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HARMONIC ELIMINATION IN THREE PHASE DISTRIBUTION SYSTEM USING SHUNT ACTIVE POWER FILTER

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Abstract - *In present days loads used by the various consumers are of nonlinear in nature such as industrial, residential, and commercial loads. All these nonlinear loads required harmonic current for their function, due to these harmonic components of load current power quality of power system gets reduced. Efficiency of the power system network also gets reduced due to same harmonic component of line current. Therefore for the elimination of harmonic from the power system network shunt active power filters are widely used in recent days. Basically shunt active power filter produces harmonic current same as that produces by the nonlinear load but opposite in phase. So that only the fundamental component of current flow from the supply mains and power factor of supply source maintained near to unity. In this paper a voltage controlled voltage source inverter is used with PWM method for controlling the switching of the converter. Here the reference voltage signals are generated with the help of the d-q theory method also called as the synchronous reference frame method. This paper shows the application of the proposed method for harmonic elimination under different load condition, simulations are done using MATLAB.*

Keywords: Shunt Active Power Filter (SAPF), PI controller, Power quality.

INTRODUCTION

In recent years, nonlinear loads are widely used by the various consumers such as commercial, industrial etc. These nonlinear loads are the major source of harmonic production in the power system network which is undesirable. In present days the main objective of the power system engineers is to remove the unwanted harmonics from the entire power system to improve the power quality of the power system. Generally the main sources of the harmonics are adjustable speed drives, Switch mode power supply, Power electronics converter etc. Purity of the voltage and current waveform defines the quality of power. Power quality of the power system network are also reduces due to the disturbance such as voltage sag, voltage swell. Harmonics are the measure cause of the poor power quality. Basically distortion of current and voltage waveforms are expressed in terms of the harmonics. Unwanted Harmonics are produced in the power line due to the nonlinear loads. Harmonic present in the line current produces extra voltage drop in the line impedance due to which source current and voltage waveform also get distorted.

1. OBJECTIVE OF PROJECT WORK

a. Designing of shunt active power filter for reducing the total harmonic distortion.
b. To study the various power quality problems in different industries and electrical power system.
c. Analyze the percentage of harmonic of harmonic reduction in the source current due to the use of the active power filter.
d. Modeling of active power filter with their control method in MATLAB.
e. Simulations are done for different loads.
f. Percentage of harmonic reduction with and without filter for different load will be analyzed.

2. SHUNT ACTIVE POWER FILTER

Shunt active power filter with dc bus configuration is same as the static compensator used for the compensation of reactive power in the power system network. Shunt active power filter is basically a power electronic device which is used for producing harmonic current of same magnitude and opposite in phase to that generated by the nonlinear load. Voltage source inverter is the main source of the shunt active power filter which gives the necessary compensation

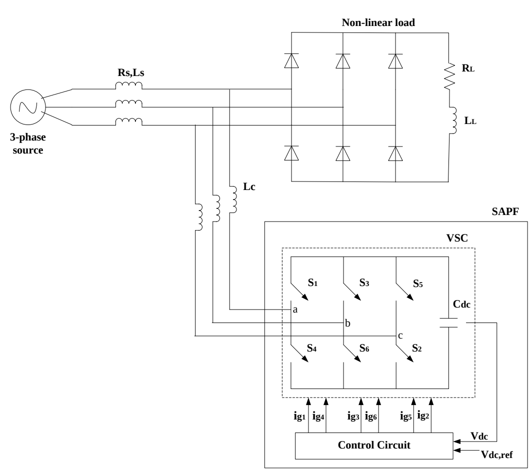

Figure1. Shunt active power filter

3. OPERATING PRINCIPAL OF SAPF

Basic compensation principal of the shunt active power filter is shown in the figure2. Shunt active power filter are connected in shunt with the load to continue monitor the load current and inject the current into the system according to load current. On monitoring of load current, reference compensating current are generated by the active power filter. The main function of the shunt active power filter is to eliminate the harmonic current generated by the nonlinear load by injecting the same amount of current but opposite in the phase. For compensating the load harmonic current SAPF uses the converter of current controlled voltage source topology based on the IGBT.

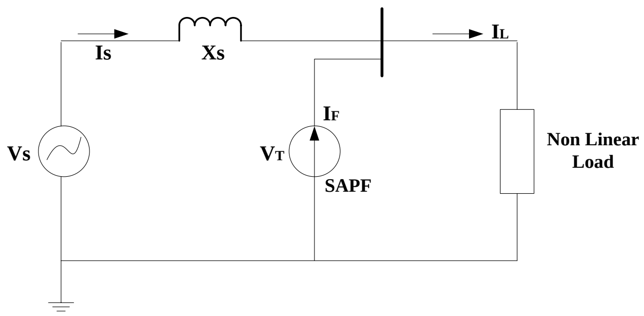

Figure2. Operating principal of SAPF

4. SYNCHRONOUS REFERENCE FRAME THEORY (D-Q METHOD)

Synchronous reference theory can also be used for the separation of harmonic current from the fundamental component of current. For this separation reference current will be generated by this method. Using this technique synchronous d-q frame will be obtained and three phase a-b-c quantity are converted into the d-q coordinate using park transformation. D-q coordinate are rotating with the angular frequency, where as the a-b-c coordinate are stationary. Harmonics are appeared as ac component in d-q frame but the fundamental component of the current are appeared as dc. It is necessary to convert the quantity into the d-q frame because in d-q frame analysis are appeared as dc and control of dc quantity are more easy then ac. Park transformation are used to calculate the components of the d-q frame. The synchronism between the reference voltage and actual voltage will be maintained using PLL block. This method is comparatively slower than the p-q method for the harmonic elimination. Action taken by this method is not instantaneously as that in the p-q method therefore this method is slower than the p-q method. Block diagram for the d-q method are shown in the below figure.

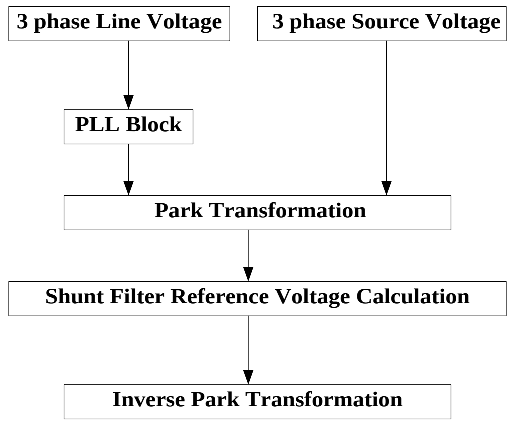

Figure3. Flow diagram of d-q method

5. PI CONTROLLER

PI controller is used for the process of non integrating that means the process which gives the same output with the same disturbance and the input. For the non integrating process, PI controller is the perfect one. In the control scheme various controller blocks such as limiter, sine wave generator, switching signal generator. Highest value of the reference current will be regulated by the dc link. Capacitor voltage are compared with the set reference voltage value. The error between the actual capacitor voltage and reference voltage is given as input to the PI controller for the reference current generation. Output of the PI controller is considered as the maximum value of the system current (Imax). Output of the PI controller consist two component, first is fundamental active power component of the load current and the second component is losses of active power filter. For maintaining the constant voltage across the capacitor, the output of the PI controller is taken as the peak value of the system current. For obtaining the compensating current, Imax is multiplied with the unit vector in phase with the respective source voltage. Error signal are used for the switching of the converter switches.

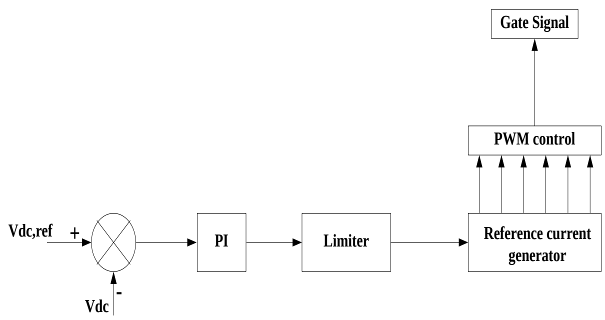

Figure4. PI controller

6. SIMULATION AND RESULTS

In this research work shunt active power filter is simulated with nonlinear balanced and unbalanced load. Figure5 shows the simulation diagram of SAPF with the nonlinear and balanced R-L load. In this paper simulation of SAPF is done with balanced R-L and unbalanced R-L load in both the simulation nonlinear load is common. In this work nonlinear load based on the diode bridge rectifier is used. Figure6 shows the simulink designing of the reference signal generation block. In this paper PWM controller is used for switching the converter switches. Comparative analysis of THD values for both balanced and unbalanced load is shown in the table1.

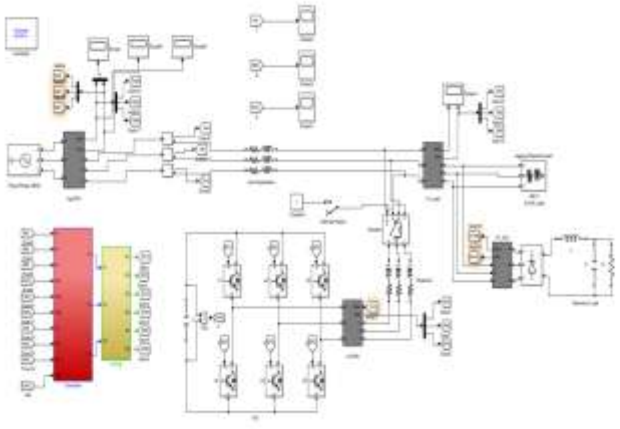

Figure5. Simulation diagram of SAPF

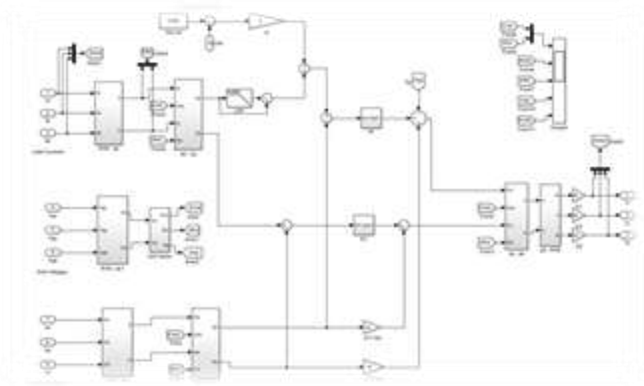

Figure6. Reference signal generation

7.1 SIMULATION WITH NONLINEAR AND BALANCED R-L LOAD

Output waveform and THD analysis of SAPF simulation for nonlinear and balanced R-L load are shown below. Figure7 shows the grid current waveform before compensation. As seen from the figure7 harmonics present in the grid current which is compensated by connecting active power filter. Figure8 shows the grid current after compensation which is a sinusoidal current waveform. Figure9 and figure10 shows the harmonic spectrum without and with SAPF respectively. It is seen from the figure that harmonic present in the grid current before connecting filter is 21.86% and figure10 shows the reduced harmonic distortion of 6.96%. This paper shows the effectiveness of the filter used with the reduction in the harmonic from 21.86% to 6.96%.

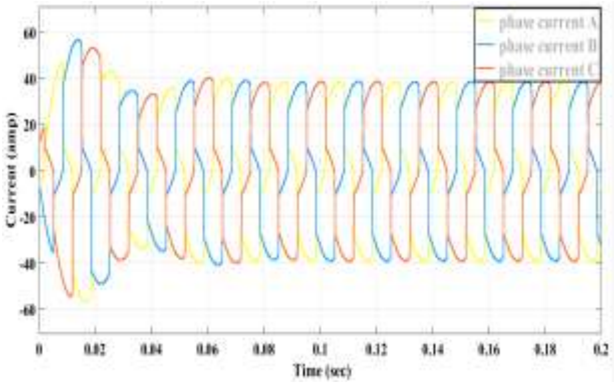

Figure7. Grid current without SAPF

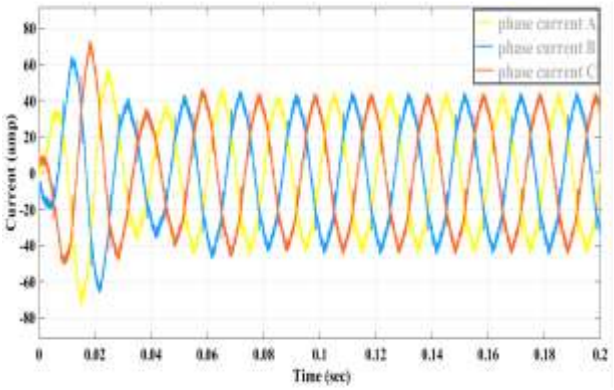

Figure8. Grid current with SAPF

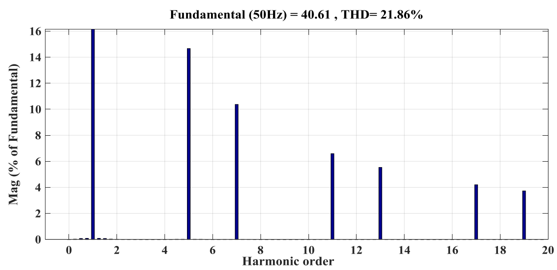

Figure9. THD without SAPF

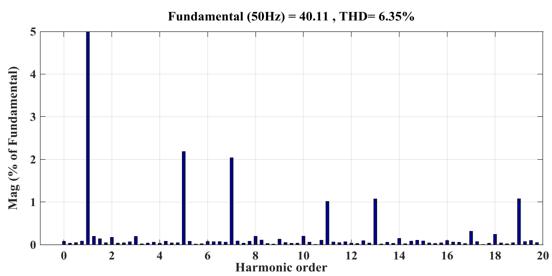

Figure10. THD with SAPF

7.2 SIMULATION WITH NONLINEAR AND UNBALANCED R-L LOAD

Simulation result of shunt active power filter with unbalanced R-L load are shown here. Figure11 shows the grid current waveform without SAPF which having harmonic because of the nonlinear load. Figure12 shows the grid current waveform in presence of the SAPF. This shows the almost sinusoidal current waveform. Figure12 and figure13 shows the harmonic spectrum for unbalanced load without and with active power filter, it is seen from both the figure that the harmonics are reduced to 7.55% from 24.98%. Comparative analysis of THD values for both balanced and unbalanced load is shown in the table1.

As seen from the figures only fundamental harmonic is present after compensation whereas other higher order harmonics are eliminated by the active filter.

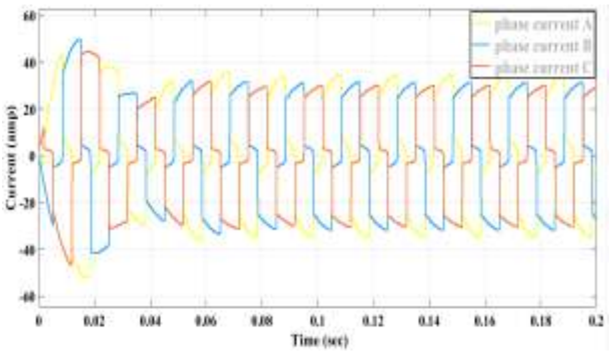

Figure11. Grid current without SAPF

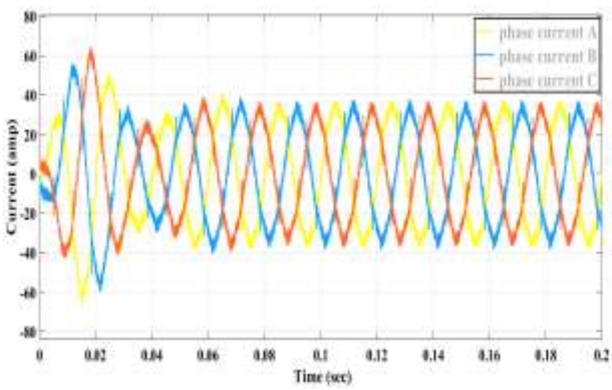

Figure12. Grid current with SAPF

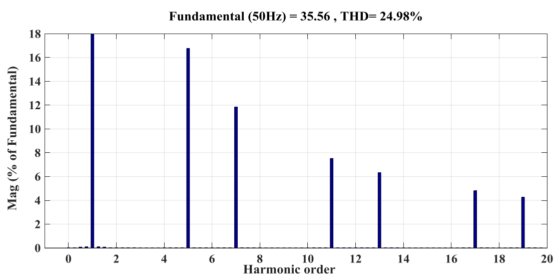

Figure13. THD without SAPF

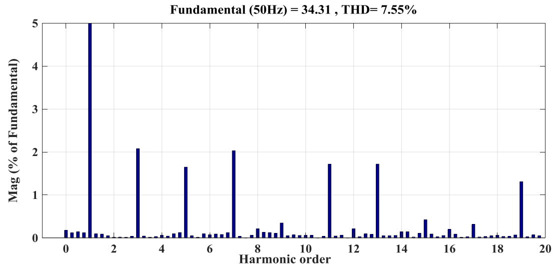

Figure14. THD with SAPF

Table 1 : Comparison of supply current THD value with and without SAPF

Loads	*THD without SAPF*	*THD with SAPF*
Nonlinear load with balanced R-L load	21.86%	6.35%
Nonlinear load with unbalanced R-L load	24.98%	7.55%

7. CONCLUSION AND DISCUSSION

Simulation of three phase three wire SAPF with a nonlinear balanced and unbalanced load consisting of the three phase diode bridge rectifier is done in MATLAB. Harmonic component are present in the line current of the three phase system due to the nonlinear loads. Total harmonic distortion found as very high, to reduce the harmonic from the grid current, shunt active power filter with the synchronous reference frame (d-q method) control and PWM technique are designed using MATLAB. Comparative analyses of THD with and without compensation for different load conditions are shown in the Table1. Synchronous reference frame theory based SAPF are effectively used for the harmonic elimination. Proposed method is able to eliminate the harmonics from the supply current and THD values for different loads are tabulated.

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