HARMONIC INTELLIGENT CONTROL WITH ACTIVE POWER FILTER

Dr. Eng.Talaat Abu El-Fetoh
North Delta Electricity Distribution Company- EGYPT
drtalat2006@yahoo.com

ABSTRACT

This paper presents the procedures required to determine the locations and sizes of multiple-Active Power Filters (APFs) to reduce harmonic distortion in a power system with harmonic sources. The objective function is to minimize the APFs injection currents while satisfying harmonic voltages, total harmonic voltage distortions within IEEE-519 recommended limits and the maximum rating current limit of each installed APF. The APFs are located at the points having harmonic sources or higher harmonic distortions, while minimizing injection currents. The ANN Model is developed to determine size and location of APF. A typical 28-bus distribution system is selected to verify the validity of the proposed procedures.

1- INTRODUCTION

Harmonic filters are recommended if a problem exists with harmonic distortion before the application of power factor correction, or if the harmonic distortions above the limits. Passive filters (PFs) have traditionally been used to absorb harmonic currents generated by non-linear loads, because of their low cost and high efficiency. The installation of tuned filters does however have some major, well documented, disadvantages that impair their effectiveness[1,6]. **First:** (PFs) may cause parallel resonance with the AC sourc. Therefore, amplification of the harmonic currents of the source side at specific frequencies occurs. **Second**: The passive filter can generate a series resonance with the AC source.

The problems associated with passive filters has led to the development of the parallel connected active filter. The active filter comprises a reactive energy storage element on the compensator DC side, a high frequency power electronic converter and an output filter that is used for filtering of the converter switching frequency on the output current. The characteristics of the active filters are [2,8] : **First:**The performance obtained with APFs is high compared with that obtained with PFs .**Second:** The initial and runnig costs of the APFs are high compared to that of the passive filters. The APFs are located at the points having harmonic sources or higher harmonic distortions, while minimizing injection currents are determined using a nonlinear optimization technique based ANN algorithm[3]. The ANN Model is developed to determine size and location of APF[4].

2- PROBLEM FORMULATION

Consider an N-bus power system that contains nonlinear loads (sources of harmonics). Also, there are an M-buses which candidates for APFs placement to reduce harmonic distortion[5,7].

2.1 Objective Function

The high rating of power electronic converter used in APFs causes high electro-magnetic interference, high power losses, and high cost of these filters. Due to these reasons, the objective function considered here is to minimize the nonsinusoidal injecting current from the APFs located at buses (m=1, 2, …, M).

The injection nonsinusoidal current of an APF at candidate bus m is given by**,**

$$I_m = [\sum_{h=2}^{H} \{(I_m^{h,r})^2 + (I_m^{h,i})^2\}]^{0.5} \qquad (1)$$

The objective function is to minimize the total of squared injection nonsinusoidal currents of APFs for a set of candidate buses M, then

$$f(I_m) = \sum_{m=1}^{M} \sum_{h=2}^{H} \{(I_m^{h,r})^2 + (I_m^{h,i})^2\} \qquad (2)$$

where

H : Maximum harmonic order of interest.

M : Total number of candidate buses for installing APFs.

Im : Installed APF rating current at candidate bus m.

$I_m^{h,r}$: Real part of APF current for harmonic h at candidate bus m. $I_m^{h,i}$: Imaginary part of APF current for harmonic h at candidate bus m.

2.2 System Constraints

The system constraints considered here are

2.2.1 Maximum APF rating current

The injected APF current must be upper constrained to its rating value. This constraint can be stated as,

$$I_m \le I_m^* \qquad (3)$$

where, I_m is given by equation (1), and I_m^* is the maximum rating current of an APF at installed bus m.

2.2.2 Individual harmonic distortion voltages

There are two types of voltage harmonic distortion constraints in IEEE-519. The first type applies to individual harmonic voltages at bus k,

$$\frac{\left|V_k^{(h)}\right|}{\left|V_k^{(1)}\right|} \leq V_k^{(h)*} \qquad (4)$$

for k= 1, 2, …, N, and h= 2, 3, …, H
where

$\left|V_k^{(h)}\right|$: Voltage magnitude at bus k for harmonic h.

$\left|V_k^{(1)}\right|$: Voltage magnitude at bus k at fundamental frequency.

$V_k^{(h)*}$: Is the high limit of voltage distortion for harmonic h at bus k.

2.2.3 Total harmonic distortion

The second type of IEEE-519 constraints applies to total harmonic voltage distortion. The total harmonic voltage distortion at any bus k (THDk) is given by

$$THD_K = \frac{\sqrt{\sum_{h=2}^{H} \left|V_K^{(h)}\right|^2}}{\left|V_K^{(1)}\right|} \qquad (5)$$

This constraint can be stated as,

$$THD_K \leq THD_K^* \qquad (6)$$

Where, THD_K^* is the high limit of total harmonic distortion of voltage at bus k.

The harmonic voltage at bus k for harmonic h, after installing all M APFs, is

$$\left|V_K^{(h)}\right| = \left|V_{K,old}^{(h)} + \Delta V_K^{(h)}\right| \qquad (7)$$

The voltage change at bus k is

$$\Delta V_K^{(h)} = \sum_{m=1}^{M} Z_{K,m}^{(h)} . I_m^{(h)} \qquad (8)$$

Where $V_{K,old}^{(h)}$ is the voltage distortion at bus k before installing the APFs, and $Z_{K,m}^{(h)}$ is the harmonic transfer impedance between bus k and m.

A general problem formulation for the determination of locations and sizes of APFs to reduce harmonic distortion is

Min f(X) (9)

Subject to

h(X) ≤ 0 (10)

g(X) ≤ 0 (11)

Where f represents the sum of squared injection currents of APFs for a set of candidate buses (equation (2)), the vector of h signifies the inequality constraints for the maximum installed amount of APF for each candidate bus (equation (3)); the vector g signifies the inequality constraints for the harmonic IEEE-519 standard (equations (6, 10)). The vector of x includes the real and imaginary components of the injection currents for each APF at each harmonic order. We can see from the above formulation that the objective function is quadratic and the constraints are also quadratic and convex.

3 - SOLUTION PROCEDURE USING NEURAL NETWORK

Step1	**:** Build harmonic data base and determine the spectrum of harmonic voltage and current at each bus.
Step2	**:** Identify the buses that have higher harmonic distortion.
Step3	**:** Install APF at buses of A - increased harmonics or B - sources of harmonics.
Step4	**:** Inject harmonic current at APF buses by a percentage 25% of injected harmonic current.
Step5	**:** Repeat steps from 1 to 4 for 50%, 75%and 100% of injected harmonic current.
Step6	**:** Identify for each APF busbar the value of THD and minimum value of injected current.
Step7	**:** Repeat steps for all busbars with increased and sources of harmonics.
Step8	**:** Build harmonic ANN patterns.
Step9	**:** Train the ANN with (THD) before and Harmonic injection current(I_5,I_7,I_{11} and I_{13}) at each APF busbar and output is busbars THD after installation.
Step10	**:** Test the trained ANN of APF with selected patterns.
Step11	**:** Identify the sizing of APF.

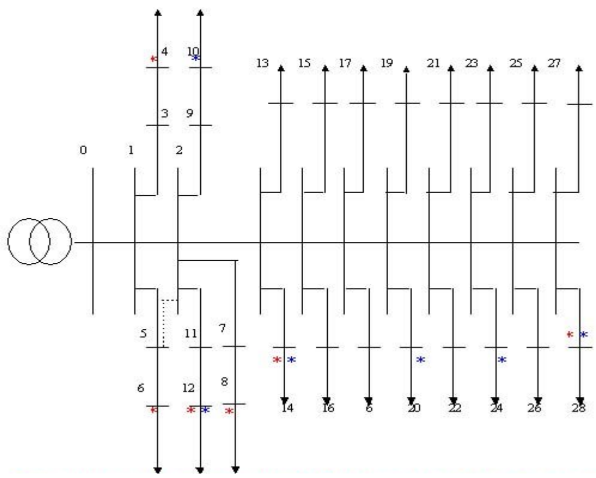

Fig (1) One-line diagram for 28-bus distribution system.

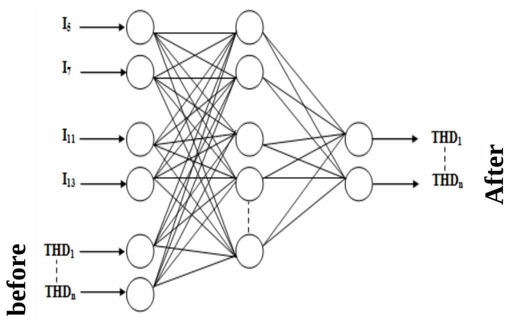

Fig (2) Neural Network Architecture

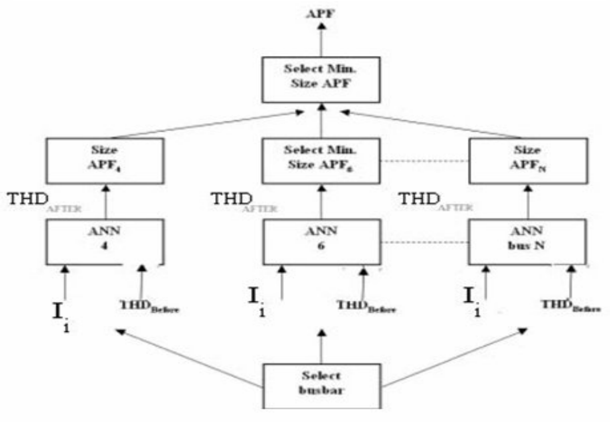

Fig (3) Flow chart of the ANN Based Technique

4 – TEST RESULTS

The proposed solution procedures for multiple APFs problem are tested using a typical 28-bus industrial distribution system. The single line diagram for the test system are given in Figure 1. The system has 13 main busbars with different loads. There are nonlinear loads at buses 4, 6, 8, 12, 14 and 28 which inject harmonic currents into the system. The dominant harmonics in the system are of the order 5, 7, 11 and 13. Before installing the APFs, the harmonic voltages, total harmonic distortions are determined by the harmonic power flow program. The buses 10, 12, 14, 24 and 28 having the higher THDs, it is reasonable to install the APFs at buses of - increased harmonics or sources of harmonics. by the proposed method. The solution procedure using Neural Network is then utilized to determine the optimal injections from multiple APF_s located at these buses to meet IEEE-519 standard limits and Identify the sizing of APF. By injecting harmonic current at APF busbar by 25%, 50%, 75% and 100% of injected harmonic current, to idententify the minimum value of THD and injected current. From results we find that the buses having higher harmonics distortion are the best locations to install the APFs for economical and Technical consideration from the result we find also that 50% of injected harmonic current, give the minimum value of THD and injected current . The individual harmonic voltages in P.U at buses 10, 12 14, 24 and 28 before/after the installation of the APFs are illustrated in figures 4-8 respectively. The harmonic voltages are greatly reduced by APFs injection currents at level 50% of injected harmonic current. Figure 9 shows Comparison between THDs (%) of voltage before/after the installation of the APF. The results show that THD is greatly decreased by using APF. Figure 10 shows the APF sizing at location of increased harmonics and location of harmonic sources. The results show also that the size of APF at increased harmonics at 50% is less than corresponding value at sources of harmonic

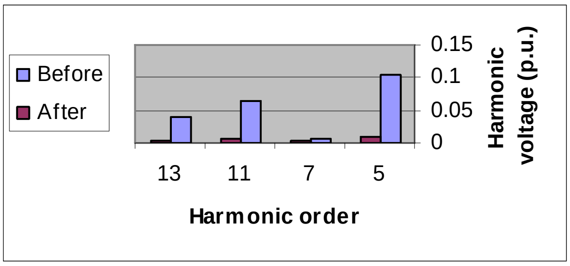

Fig (4) Harmonic voltages at bus 10 before/after APF installed.

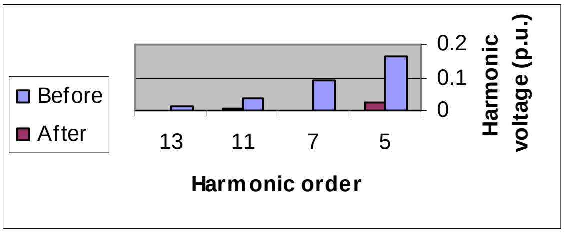

Fig (5) Harmonic voltages at bus 12 before/after APF installed.

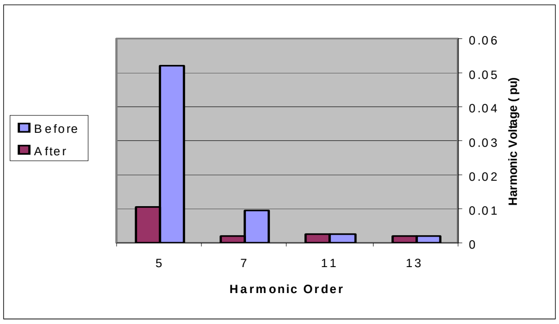

Fig (6) Harmonic voltages at bus 14 before/after APF installed.

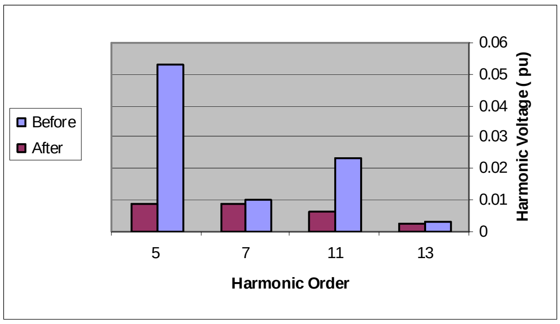

Fig (7) Harmonic voltages at bus 24 before/after APF installed.

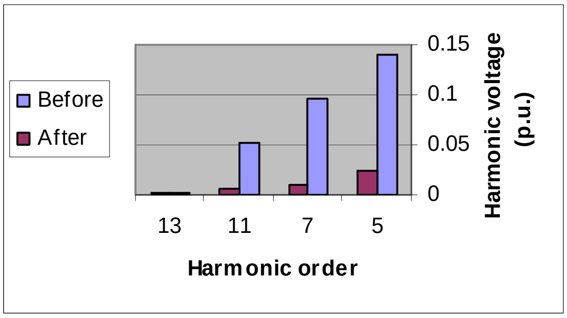

Fig (8) Harmonic voltages at bus 28 before/after APF installed.

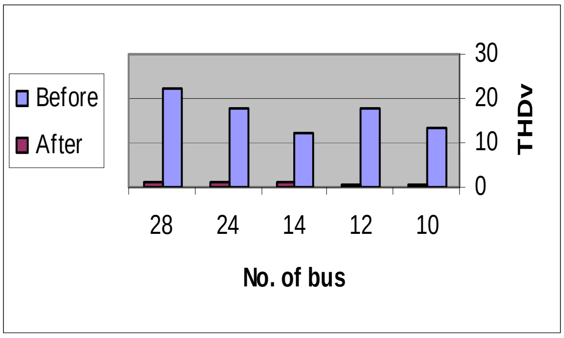

Fig (9) Comparison between THD (%) of voltage before/after the installation of the APF

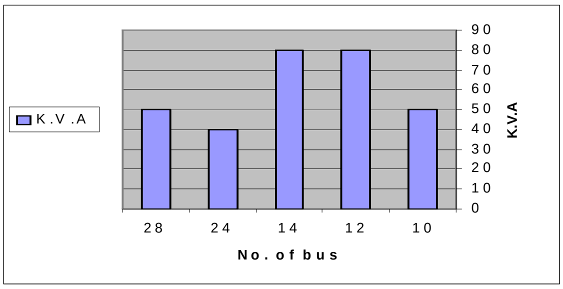

Fig (10[A])

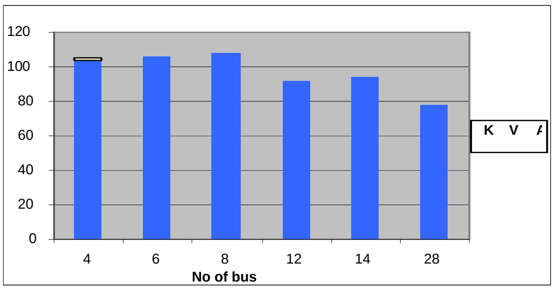

Fig (10[B])

Fig (10) ([A] , [B]) The APF Sizing at location of increased harmonics and location of harmonic sources

5- CONCLUSION

This paper presents the solution procedures required for applying multiple-APFs to reduce total harmonic distortion in a distribution system with harmonic sources. The objective function is to minimize the total injection currents of APFs while satisfying the maximum limits of each APF rating current and the IEEE-519 recommended limits of harmonic voltages and total harmonic distortions. The points having the higher harmonic distortions are the best locations to install the APF. The minimum injection currents of APF are determined using the solution procedure of Neural Network. The test results for a typical 28-bus distribution system show that Neural Network is reliable and efficient for the determination of locations and sizes of APFs. The harmonic voltages are greatly reduced by APFs injection currents at level 50% of injected harmonic current. The results show that THD is greatly decreased by using APF. The results show also that the size of APF at increased harmonics at 50% is less than corresponding value at sources of harmonics.

6- REFERENCES

[1] Gary W. Chang, Hung-lo Wag and Shw-Yung Cho, "Strategic Placement and Sizing of passive Filters in a power system for controlling voltage distortion", IEEE Trans. On power delivery, January 2004.

[2] Ferinin Barrero, Salvandor Martinez, Fenando Yeves, Francisco Mor, and Pedro M.Martine, "Universal and Reconfigurable to UPS Active Power Filter for line conditioning", IEEE Trans. On power delivery, Vol.18, No.1, January 2003.

[3] P. E. Gill, W. Murray, M. H. Wright,"Practical Optimization",Academic Press, New York, 1981.

[4] A. M. Riad, A. A Hassan, A. Hussam El-Din, K.Youssef, M.El-Haroon and T.A El-Ftouh, "Power system Harmonics prediction using Neural Network", 4th International Engineering Confernce, Mansoura-Sharm El-Shiekn, April 2004.

[5] M.A.S Masoum, A. Jafarian, M.Ladjecardi, E.F. Fuchs, and W.M. Grady, "Fuzzy Approach for optimal placement and sizing of capacitor Banks in the presence of Harmonics", IEEE Trans. On power delivery, Vol.12, No.2, April 2004.

[6] Leszek S. Czarnecki and Herbertl Ginn, "Effects of Damping on the performance of resonant harmonic Filters", IEEE Trans. On power delivery, Vol. 19, No.2, April 2004.

[7] A.A. El Magueed, M.E. El Said and T.A. El-Fetouh, "Locating and sizing of Active power filters to reduce harmonic distortion in power systems", MEPCON-98, Mansoura, Egypt, Vol.2, PP. 512-518.

[8] K. Chan, A. Kara, P. Daehler, J. Gvay and R. Tinggren"Innovative System Solutions for Power Quality Enhancement", Record of the 15th international CIRED' 99' Conference, university of Liege, Belgium, June 1999.