Improvement of Power Quality Using IRP-Theory Base Shunt Active Power Filter

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Abstract - *This paper deals with the performance and evaluation of shunt active power filter(SAPF) for power quality improvement. Power quality complications can be take up using SAPF. A Simulation model of the three-phase shunt active filter had been implemented based on IRP theory The system where we can observe the considerable Improvement in the source current in the norms of total Harmonic distortion (THD) of source current. We can also Observe the correction in the). Properties are restored in the terms of source voltage and Source current are in phase by this implementation. The performance of the SAPF by using the IRP theory for nonlinear load is demonstrated with the MATLAB simulation results.*

***Key Words;* shunt active power filter (SAPF), Instantaneous reactive power (IRP), Point of common coupling (PCC), power factor (PF)**

1. INTRODUCTION

These days, because of the progressive technology, power electronic devices have wide application. These power electronic devices had encroached deeply into the domestic and industrial uses, but because of them we come across the problem of power quality. This problem is caused due to the fact that these power electronic devices act as non-linear loads. These non-linear loads disturb the supply voltage waveform which pass the system lines results in supply currents rich in high degree of harmonics and thus reduces the input power factor. Uncontrolled bridge rectifier and phase controlled converters are the main sources of the non-linear systems. Thus the improved power electronic devices used in speed controlled motor drives, rectifier, and thyristor, personal Desktops and uninterruptible power supplies (UPSs) are the large source of distortion in the voltages at the point of common coupling (PCC) and the current in the lines of the power system. They results in THD of source currents much greater than 5% permissible limit as set by IEEE 519 standard.

The system where we can observe the considerable Improvement in the source current in the norms of total Harmonic distortion (THD) of source current. We can also Observe the correction in the power factor (PF). Properties are restored in the terms of source voltage and Source current are in phase by this implementation. The performance of the SAPF by using the IRP theory for nonlinear load is demonstrated with the MATLAB simulation results is carried out using instantaneous reactive power (IRP) theory for compensation of the reactive power, unbalance, reducing total harmonic distortion (T.H.D) and improving power factor of the system.

2. THE PROPOSED SYSTEM

A distribution feeder connected to nonlinear load is shown in the below Fig. 1. Working performance of the wind energy base SAPF using instantaneous reactive power theory (IRP) is analyzed by the modeling system shown in Fig.1 in MATLAB Simulink tool.

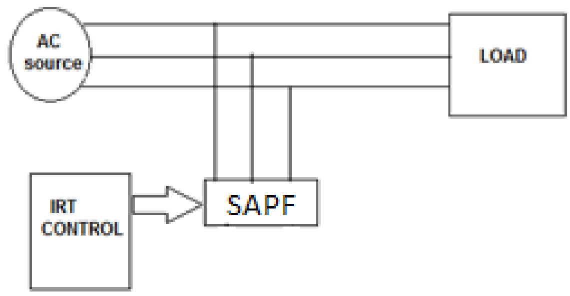

Fig-1: The proposed system

3. RELATION BETWEEN THD & POWER FACTOR (PF)

$$pf = \frac{P}{S} = \frac{dpf}{\sqrt{1+THD^2}}$$

From the above equation, if Percentage THD is more, proportionally power factor decreases. Therefore THD is inversely proportional to power factor which is illustrated in figure 2.

For the first waveform in the figure THD is 80% and respective power factor is 0.78. For the seconded waveform the THD is 37% and respective power factor is 0.93. It is observed that by reducing THD in the system, the power factor is improved.

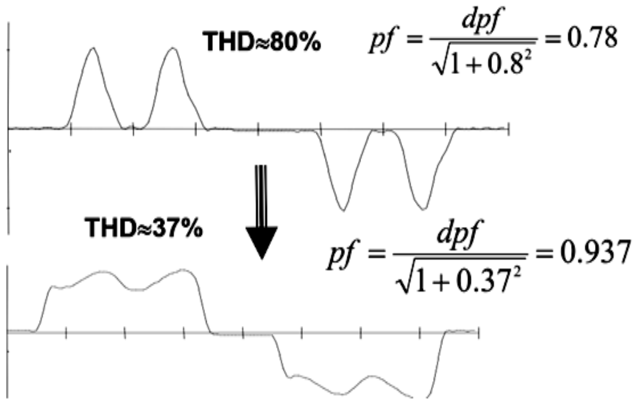

Fig-2: Relation THD and power factor (pf)

4 INSTANTANEOUS REACTIVE POWER THEORY

The P-Q theory was introduced by H.Akaqi in 1983.The speed response of converter is used and they generate reactive power and harmonic component to compensate for harmonics or reactive power. The conventional approaches to the analysis of power are not sufficient in terms of RMS or average value of variables. Time domain analysis has evolved a new manner to analyses and understand the energy flow in nonlinear circuit. The p-q theory is based on the set of instantaneous power defined in time domain. No restrictions are imposed on the voltage or current waveform and it can be applied on the three phase system with or without neutral. The p-q theory uses Clarks' transformation to converter from a-b-c coordinates to α-β-0 coordinates for both three phase currents and voltages and then defines instantaneous powers on these coordinates. The p-q theory uses Clarke transformation or α-β-0 transformation which consists of a real matrix that transforms three phase components into α-β-0 stationary reference frames. In this method reference current is generated from the instantaneous active and reactive power of the non-linear load.

4.1 CLARKE TRANSFORMATION

The three phase current or voltage waveforms from *a-b-c* coordinates system transforms to α-β-*0* coordinates. It corresponds to an algebraic transformation, known as *Clarke* transformation, where coordinates α-β are orthogonal to each other, and coordinate corresponds to the zero-sequence component.

$$\begin{bmatrix} V_\alpha \\ V_\beta \\ V_o \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & \frac{-\sqrt{3}}{2} \\ \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \end{bmatrix} \begin{bmatrix} V_{ca} \\ V_{cb} \\ V_{cc} \end{bmatrix}$$

$$\begin{bmatrix} I_\alpha \\ I_\beta \\ I_o \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & \frac{-\sqrt{3}}{2} \\ \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \end{bmatrix} \begin{bmatrix} I_{ca} \\ I_{cb} \\ I_{cc} \end{bmatrix}$$

4.2 INVERSE CLARKE TRANSFORMATION

The α-β-*0* coordinate system is again transformed to three phase *a-b-c* coordinates system. This corresponds to an algebraic transformation, known as Inverse Clarke transformation.

$$\begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & 0 & \frac{1}{\sqrt{2}} \\ -\frac{1}{2} & \frac{\sqrt{3}}{2} & \frac{1}{\sqrt{2}} \\ -\frac{1}{2} & -\frac{\sqrt{3}}{2} & \frac{1}{\sqrt{2}} \end{bmatrix} \begin{bmatrix} i_\alpha \\ i_\beta \\ i_o \end{bmatrix}$$

$$\begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & 0 & \frac{1}{\sqrt{2}} \\ -\frac{1}{2} & \frac{\sqrt{3}}{2} & \frac{1}{\sqrt{2}} \\ -\frac{1}{2} & -\frac{\sqrt{3}}{2} & \frac{1}{\sqrt{2}} \end{bmatrix} \begin{bmatrix} V_\alpha \\ V_\beta \\ V_o \end{bmatrix}$$

4.3 INSTANTANEOUS POWER

The conventional instantaneous power on the three phase circuit can be defined as

Where p is equal to the conventional equation

$$p = v_\alpha i_\alpha + v_\beta i_\beta$$

The Instantaneous Reactive power q is defined as

$$q = v_\alpha i_\beta - v_\beta i_\alpha$$

The Instantaneous active power p and reactive power q are defined as

$$\begin{bmatrix} p \\ q \end{bmatrix} = \begin{bmatrix} v_\alpha & v_\beta \\ -v_\beta & v_\alpha \end{bmatrix} \begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix}$$

P and q can resolved a mean value and an alternating value.

$$p = \overline{p} + \tilde{p} \qquad q = \overline{q} + \tilde{q}$$

$\overline{p}$ And $\overline{q}$ are created from positive sequence components of the load current and $\overline{p}$ and $\overline{q}$ from the harmonic components of load current.

The oscillating components of p and the entire q should be supplied by the active power filter. So the required compensating currents can be calculated as

4.4 CALCULATION OF REFERENCE COMPENSATING CURRENTS I_{CA*}, I_{CB*}, I_{CC*}

Compensating current $i_{c\alpha}$ and $i_{c\beta}$ is obtain by the Instantaneous active power p and reactive power q

$$\begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} = \begin{bmatrix} v_\alpha & v_\beta \\ -v_\beta & v_\alpha \end{bmatrix}^{-1} \begin{bmatrix} P \\ q \end{bmatrix}$$

$$\begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} = \frac{1}{v_\alpha^2 + v_\beta^2} \begin{bmatrix} v_\alpha & -v_\beta \\ v_\beta & v_\alpha \end{bmatrix} \begin{bmatrix} \overline{P} \\ q \end{bmatrix}$$

Instantaneous active current on the α axis $i_{c\alpha*}$

$$i_{c\alpha*} = \frac{v_\alpha}{v_\alpha^2 + v_\beta^2}\overline{p} - \frac{v_\beta}{v_\alpha^2 + v_\beta^2} q$$

Instantaneous reactive current on the β axis $i_{c\beta*}$

$$i_{c\beta*} = \frac{v_\beta}{v_\alpha^2 + v_\beta^2}\overline{p} + \frac{v_\alpha}{v_\alpha^2 + v_\beta^2} q$$

The Instantaneous reactive currents $i_{c\alpha*}$, $i_{c\beta*}$ are transformation into the three phase reference compensating currents i_{ca*}, i_{cb*}, i_{cc*}

$$\begin{bmatrix} i_{ca*} \\ i_{cb*} \\ i_{cc*} \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & 0 \\ -\frac{1}{2} & \frac{\sqrt{3}}{2} \\ -\frac{1}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} i_{c\alpha*} \\ i_{c\beta*} \end{bmatrix}$$

The three phase reference compensating currents i_{ca*},i_{cb*},i_{cc*} are given to hysteresis current controller

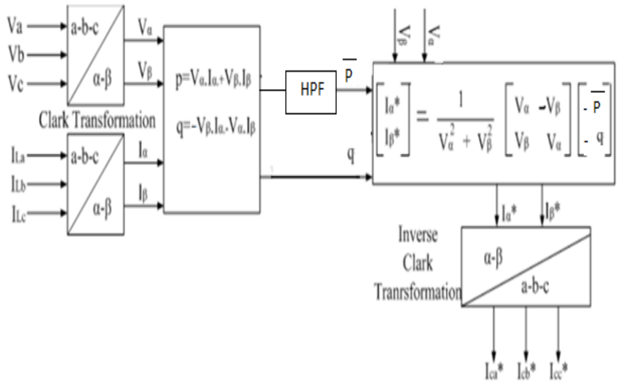

Fig-3: calculation of reference compensating currents i_{ca*},i_{cb*},i_{cc*}

Harmonics are generated by nonlinear loads and are injected into power system. The calculated compensating three phase currents using instantaneous reactive power theory i_{ca*},i_{cb*},i_{cc*} are used as reference currents for hysteresis current controller. The Hysteresis current controller will generate pulses given to the controller switches. Finally controller will generate compensating currents i_{ca*},i_{cb*},i_{cc*} and injected into power system.

Therefore reactive power demand in the power system decreases. By the way, with the reduction in reactive power demand, the Harmonics in the system are reduced. The value of THD is decreased and power factor is improved

5. SIMULATION RESULTS

Case1: with out SAPF

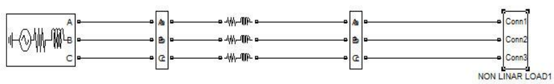

Fig-4: without SAPF

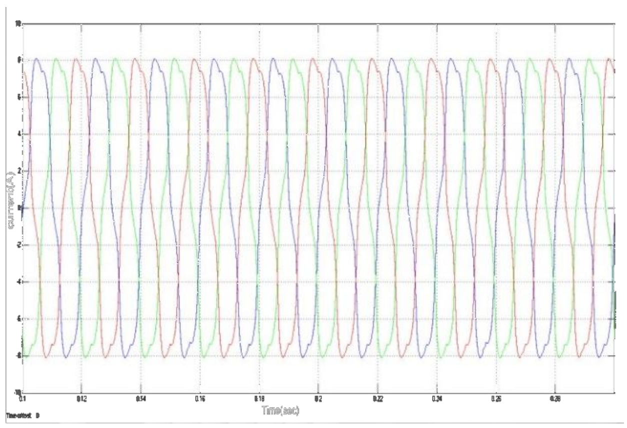

Fig-5: current wave form at the source without SAPF

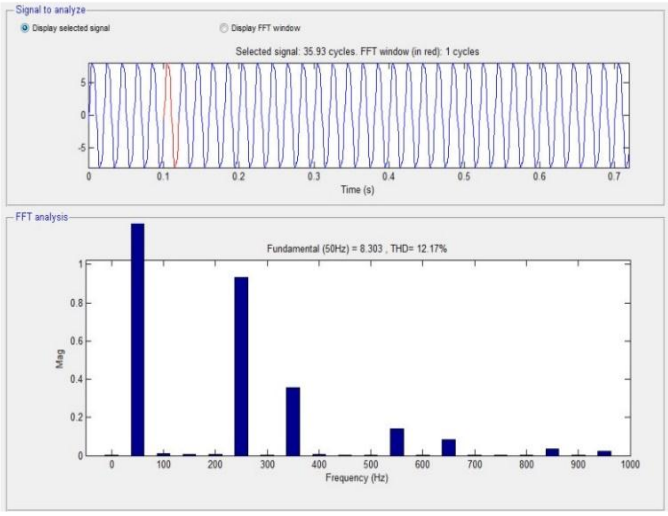

Fig-6: FFT analysis for current wave form at the source without SAPF

Case 2 with SAPF

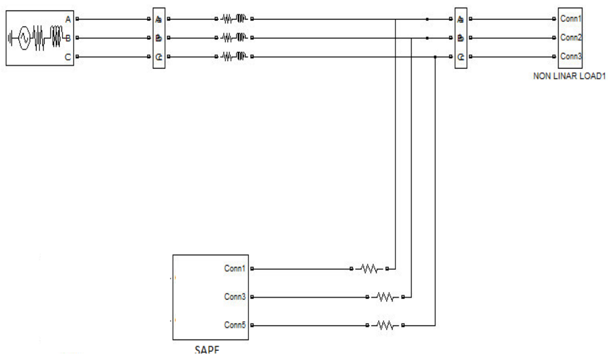

Fig-7: with SAPF

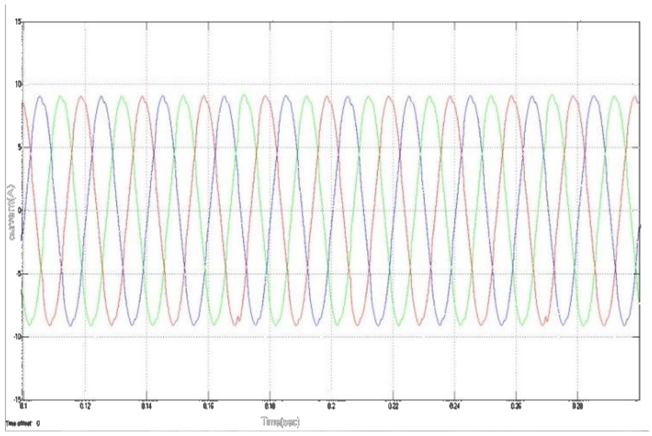

Fig-8: current wave form at the source with SAPF

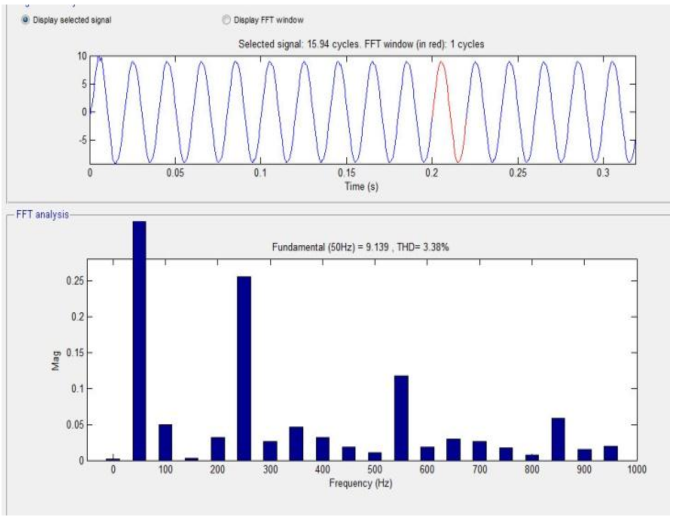

Fig-9: FFT analysis for current wave form at the source with SAPF

6. Results

Table: 5.1 comparison of results with and with out

Power quality issues	Without SAPF	With SAPF
THD –I (current)	12.17	3.38
REACTIVE POWER	801	256.7
POWER FACTOR	0.91	0.99

7. CONCLUSION

In this system SAPF will improve power quality at point of common coupling. Custom power devices can be used for power quality improvement in the distribution system, IRP theory for controlling the SAPF reduces harmonic components are reduced. Hence Power factor of the system is improved and maintained equal to unity.

8. REFERENCE

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