Analysis of Power Quality Improvement Using Active Shunt Filters

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Abstract:

Electricity consumption has been increasing so rapidly once in line with the development of the country to achieve its status as the industrial countries. The paper shows the method of improving power quality using shunt active filters which are used in reduction of total harmonics distortion .Paper shows a comparison of reduction in harmonics with and without shunt active filter for nonlinear loads. The analysis is done in MATLAB /SIMULINK. FFT analysis is also carried out and the model successfully reduces the harmonics.

Keywords: Power System, Harmonic Distortion, Shunt Active Power Filter, Non-Linear Loads, Total Harmonic Distortion.

1 INTRODUCTION

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Power quality is important in the distribution system. To provide power supply with good quality is not easy because it depends on the type of load used. Phenomenon that causes an interruption in the electrical system such as overvoltage, voltage sags, voltage surges and harmonic [3]. Harmonic distortion problem has existed in the power system for a long time. it causes a wave of the line current and voltage in the power system to be distorted. In the past, discussions about the existence of harmonics have been discussed. However, at that time, the impact and influence of harmonic distortion is slightly lower than at present, where it only covers in the delta grounded w-ye connection of the transformer and also in some design of power transformer [4]. At present, the creation of modern equipment, especially electronic equipment and also the increased use of non-linear loads in industry has produced harmonic distortion, harmonic distortion in electrical systems became more serious because the use of electronic equipment are among the largest contributors to the formation of harmonic distortion. In recent years, with the increasing use of adjustable speed drives, arc furnace, controlled and uncontrolled rectifiers and other nonlinear loads, the power distribution system is polluted with harmonics. Such harmonics not only create more voltage and current stress but also are responsible for Electromagnetic interference, more losses, capacitor failure due to overloading, harmonic resonance, etc. Introduction of strict legislation such as IEEE519 [5] limits the maximum amount of harmonics (THD-Total Harmonic Distortion) that a supply system can tolerate for a particular type of load. Therefore, use of active or passive type filters is essential. To solve the current harmonic related problems, passive filters connected in several circuit configurations present a low cost solution. However passive filter implementations to filter out the current harmonics have the following disadvantages:

- Possibility of resonances with the source Impedance
- Supply impedance dependent system performance
- Fixed compensation

In order to diminish the preceding disadvantages of the passive filters, active power filters(APF) have been worked on and developed in recent years. Elimination of the current harmonics, reactive power compensation and voltage regulation are the main functions of active filters for the improvement of power quality. APFs have a number of advantages over the passive filters. First of all, they can suppress not only the supply current harmonics, but also the reactive currents. Moreover, unlike passive filters, they do not cause harmful resonances with the power distribution systems. Consequently, the APF performances are independent of the power distribution system properties.

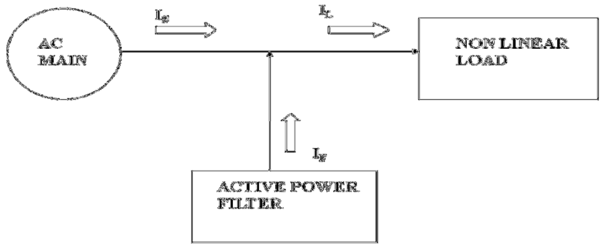

Fig 1. Active power filter with non-linear load**.**

On the other hand, APFs have some drawbacks. APF necessitates fast switching of high currents in the power circuit resulting high frequency noise that may cause an electromagnetic interference (EMI) in the power distribution system.

2. INSTANTANEOUS ACTIVE AND REACTIVE POWER THEORY

This method offers a good precision and ease of implementation. Its main disadvantage is that it can't be applied in the case of unbalanced grid voltage [13]. In this case, A Self Tuning Filter (STF) can be used after the measurement of the grid voltages to extract the fundamental balanced three phase voltage components of the distorted unbalanced one. This transformation may be viewed as a projection of the three-phase quantities onto a stationary two-axis reference frame. The Clarke transformation for the voltage variables is given by [14]:

$$\begin{bmatrix} u_\alpha \\ u_\beta \\ u_0 \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \\ \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \end{bmatrix} \begin{bmatrix} u_a \\ u_b \\ u_c \end{bmatrix}$$

………. (1)

Similarly, this transform can be applied on the distorted load currents to give

$$\begin{bmatrix} i_{l\alpha} \\ i_{l\beta} \\ i_{l0} \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \\ \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \end{bmatrix} \begin{bmatrix} i_{la} \\ i_{lb} \\ i_{lc} \end{bmatrix} \quad \text{……… (2)}$$

The instantaneous active power *p(t)* can be defined by:

$$p(t) = u_a\, i_{la} + u_b\, i_{lb} + u_c\, i_{lc} \quad \text{….. (3)}$$

This expression is given in the stationary frame by:

$$p(t) = u_\alpha\, i_{l\alpha} + u_\beta\, i_{l\beta}$$
$$p_0(t) = u_0\, i_{l0} \quad \text{…….(4)}$$

Where, *p(t)* is the instantaneous active power, *$p_0(t)$* is the instantaneous homo-polar sequence power. Similarly the instantaneous reactive power can be given by:

$$q(t) = -\frac{1}{\sqrt{3}}[(u_a - u_b)i_{lc} + (u_b - u_c)i_{la} + (u_c - u_a)i_{lb} = u_\alpha\, i_{l\beta} + u_\beta\, i_{l\alpha} \quad \text{……(5)}$$

From eqns. 4 and 5, the instantaneous active and reactive power can be given in matrix form by:

$$\begin{bmatrix} p \\ q \end{bmatrix} = \begin{bmatrix} u_\alpha & u_\beta \\ u_\beta & u_\alpha \end{bmatrix} \begin{bmatrix} i_{l\alpha} \\ i_{l\beta} \end{bmatrix} \quad \text{......(6)}$$

In order to separate the harmonics from the fundamental of the load currents, it is sufficient to separate the alternating term of the instantaneous power from the direct.After the separation of the direct and alternating terms of instantaneous power, the harmonic components of the load currents can be given using the inverse of equation (3.6) which gives:

$$\begin{bmatrix} i^*_{s\alpha} \\ i^*_{s\beta} \end{bmatrix} = \frac{1}{v_\alpha^2 + v_\beta^2} \cdots \begin{bmatrix} v_\alpha & -v_\beta \\ v_\beta & v_\alpha \end{bmatrix} \text{…….(7)}$$

The inverse Clarke transform can be used as follow:

$$\begin{bmatrix} i^*_{fa} \\ i^*_{fb} \\ i^*_{fc} \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & 0 \\ -1/2 & \sqrt{3}/2 \\ -1/2 & -\sqrt{3}/2 \end{bmatrix} \begin{bmatrix} i_{l\alpha} \\ i_{l\beta} \end{bmatrix} \quad \text{….(8)}$$

Figure presents the principle of the active and reactive instantaneous power.

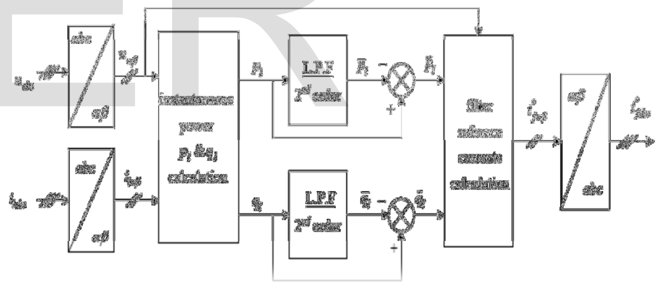

Fig. 3 Principle of instantaneous active and reactive power theory.

3. MODELLING OF SHUNT ACTIVE POWER FILTER

The simulation model of system without SAPF is shown in fig 4.1 and the simulation model of system with SAPF is shown in fig 3 which shunt active power filter (SAPF) is connected across the non linear load. The control of Shunt active power filter (SAPF) is divided in two parts. First part is used for the harmonic current extraction. There are instantaneous active and reactive power method (p-q method). Second part is used for the generation of gate pulse to control of voltage source inverter. Hysteresis Current Control Method is used.

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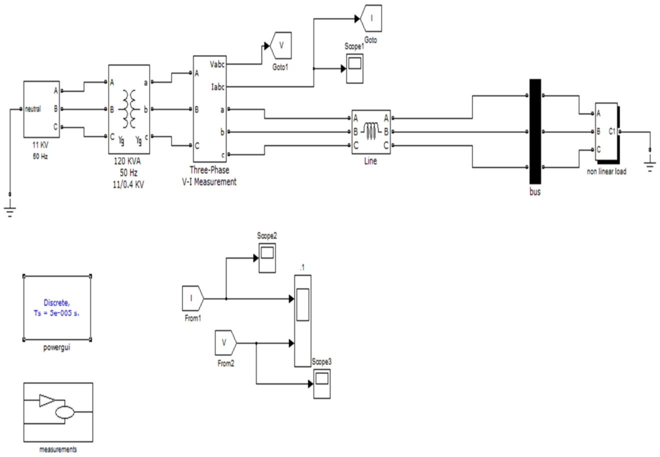

Fig.4. Simulation model of system without SAPF

3.1.1 Simulation Result

shows source current without shunt active filter. Due to the presence of the non linear load, so the current waveform is in distorted manner. The current is taken along the Y-axis and time is taken along the X-axis.

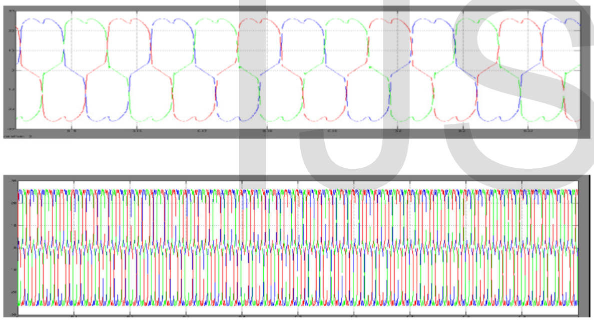

Fig 5. Voltage and Current waveform without filter.

3.2 Simulation Model of System With Shunt Active Power Filter

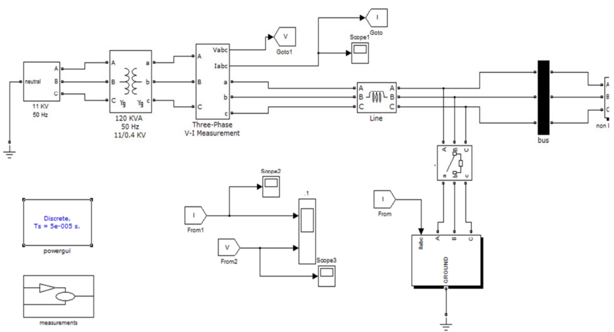

Fig .6 Simulation model of system with SAPF.

3.2.1 Simulation Results

A number of simulations have been performed to check the working of the shunt active power filter under various non-linear loadings (w.r.t connection of the loads at the PCC) and non ideal supply. The analysis of the results show that the working of the active filter is very satisfied to compensate the harmonics and reactive power even under unbalanced and distorted conditions of distribution supply.

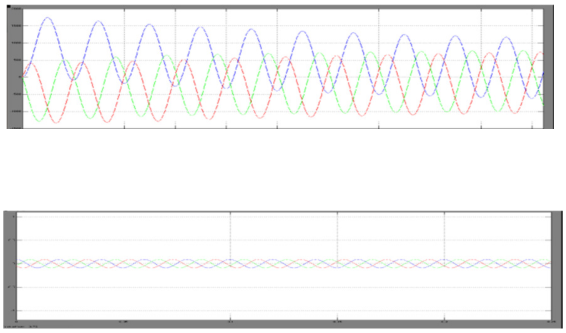

Fig 7. Voltage and current waveform with SAPF

4. FFT ANALYSIS

The following fig.12 shows the THD analysis of source current without SAF. THD is found to be 20.49% respectively due to nonlinear load which creates harmonics in the three phase system. In order to reduce the THD the proposed system is implemented.

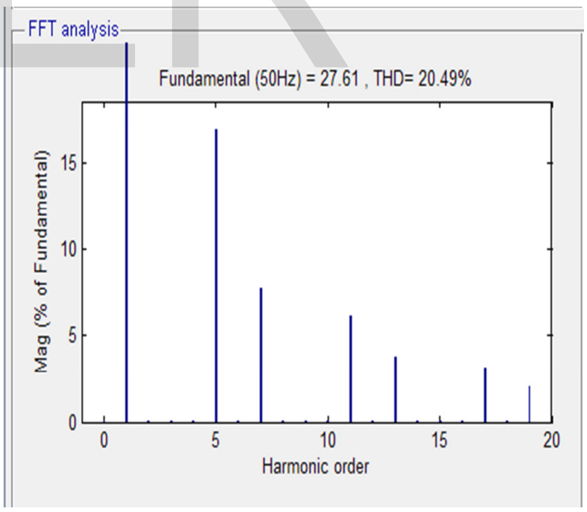

Fig 8. FFT analysis without SAPF

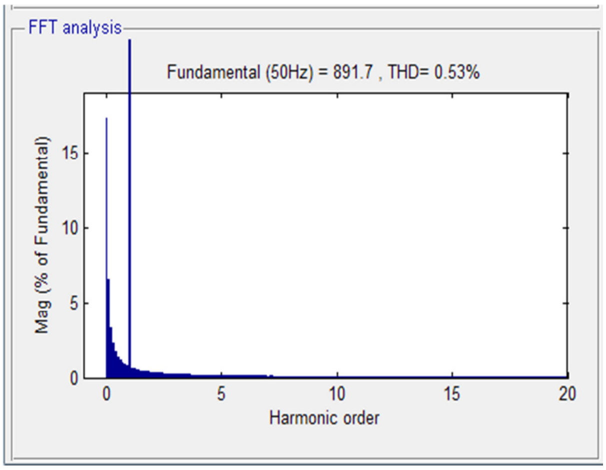

Fig 9. FFT analysis with SAPF.

5. SIMULATION RESULT

The Total harmonic distortion (THD) spectrum in the system without filter is shown in figure 8 which indicate a THD of 20.49% and THD with active filter is observed to be 0.53%. which is with in allowable limit.

6. CONCLUSION

The three phase three wire shunt active filter with controller based on instantaneous active and reactive power theory to compensate the problems of the harmonics and reactive power which are encountered from power electronic non-linear loads is simulated in MATLAB/SIMULINK. The performance of the shunt active power filter is investigated under different scenarios. It is investigated that the p-q theory based active filter manages to compensate the harmonics and reactive power of the power distribution network even under unbalanced and distorted supply voltages. The active power filter is able to reduce the THD in source current at a level well below the defined standards specified by power quality standards. The THD in source current after the active filtering is not exactly zero. It is because internal switching of the compensator itself generates some harmonics .Thus SAPF is proved to be effective to keep harmonic content in power lines with in permissible limit

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