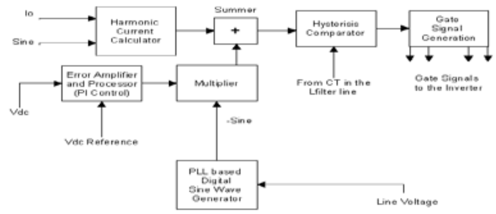

Figure 8 Block diagram of control of an APF using Hysteresis current control

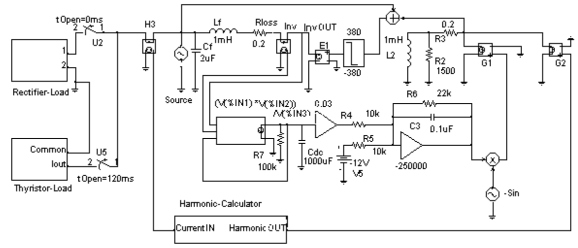

Figure 9 Simulation model for a Shunt Active Power Filter

Figure 10 shows the waveform of supply current after compensation. It consist of fundamental current only. The harmonic current present in the supply current is eliminated by using the Shunt Active Power Filter. The distortion present in the supply current is reduced when compared to PPF compensation.

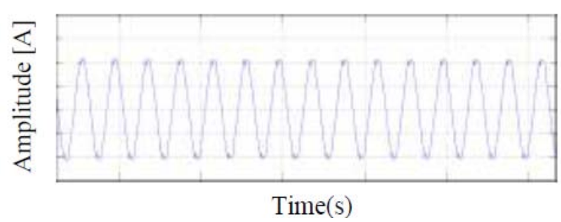

Figure 10 Supply current waveform –after compensation using SAPF

Figure 11 shows the spectrum analysis of supply current after compensation. The Total Harmonic Distortion of the supply current is reduced to 4.85% from 30.44%.

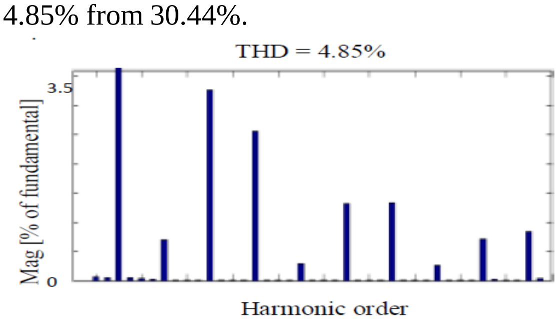

Figure 11 Spectrum analysis of supply current- after compensation using SAPF

3.3 Results For the combination of shunt Active Power Filter and Passive Power Filter

The simulation diagram with shunt Active Power Filter and PPF is shown in Fig.12. The diagram consists of the source, non-linear load, Passive Power Filter, shunt Active Power Filter and its control circuit.

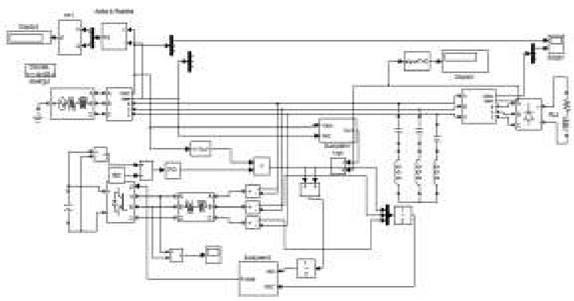

Figure 12 simulation diagram with SAPF and PPF

Figure 13 shows the waveform of supply current after compensation. The waveform is more sinusoidal when compared to other two techniques.

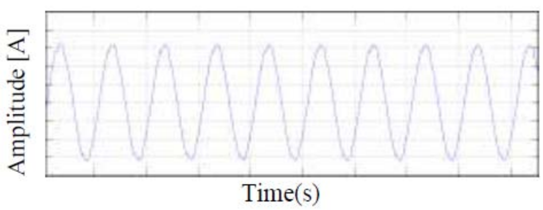

Figure 13 Supply current waveform –after compensation using SAPF and PPF

Figure 14 shows the spectrum analysis of supply current after compensation. The Total Harmonic Distortion of the supply current is reduced to 1.95% from 30.44%.

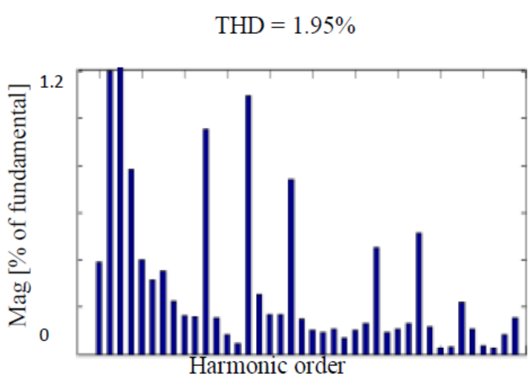

Figure 14 Spectrum analysis of supply current- after compensation using SAPF and PPF

3.4 Comparison of Results

The numarical values of the harmonics are listed in table 1. The comparisons are made between before compensation, Shunt Active Filter and the combination of Shunt Active Power Filter and Shunt passive Filter.

Table 1. Comparison of % of harmonics

Harmonic order	% of harmonics		
	Before compensation	SAPF	SAPF+PPF
3rd	4.80	0.71	0.36
5th	18.91	3.28	0.96
7th	14.54	2.78	1.30
9th	1.16	0.09	0.76
11th	1.77	1.35	0.11
13th	7.77	1.37	0.48

Table 1 shows the comparison chart of harmonic order. The % of harmonics can be reduced in the combination of Shunt Active Filter and Passive Power Filter when compared to Passive Power Filter alone. For the comparison only even order harmonics only considered.

Table 2 shows the % of THD of PPF, SAPF and the combination of SAPF and PPF. When compared to all methods the % of THD can be reduced to1.95% by the combination of the two methods.

Table 2.Comparision of %THD

SYSTEM	%of THD
Before Compensation	30.44
Passive power filter	4.96
Shunt active power filter	4.85
Combination of shunt active power filter and passive power filter	1.95

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Table 3. Comparison of Power factor

System	Power factor
Passive power Filter	0.9218
Shunt active Power Filter	0.9547
Combination of PPF+SAPF	0.9554

As listed in table 3 the power factor also improved to 0.9554 when compared to other two methods.

Table 4. System parameters

SYSTEM PARAMETERS	VALUES
SOURSE IMPEDANCE	R=0.5 OHM L=1mH
LOAD	R=10.6 OHM L=58.2 mH
PPF	C=625µF L=20.17µH
SAPF	R=0.001OHM L=3.5mH

Table 4 gives the system parameters of the simulation system.

4. CONCLUSION

The system of Passive power Filter, Shunt Active Power Filter and the combination of Passive power Filter and Shunt Active Power Filter is proposed in this work. When compared to the three methods the combination of Passive power Filter and Shunt Active Power Filter is efficient for harmonic suppression and power factor improvement. By this method the % of THD can be reduced to 1.95 and the power factor is increased to 0.9554.

5. REFERENCES

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