International Refereed Journal of Engineering and Science (IRJES)
ISSN (Online) 2319-183X, (Print) 2319-1821
Volume 3, Issue 11 (November 2014), PP. 126-131

Effects of Harmonics on Electrical Equipment and their Compensation by using Shunt Active Power filter

A.Santosh*, A Tejulal**
,Department Of EEE,Sreedattha Institute Of Engineering & Science*

ABSTRACT: This paper represents the analysis and simulation of a Shunt Active Power Filter (SAPF) using Matlab/Simulink for reducing the harmonics current produced by nonlinear loads. Due to increasing the usage of non linear load, the increase of the harmonics disturbance in the ac mains currents has became a major concern due to the unpleasant effects on all equipment mostly capacitors, transformers, and motors, causing additional losses, overvoltage, failure, overloading, malfunctioning and overheating and interferences. Shunt Active Power filter is used to compensating the harmonic non-linear loads harmonics by injecting equal but opposite harmonic compensating current which gives pure sinusoidal wave.
Keywords: Power System, Harmonic Distortion, Shunt Active Power Filter, Non-Linear Loads, Total Harmonic Distortion**.**

I. INTRODUCTION

Nowadays, the uses of non linear loads connected to electrical power systems consist of power electronic converters, saturated magnetic devices, arc discharge devices and rotating machines. Static power converters are the largest nonlinear loads and used in industries for many purposes, such as adjustable speed drives, uninterruptible power supply and electromechanical power supply. These devices are useful for ac dc, dc to ac, ac to ac, dc to dc conversion.

Non-linear loads draw current from the ac main that is not sinusoidal, thus resulting in the flow of harmonic currents in the ac power system that can cause adverse effects in ac power system equipment such as overheating, overloading, perturbation of sensitive control and electronic equipment, capacitor failure, communication interference, additional losses, motor vibration, excessive neutral currents, resonances problem and low power factor.

When reactive power compensation is used with these non linear loads in the form of power factor improvement capacitor, resonant condition can occur that may result high level of harmonic current and voltage when the resonance condition occurs at a harmonic associated with non linear loads. As a result, effective harmonic compensation from the system has become important for both the utilities and the users.

Power electronic control devices due to their inherent non linearity draw harmonic and reactive power form the supply mains. Due to wide use power electronic equipments with linear load, causes an increasing harmonics distortion in the ac mains currents. Harmonics component is a very serious and a harmful problem in Electric Power System. In three phase systems, they could also cause unbalance and excessive neutral currents.

The injected harmonics, reactive power burden and excessive neutral currents cause low system efficiency and poor power factor and also cause transients. These transients also would affect the voltage on distribution system. Excessive reactive power of non linear loads would increase generating capacity of generating stations and also increase losses in the transmission lines. Hence supply of reactive power at the load ends becomes important. Mostly non-linear loads based on solid-state converters are like UPS, SMPS etc. These Non-linear loads draw current that is not sinusoidal and thus create voltage drops in distribution conductors.

The main adverse effect of harmonic current and voltage on power system equipment such as overheating, overloading, perturbation of sensitive control and electronic equipment, capacitor failure, communication interferences, process problem, motor vibration, resonances problem and low power factor. As a result, effective harmonic suppression from the system has become very important for both the utilities and the users.

Active Power filtering constitutes one of the most effective proposed solutions. Active power filter (APF) can solve the problems of harmonic and reactive power at the same time. The quality of electric power is deteriorating mainly due to current and voltage harmonics, negative sequence components, voltage sag, swell, flicker, and interruption. Hysteresis control method is the most popular method in terms of quick current controllability, versatility and easy implementation.

Many theories have been developed for instantaneous current harmonics detection in active power filter such as FFT (fast Fourier technique) technique, neural network, instantaneous p-q theory(instantaneous reactive power theory), synchronous d-q reference frame theory or by using suitable analog or digital electronic filters separating successive harmonic components, PLL with fuzzy logic controller, neural network etc.

This paper basically deals with the modelling and simulation of shunt active filter with hysteresis current control method for harmonic compensation and power filtering.

2. SHUNT ACTIVE POWER FILTER

Figure 1 shows the basic configuration of a shunt active filter for harmonic current compensation of a specific load. Shunt active filter inject harmonic current equal and opposite in phase to harmonic current produced by load into line.

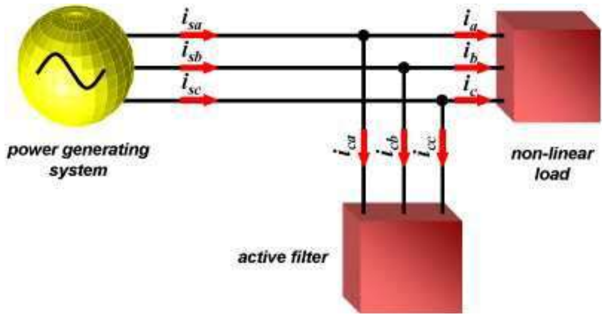

Fig. 1 Principle of Shunt Active Filter

II. INSTANTANEOUS REACTIVE POWER THEORY

This theory was proposed by (Akagi et al. 1983) for three-phase systems with or without neutral wire and it is valid for both steady state and transient conditions. This theory is also known as p-q theory. In this theory, instantaneous three-phase load voltages and current are transformed into α-β coordinates from a-b-c coordinates by using Clarke transformation as shown in equation (1) and (2) respectively.

$$\begin{bmatrix} v_\alpha \\ v_\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & -1/2 & -1/2 \\ 0 & \sqrt{3}/2 & -\sqrt{3}/2 \end{bmatrix} \begin{bmatrix} v_a \\ v_b \\ v_c \end{bmatrix} \text{........... (1)}$$

$$\begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & -1/2 & -1/2 \\ 0 & \sqrt{3}/2 & -\sqrt{3}/2 \end{bmatrix} \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} \text{............ (2)}$$

In the p-q theory, the voltages are always assumed to be sinusoidal; the power components must be computed by using sinusoidal voltages. In the α-β voltage system, the AC components of the voltage are eliminated in order to the IRPT to provide good performance.

The powers required to be compensated by the SAPF are calculated by using below equation:

$$\begin{bmatrix} p \\ q \end{bmatrix} = \begin{bmatrix} v_\alpha & v_\beta \\ -v_\beta & v_\alpha \end{bmatrix} \begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} \text{……….. (3)}$$

After adding the active power required to regulate the DC bus voltage, p_{-loss} to the alternative value of instantaneous real power. The reference currents $i_{s\alpha}^*$ and $i_{s\beta}^*$ are calculated by using equation (4):

$$\begin{bmatrix} i_{s\alpha}^* \\ i_{s\beta}^* \end{bmatrix} = \frac{1}{v_\alpha^2 + v_\beta^2} \begin{bmatrix} v_\alpha & -v_\beta \\ v_\beta & v_\alpha \end{bmatrix} \begin{bmatrix} p_0 + p_{-loss} \\ 0 \end{bmatrix} \text{..........(4)}$$

By deriving from above equations, the compensating reactive power can be identified. The compensating current can be derived by using the inverse clarke transformations as shown below:

$$\begin{bmatrix} i_{ca}^* \\ i_{cb}^* \\ i_{cc}^* \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & 0 \\ -1/2 & \sqrt{3}/2 \\ -1/2 & -\sqrt{3}/2 \end{bmatrix} \begin{bmatrix} i_{s\alpha}^* \\ i_{s\beta}^* \end{bmatrix} \text{……… (5)}$$

III. HARMONIC CURRENT CONTROL METHOD

The principles of hysteresis band current control can be seen in fig. 3. The difference between the reference value and the actual value of current will be directed to one comparator with a tolerance band. The controller generates the sinusoidal reference current waveform of required magnitude and frequency that is compared with the actual line current. If the current exceeds the upper limit of the band, the upper switch of the inverter limb is turned off and the lower switch is turned on. Thus, the current starts to decay.

If the current crosses the lower limit of the band, the lower switch of the inverter limb is turned off and the upper switch is turned on. So the current gets back into the band. Hence, the actual current is forced to track the reference current within the band as shown in fig. 3 and fig. 4.

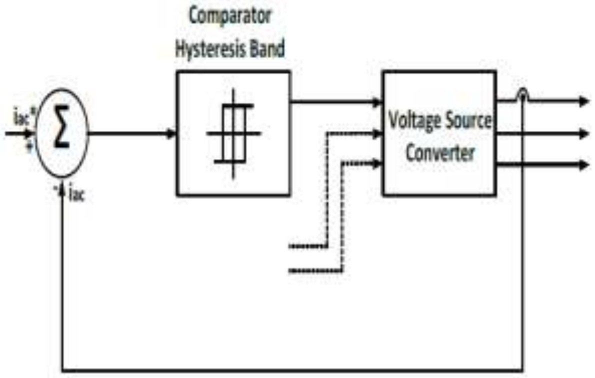

Fig.3 Basic principle of Hysteresis Current Control

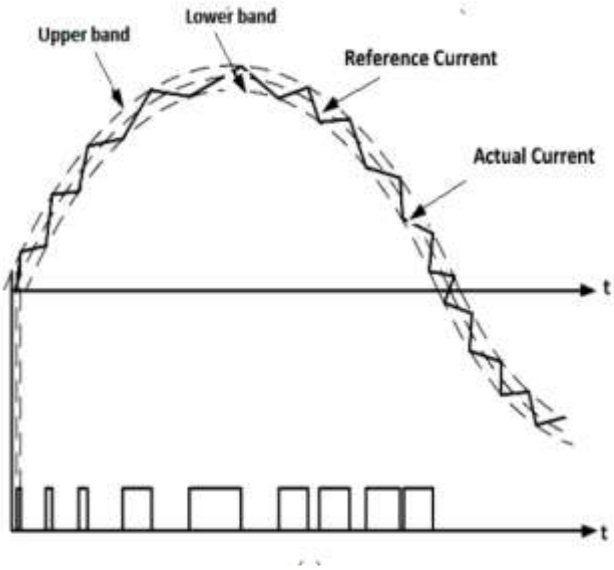

Fig.4 Hysteresis Band

IV. SIMULINK MODEL OF THE APF

The overall system model containing the power source, the shunt active power filter and the nonlinear loads is shown in fig.5.

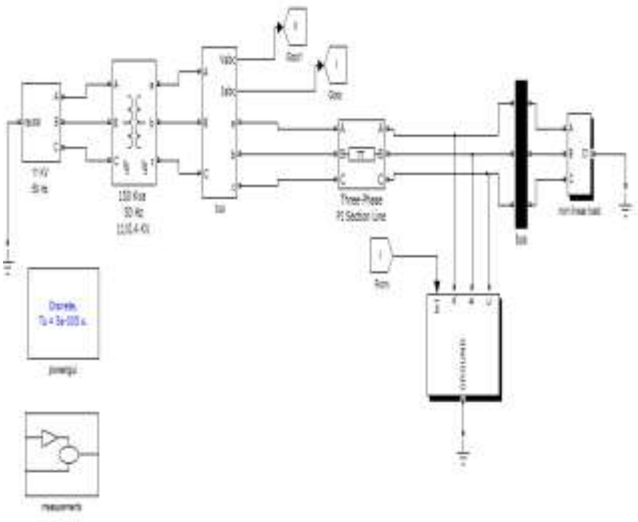

Fig. 5 system model with filter

The system model consists many components of the system are described below:
The power source, which was designed as a three-phase 11KV/50Hz voltage sources connected together in a Y configuration with neutral and a three phase RL branch.The single-phase nonlinear loads are containing a single-phase uncontrolled diode rectifier supplying a series RL load for phase A, a single-phase uncontrolled diode rectifier supplying a parallel RC load for phase B, a single-phase uncontrolled diode rectifier supplying a series RL loads for phase C.The PWM IGBT voltage source inverter, which contains a three-leg voltage source inverter with neutral clamped DC capacitors and the control scheme presented in fig. 6.

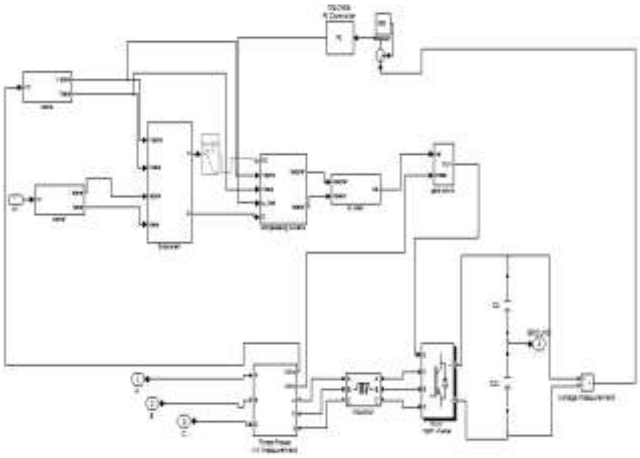

Fig.6 Model of APF

V. SIMULATION RESULT

The complete model of active power filter is shown in fig.6 and results were obtained by using MATLAB/Simulink Simpowersystem Toolbox software for a three phase neutral clamped APF compensating harmonics, reactive power produced by nonlinear loads. Fig. 7 shows the simulation results obtained in harmonic distortion analysis of the load current, for each phase with nonlinear load. Without APF, the total harmonic distortion (THD) is 30.25%. The highest harmonics are the 5th and 7th order, representing 13.62% and 8..52% of the fundamental respectively.

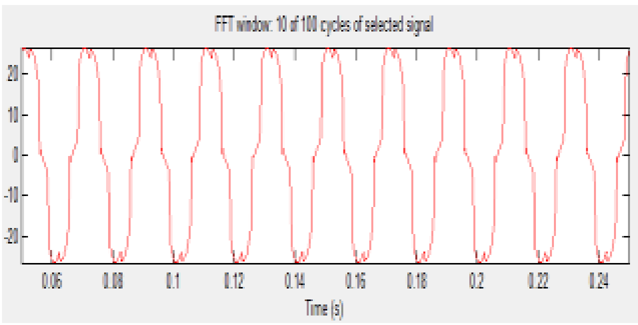

Fig. 7 Load Current (System without APF)

Fig. 8 shows the simulation result of the source current obtained using APF to compensate harmonics created by nonlinear load.

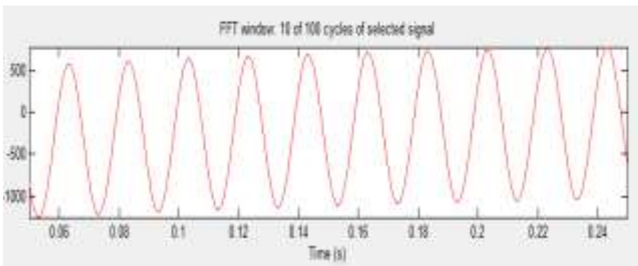

Fig.8 Source Current (System with APF)

By using APF, the THD of the source current is now 0.69% and magnitude of 5th and 7th harmonics are respectively 0.10% and 0.14% of the fundamental value, thus meeting the limit of harmonic standard of IEEE STD. 519-1992. The highest harmonics are still the 5th and 7th, but now they represent only 0.10% and 0.14% of the fundamental, which meets the harmonic standard of (IEEE STD. 519-1992).
Fig. 9 shows the waveform of active and reactive power of system with APF .

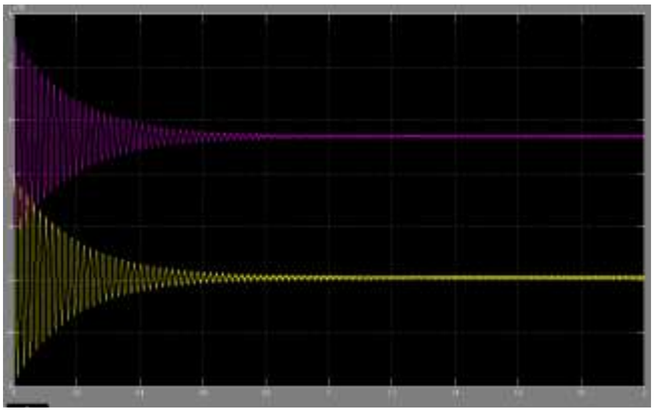

Fig.9 Active and Reactive Power (system with APF)

Fig. 9 shows that when connecting the APF to the system, the reactive power decreases below to Zero. This is proven that APF is a very effective tool to compensate reactive power.

VI. CONCLUSION

Simulation results using matlab/simulink shows that shunt active filter gives effective compensation of harmonics and reactive power. The THD is reduced to 0.69% which is very below than the harmonics limit 5% forced by the IEEE-519 standard.

REFERENCES

[1]. Akagi. H, 1996. "New Trends in Active Filters for Power Conditioning", IEEE Transaction on Industrial Applications, vol. 32, No 6, Dec., pp 1312-1322.
[2]. Akagi. H, 2006. "Modern active filter and traditional passive filters", Bulletin of the polish academy of sciences technical sciences vol.54.No.3
[3]. Ali Ajami and Seyed Hossein Hosseini, 2006. "Implementation of a Novel Control Strategy for Shunt Active Filter", ECTI Transactions on Electrical Eng., Electronics, And Communications Vol.4, No.1
[4]. Akagi, Hirofumi. Active Filters for Power Conditioning. In Timothy L.Skvarenina. The Power Electronics Handbook: Industrial Electronics Series. United State of America: CRC Press. Chap. 17:30-63. 2002.
[5]. Peng, F. Z., Akagi, H. and Nabae, A. A Novel Harmonics Power Filter.IEEE Transactions on Power Electronics Specialists Conference. April 11-14. PESC '88 Record: IEEE. 1988. 1151-1159.
[6]. Grady, W. M., Samotyi, M. J. and Noyola, A. H. Survey of Active Line Conditioning Methodologies. IEEE Transactions on Power Delivery.1990. 5 (3): 1536-1542.
[7]. C. Sankaran, "Power Quality", CRC Press, 2002.
[8]. H. Akagi, E. Hirokazu Watanabe and M. Aredes, "Instantaneous power theory and applications to power conditioning", IEEE-press, 2007.
[9]. S. Buso, L. Malesani and P. Mattavelli, "Comparison of current control techniques for active filter applications," IEEE Trans. Ind. Electron., vol. 45, no. 5, pp. 722-729, Oct. 1998.
[10]. Karuppanan P, Kamala kanta mahapatra, Jeyaraman K and Jeraldine Viji, "Fryze power theory with adaptive hcc based active power line conditioners". ICPS, Dec 22-24, 2011.
[11]. Bhakti I. Chaughule, Amit L. Nehete, Rupali Shinde, "Reduction in Harmonic Distribution of the system using active power filter in MATLAB/SIMULINK", IJCER, vol. 03, issue, 6, june 2013.
[12]. George Adam, Alina G. Stan (Baciu) and Gheorghe Livint, "A MATLAB-SIMULINK approach to shunt active power filters", Technical University of Iasi 700050, Iasi, Romania.
[13]. Amit Gupta , Shivani Tiwari , Palash Selot, "Reduction Of Harmonics By Using Active Harmonic Filter", International Journal of Engineering Research & Technology (IJERT) Vol. 1 Issue 9, November- 2012 ISSN: 2278-0181.

[14]. Patel Pratikkumar T., P. L. Kamani, A. L. Vaghamshi, “Simulation of Shunt Active Filter for Compensation of Harmonics and Reactive Power”, International Journal Of Darshan Institute On Engineering Research & Emerging Technologies Vol. 2, No. 2, 2013