Sinusoidal Current Control Strategy for Shunt Active Filter for Mitigation of Harmonics from Non Linear Loads

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Abstract— In recent decade the availability of power is replaced by quality of power for the optimal operation of the instruments which are to be used. Day by day uses of non linear loads like arc furnaces power electronics based drive are widely used in most industries which produces the harmonics in the system and to eliminate this harmonics SAPF (shunt active power filter) is used. This paper presents the two control strategies for this shunt active filter based on p-q theory are constant instantaneous power control strategy and sinusoidal current control strategy. MATLAB SIMULINK® model is developed for these two strategies is represented here with FFT analysis which clearly shows the performance of this SAPF to improve harmonics.

Keywords: - Active Filter, Harmonics, p-q theory,

I. INTRODUCTION

Shunt active filters generally consist of two distinct main blocks:

1) PWM converter (power processing)
2) The active filter controller (signal processing)

The PWM converter is responsible for power processing in synthesizing the compensating current that should be drawn from the power system. The active filter controller is responsible for signal processing in determining in real time the instantaneous compensating current references, which are continuously passed to the PWM converter. Fig shows the basic configuration of a shunt active filter for harmonic current compensation of a specific load. It consists of a voltage-fed converter with a PWM current controller and an active filter controller that realizes an almost instantaneous control algorithm. The shunt active filter controller works in a closed-loop manner continuously sensing the load current, and calculating the instantaneous values of the compensating current reference for the PWM converter. In an ideal case, the PWM converter may be considered as a linear power amplifier, where the compensating current tracks correctly its reference.

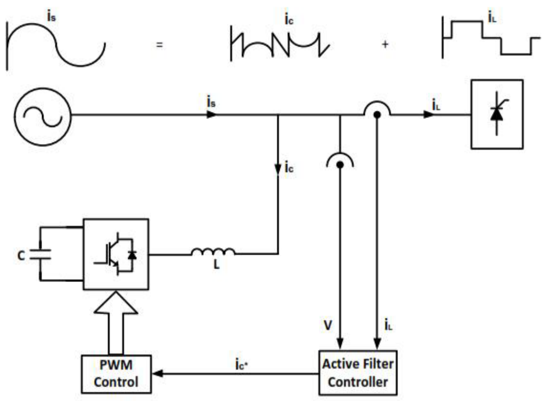

Fig. 1: showing basic configuration of SAPF

2) The active filter controller for current minimization. The control algorithm implemented in the controller of the shunt active filter determines the compensation characteristics of the shunt active filter. There are many ways to design a control algorithm for active filtering.

The controller design is particularly difficult if the shunt active filter is applied in power Systems in which the supply voltage itself has been already distorted and/or unbalanced. The General expressions of the p-q Theory show that it is impossible to compensate the load current and force the compensated source current to satisfy simultaneously the following three "optimal" compensation characteristics if the power system contains voltage harmonics and/or imbalances at the fundamental frequency:

1) Draw a constant instantaneous active power from the source
2) Draw a sinusoidal current from the source
3) Draw the minimum rms value of the source current that transports the same energy to the load with minimum losses along the transmission line. This means that the source has current waveform proportional to the corresponding voltages.

Under three-phase sinusoidal balanced voltages, it is possible to satisfy simultaneously the three optimal compensation characteristics given below. However, under nonsinusoidal and/or unbalanced system voltages, the shunt active filter can compensate load currents to guarantee only one optimal compensation characteristic. Therefore, a choice must be made before designing the controller of a shunt active filter. This is the reason to derive three Different control strategies:

1) Constant instantaneous power control strategy
2) Sinusoidal current control strategy
3) Generalized Fryze current control strategy

Under sinusoidal, balanced system voltages, the three control strategies can produce the same results. However, under non sinusoidal and/or unbalanced system voltages, each control strategy guarantees its respective compensation characteristic.

II. CONSTANT INSTANTANEOUS POWER CONTROL STRATEGY

The constant power compensation control strategy for shunt active filter was first strategy which was developed on p-q theory and it is defined in time domain. It can be applied within or without a neutral wire for voltage and current waveforms and one more advantage of this theory is that it can also be applicable to steady state as well as transient state. The p-q theory transform voltage and current from abc to αβ0 coordinates and then it defines Instantaneous power based on this and so this system uses three phase system as a unit.

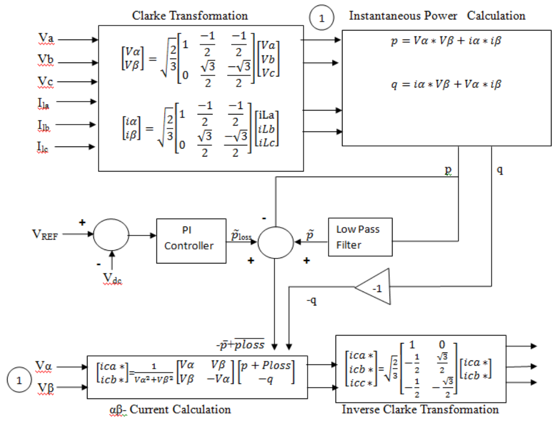

Fig. 2:

Here the three phase system without neutral wire is being considered hence there will not be any zero sequence power or we can say zero sequence power is zero in case of instantaneous power control strategy. So that the shunt active filter should supply the oscillating portion of active load current. This may be give as,

Oscillating part of instantaneous active current on α axis

$$i\alpha\tilde{p} = \frac{V\alpha}{V\alpha^2+V\beta^2}(-\tilde{p})$$

Oscillating part of instantaneous active current on β axis

$$i\beta\tilde{p} = \frac{V\beta}{V\alpha^2+V\beta^2}(-\tilde{p})$$

Here the negative sign of power indicates the direction of current. The shunt active filter compensates the oscillating real and imaginary power of the load then it draws only a constant real power from the power system, so constant instantaneous power control strategy provides optimal compensation under non sinusoidal or unbalance system loads from power flow point of view. It is here suggested that the power of the non linear load should be continuously measured and it is instantaneously separated in to its average ($\bar{p}$) and oscillating parts ($\tilde{p}$) and the oscillating power $\tilde{p} = p - \bar{p}$. In real time implementation the separation of $\bar{p}$ and $\tilde{p}$ from the p is done through a low pass filter and due to spectral component included in $\tilde{p}$ is to be compensated so the lower cut off frequency is being required. But the disadvantage of this low pass filter is that it introduces a unavoidable time delay during transient situations. Here the fifth order Butterworth low pass filter of cut off frequency 20Hz to 100 Hz is being used in this case of instantaneous power control strategy.

III. SINUSOIDAL CURRENT CONTROL STRATEGY

This sinusoidal current control strategy is a method in which the current of the nonlinear load is force the compensated current to become sinusoidal by means of active filter. So that we cannot achieve the both condition to have sinusoidal and balanced current at same so we have to decide that if we want constant power being drawn from the source than we are suppose to use the instantaneous power control strategy and if we want a sinusoidal wave form of source than we have to choose the sinusoidal current control strategy. In order to make the compensated current sinusoidal the filter should compensate all the harmonics that are present in the current and in the positive sequence current (İ+1) of it .Hence the positive sequence detector is being required in the filter.

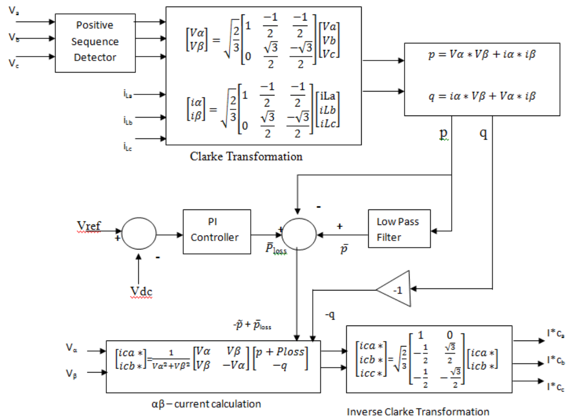

Fig. 3: sinusoidal current control strategy

Positive sequence detector: The phase voltage Va,Vb and Vc at the load side may have positive sequence mostly but it is possible that it may consists of negative sequence as well as zero sequence harmonics also be present in it. In sinusoidal current control strategy the positive sequence detector is necessary and the active portion of fundamental positive sequence component which produces average real power ($\bar{p}$) . This positive sequence detector is basically based on dual p-q theory and the voltages are transformed in to αβ component to get V α and V β which is done by the Clarke transformation. Then this Vα and Vβ are used to determine the auxiliary power p' and q' with a combination of current i'α and i'β which are output current of the PLL (Phase Locked Loop) circuit.

The αβ voltage calculation block calculates the instantaneous voltages V'α and V'β and it is a time function of fundamental positive sequence detector.

$$\begin{bmatrix} V\alpha' \\ V\beta' \end{bmatrix} = \frac{1}{i\alpha^2+i\beta^2}\begin{bmatrix} I\alpha' & -I\beta' \\ I\beta' & I\alpha \end{bmatrix}\begin{bmatrix} \overline{p'} \\ \overline{q'} \end{bmatrix}$$

Here for steady state condition the i'α + i'β = 1

The instantaneous phase voltages V'a V'b and V'c can be re determined by inverse Clarke transformation by disregarding its zero sequence component V0 this can be determined by given below equation :

$$\begin{bmatrix} Va' \\ Vb' \\ Vc' \end{bmatrix} = \sqrt{\frac{2}{3}}\begin{bmatrix} 1 & 0 \\ -\frac{1}{2} & \frac{\sqrt{3}}{2} \\ -\frac{1}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix}\begin{bmatrix} V\alpha' \\ V\beta' \end{bmatrix}$$

IV. SIMULATION AND RESULTS:

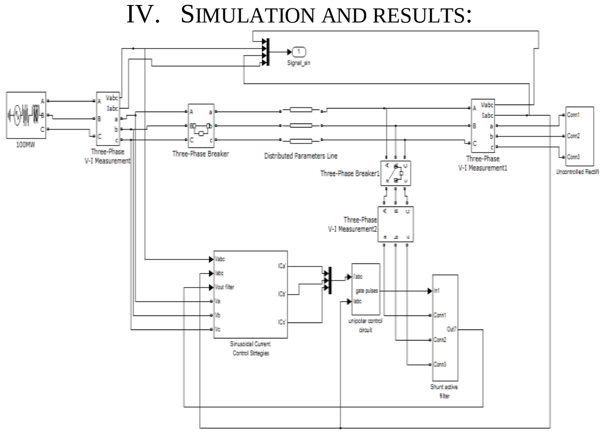

Fig. 4: showing MATLAB simulink model of sinusoidal current control strategy

Matlab file for initial condition to enter the desired load and power factor of load

```
v = 13.8e3;    p1 = 100e7; answer=0.8;
Prompt = {'Enter Load :-', 'Enter Power Factor'};
dlg_title = 'Input Fault Details';
num_lines = 1;
def = {","};
answer = inputdlg(prompt,dlg_title,num_lines,def);
 w = str2double(answer(1));
pf = str2double(answer(2));
 p = w*pf;
q = w*sqrt(1-pf^2);
 r = (v^2) / p;
l = ((v^2)/q)/(2*pi*50);
```

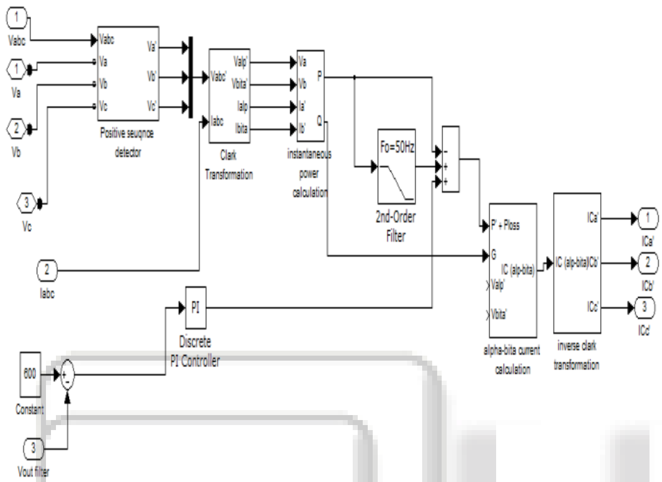

Fig. 5: showing Sinusoidal current control strategy

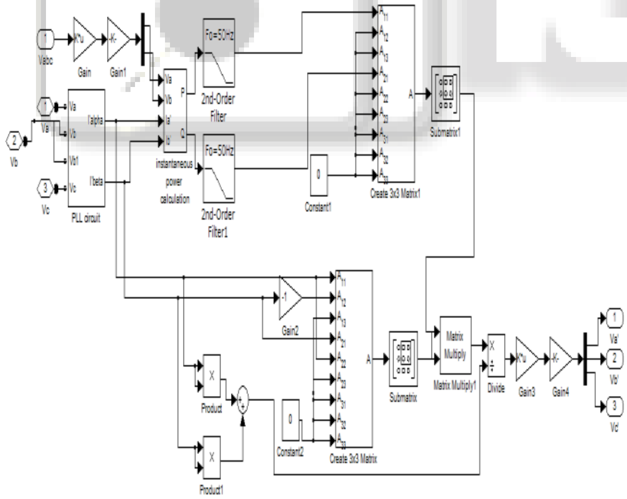

Fig. 6: for Fundamental Positive Sequence Detector

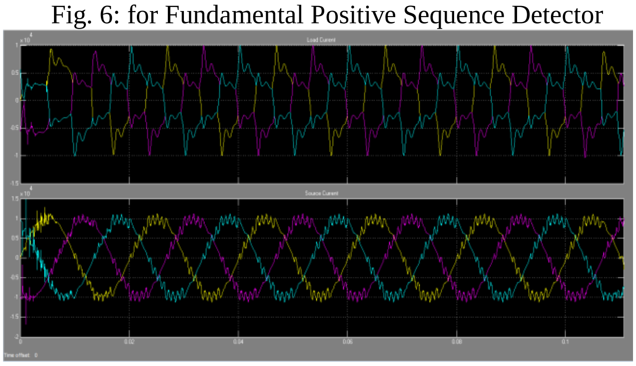

Fig. 7: Represents Load Current and Source current

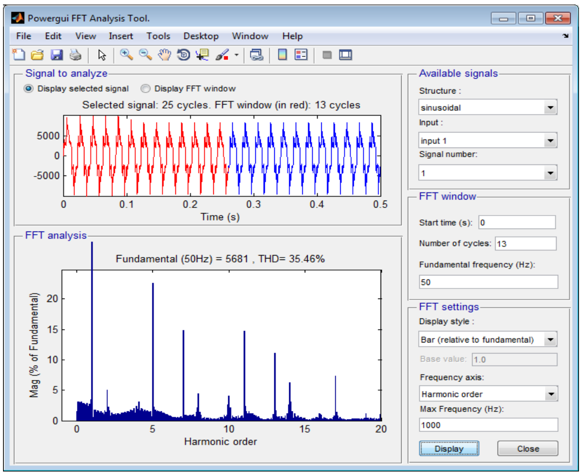

Fig. 8: Represents Load THD is 35.46%

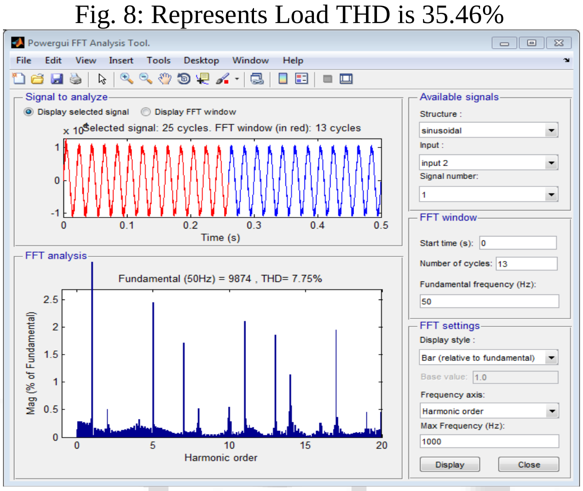

Fig. 9: Represents Load THD is 7.75%

V. CONCLUSION

As our main objective is to control the effect of load THD propagating toward the source side which causes harmful effects so to reduce this THD within IEEE standards given by IEEE 519-1992 Recommended Practices for THD.The shunt active filter proposed here is based of pq-theory and we can find that both strategies instantaneous power control strategy and sinusoidal current control strategy are implemented in MATLAB® simulation and by simulating we obtained a results which are almost within a standard limits. But while implementing the one should choose either one of strategy as instantaneous power control strategy gives constant real power to drawn from source while in case of sinusoidal strategy gives sinusoidal and balanced compensated current so either strategy should be chosen out of this two strategies. Simulation results shows that after implementation of instantaneous power control strategy the load current THD which were 35.48 % are reduced to 7.75 % which follows within a IEEE standard.

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