

Enhanced Performance Analysis of Active Filter over Passive Filter in Power Quality Issues

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Abstract: Owing to the improvement in power semiconductor devices, now days it is more common to use non-linear devices. But because of these non-linear devices a major problem called harmonics is introduced in the power system which distorts the source current as well as voltage. Hence we have to reduce these harmonics by some means to improve the quality of power. The T.H.D has been improved in the present paper by using Shunt Passive Filter (SPF) and Shunt Active Power Filter (SAPF) and at the end comparative analysis of both the methods has been done. The SAPF uses p-q theory for producing the source current and hysteresis method for generating the gate pulses.

Keywords: Shunt Passive Filter, Shunt Active Filter, Harmonics, non-linear load, Total Harmonic Distortion (T.H.D).

Introduction

Due to the tremendous growth of power semiconductor devices in recent years, non-linear loads have been used extensively. The nonlinear loads such ASD(Adjustable Speed Drives),UPS, arc furnaces, Personal computers, power converters uses power semiconductor devices like diodes ,SCR,IGBT,MOSFET widely. Hence these non linear loads are main responsible for causing harmonics in source current & voltage in the power systems. IEE519-1992 standard has imposed some specific limits on the T.H.D to keep a check on the harmonics, which should be less than 5%.

The various problems caused by harmonics are:

- *Overheating and damaging the insulation of equipment
- *Low power factor
- *Decrease in efficiency
- *Electromagnetic interference
- *Increased losses

Hence, power quality improvement and harmonic reduction becomes necessary in power systems. The harmonics can be eliminated successfully by using Passive filters and Active filters. This paper describes two methods to improve power quality i.e. by using 3 ϕ shunt passive filter and 3 ϕ shunt active filter independently and compares both the methods.

Harmonic Mitigation Techniques

Mitigation of harmonics can be done by using different types of filters:

- A. Passive Filter (PF)
- B. Active Power Filter (APF)
- C. Hybrid Filter (HF)

But this paper deals with only the first two methods to improve the power quality.

Passive Filter

In this type of filters we can control the harmonics by using passive elements like resistance, inductance and capacitance. The Passive Filters have been used more commonly to lower harmonic levels because of its reduced cost, simple design and good reliability [1-5]. The block diagram of 3 ϕ shunt passive filter is shown in Fig. 1.

Fig. 2 shows the different kinds of Passive Filters.

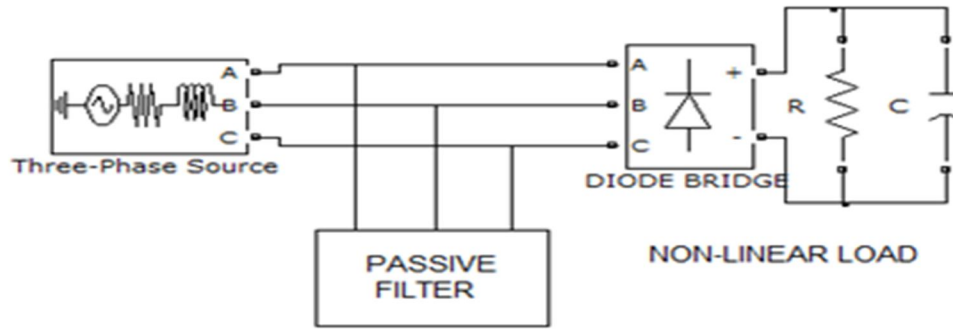


Figure1. Three phase shunt passive filter

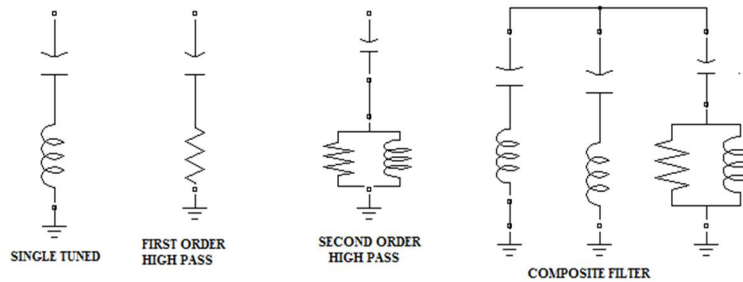


Figure2. Different configurations of shunt passive filters

Active Power Line Conditioners /Active Power Filters

The shunt APF works by producing the required harmonic current and then injecting into the line in opposite direction to remove the source current harmonics produced by the non-linear load.

Different steps involved in generation of harmonic current are [7-10]:

- Identifying the harmonic current from the load current
- Generating the gating signals for the inverter circuit to produce the harmonic current and then injecting the harmonic current into the line.
- The simplified block diagram of three phase shunt active power filter is shown in Fig. 3.

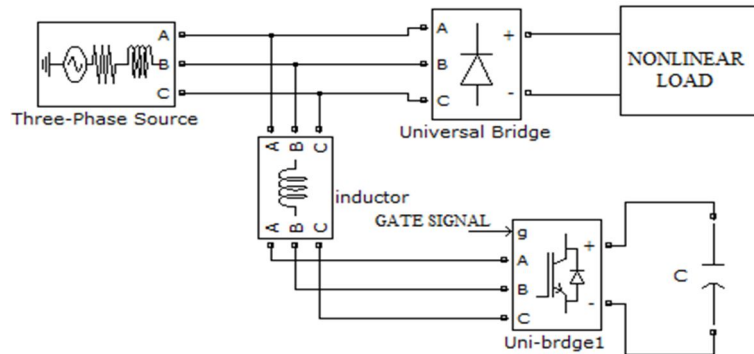


Figure3. Three phase shunt active filter

The required harmonic current is generated by the shunt active power filter by using a voltage source inverter (VSI). The VSI uses a dc voltage as input and hence produces a signal to cancel the harmonic component due to nonlinear load, by accurately controlling the conduction of power semiconductor devices in the VSI. The voltage signal created by VSI is changed to a current signal by using a large isolation inductor.

Shunt Passive Power Filter Design

Single Tuned Filter Design

The single tuned filter is used for removing particular frequency harmonics for which the filter is designed or tuned. The capacitor value of the filter depends on the power factor.

Tuned frequency (f) of the filter is given by the formula:

$$f = \frac{1}{2\pi\sqrt{LC}} \tag{i}$$

At resonant frequency, inductive reactance (X_L) = capacitive reactance (X_C).

Quality Factor (Q) of the filter is given by the formula:

$$Q = \frac{2\pi fL}{R} = \frac{1}{2\pi fCR} \tag{ii}$$

The resistance value is calculated by assuming Q in the range of 20 to 100[4].

If we want to remove the 7th order harmonics by using the passive power filter, then the tuned frequency will be seven times the supply frequency.

High Pass Second Order Filter Design

For eliminating higher order frequency harmonics, high pass second order filter is used.

The formula for calculating the resonant or tuned frequency (f):

$$f = \frac{1}{2\pi\sqrt{LC}} \tag{iii}$$

The expression for finding Quality factor (Q):

$$Q = \frac{R}{2\pi fL} = 2\pi fCR \tag{iv}$$

The filter resistance value is selected by assuming quality factor in the range of 0.5-5. [4]

Controlling Methods of Shunt Active Power Filter

Generation of Source Current

The ref. source current generation is required to identify the harmonic and reactive part of the load current. The required harmonic current can be produced by finding the difference between reference source current and the load current. The different methods used for the reference current generation are P-Q theory, d-q theory, Fourier transform, unit vector template method, multiplication with sine function and so on[7-10]. In this paper reference source current is derived by using P-Q method. The schematic diagram of the generation of the reference source current by P-Q method is shown in Fig. 4.

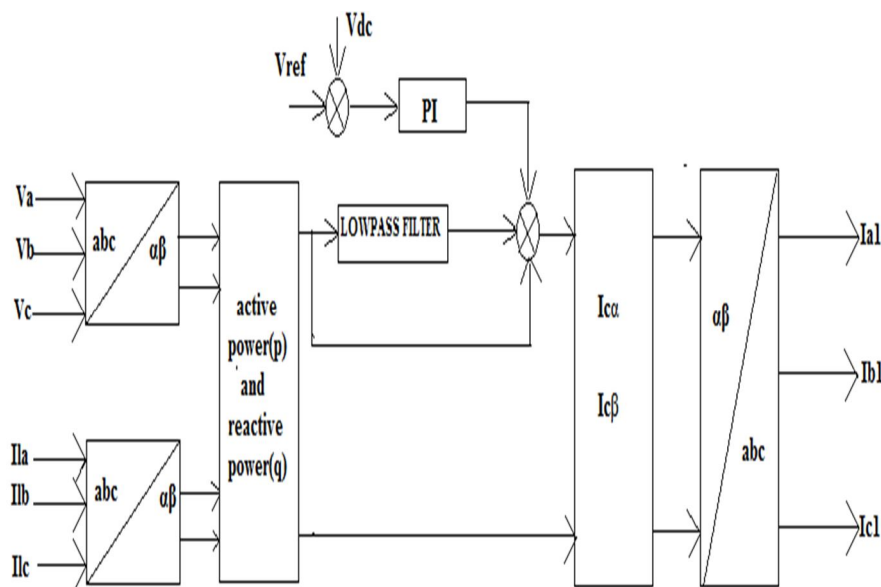


Figure4. Generation of reference source current by P-Q method

Control strategy for source current generation using P-Q method is shown in Fig. 5.

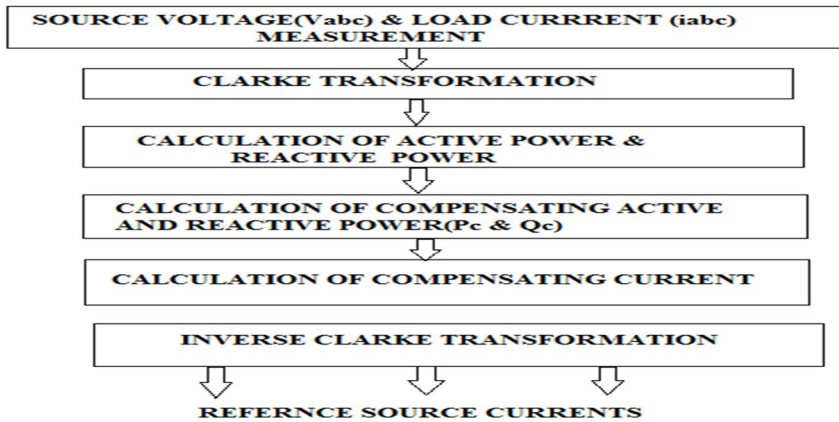


Figure5. Control strategy of P-Q method

Generation of Gating Signals

Gating signal generation is required to produce the gating signals for the power semiconductor devices of VSI. The different methods used for the gating signal generation are hysteresis control, PWM control, space vector modulation control, fuzzy control, dead beat control, fuzzy control and so on[7-10]. In this paper gating signals are derived by using hysteresis method. The appropriate gating signals are produced by the hysteresis controller depending on the input error according to the difference between the actual compensation current (I_{fabc}) and the generated harmonic current (i_{abc}^*). The matlab simulink model used for the generation of the gating signals by hysteresis controller is shown in Fig. 6.

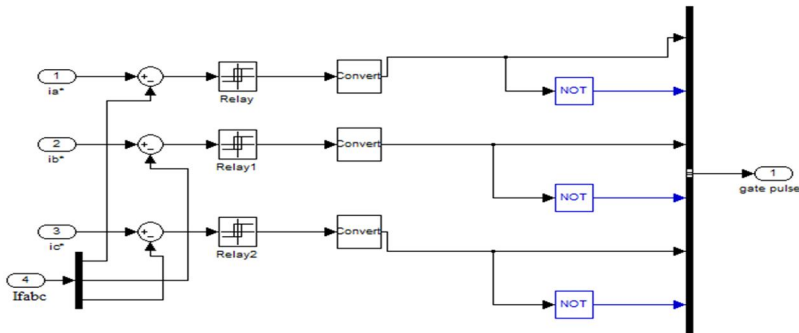


Figure6. Simulink model of hysteresis controller

Implementation of Shunt Active and Shunt Passive Filter

Implementation of the Given Circuit without any Filter

The circuit is simulated by using Matlab simulink software. The general simulation block diagram without any filter is shown in Fig. 7.

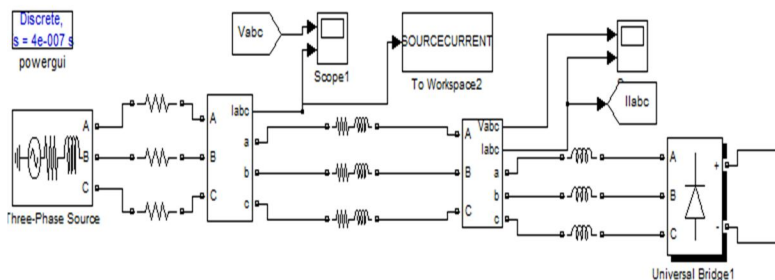


Figure7. Matlab simulink model without filter

Implementation of Passive Shunt Filter

The projected passive shunt filter uses three single tuned passive filters connected in parallel with the existing load to lessen fifth, seventh and eleventh order harmonic currents. The other higher order harmonics are minimized by using one second order high pass filter. The simulation block diagram with passive shunt filter is shown in Fig. 8.

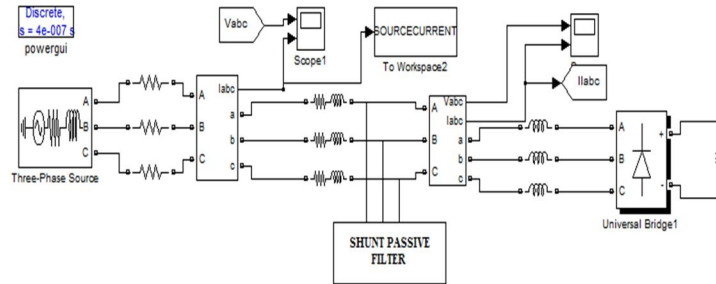


Figure8. Matlab simulink model with shunt passive filter

Implementation of Active Shunt Filter

The circuit is executed by using Matlab simulink software. The projected shunt active filter uses p-q theory for generating source current, hysteresis controller for producing gate pulses and a PI controller to reduce the inaccuracy between the actual dc capacitor voltage and the reference dc voltage. The projected simulation diagram with active shunt filter is shown in Fig.9.

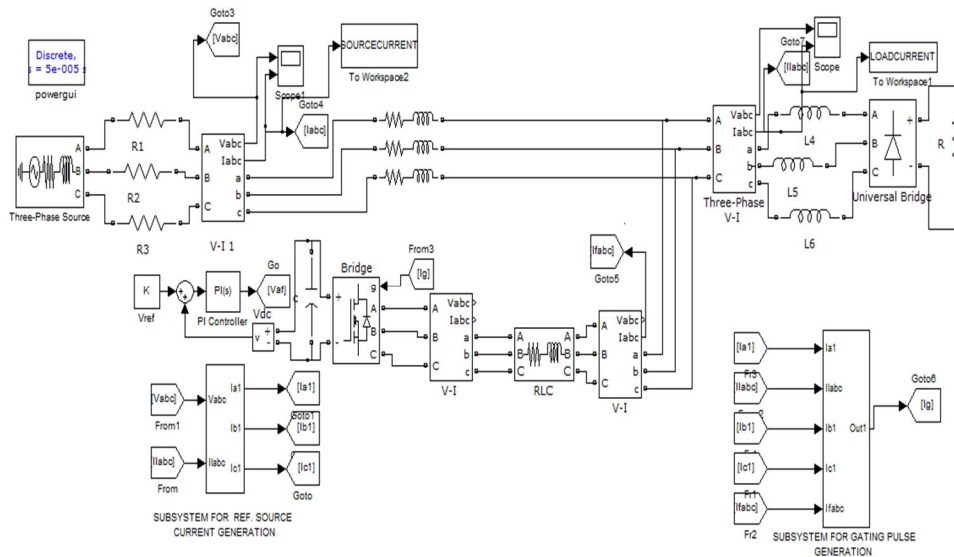


Figure9. Matlab simulink model with shunt active filter

Simulation Results and Comparison

The implementation of power quality improvement in a 3 ϕ power system is obtained using a shunt active and passive power filter. The circuit specifications of the proposed simulink model are shown in Table 1.

Table 1. Circuit Specifications Of The Proposed Simulink Model

| Sl.No | Simulation Values | |
|-------|-------------------|--------------------|
| | Parameters | Value |
| 1 | Supply Voltage | 310V,50hz |
| 2 | Source Resistance | $R_S=0.0312\Omega$ |
| 3 | Source Inductance | $L_S=6.63e-5H$ |
| 4 | Resistive Load | $R=20\Omega$ |

The supply current waveform and the harmonic spectrum without using any filter is shown in Fig. 10 and 11 , which signifies a T.H.D of 23.40 %.Hence it is clearly understood that the supply current is not smooth due to the existence of harmonics.

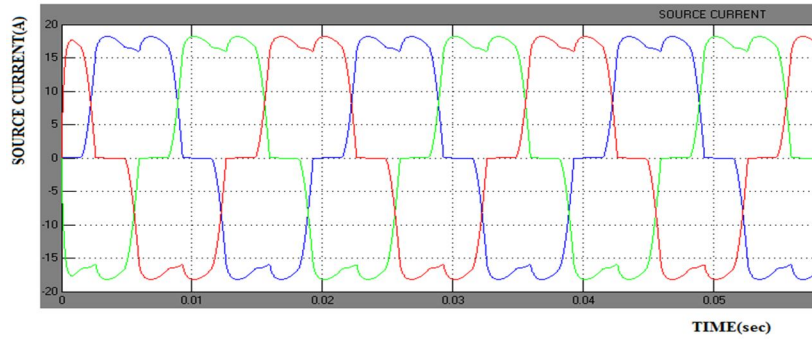


Figure10. Source current without filter

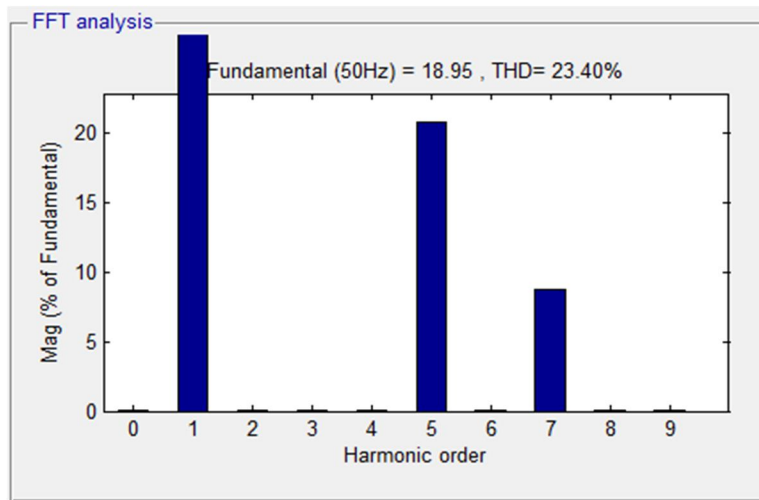


Figure11. THD spectrum without filter

Fig. 12, shows the improvement in the supply current waveform after connecting shunt passive filter. The T.H.D spectrum in the system with shunt passive filter is shown in Fig. 13, which shows a T.H.D of 7.50 % and hence we can conclude that T.H.D is better compared to the simulation results without shunt passive filter.

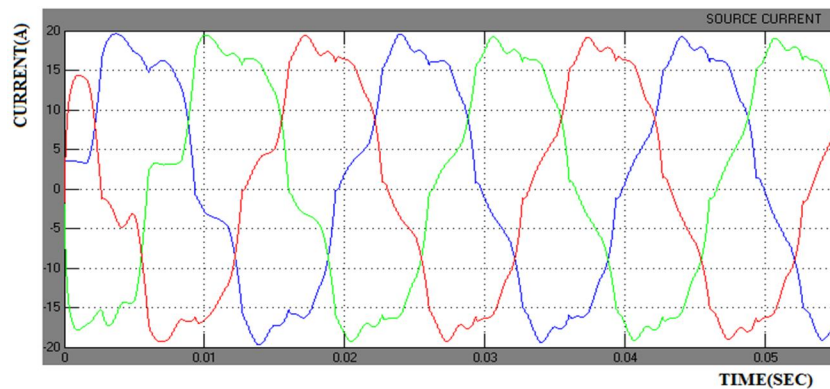


Figure12. Source current with shunt passive filter

After connecting shunt active filter, supply current waveform is nearly sinusoidal as shown in Fig.14. The harmonic spectrum in the system with shunt active filter is shown in Fig.15, which shows a T.H.D of 2.26% and hence we can conclude that THD is the best compared to the other previous simulation results.

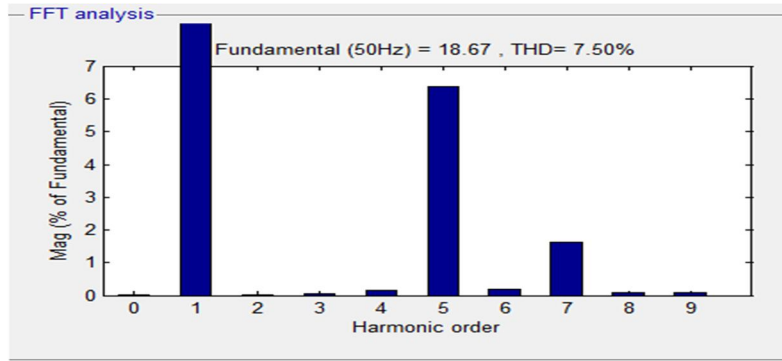


Figure 13. THD spectrum with shunt passive filter

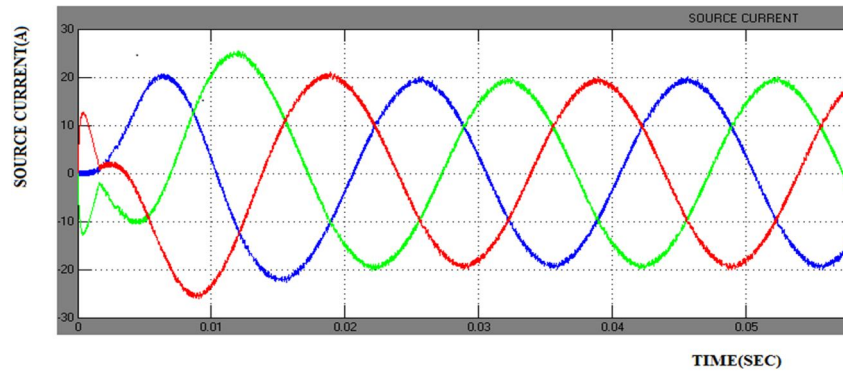


Figure 14. Source current with shunt active power filter

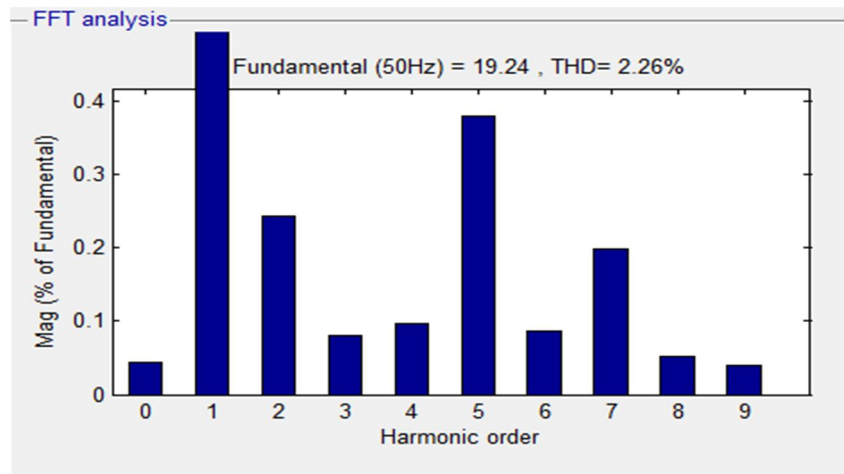


Figure15. THD spectrum with shunt active power filter

The simulation results of the different methods are compared by using Table 2.

Table 2. Comparison Of Different Methods

| Sl.No | Different Methods | THD Value |
|-------|---------------------------|-----------|
| 1 | without any filter | 23.40% |
| 2 | with shunt passive filter | 7.50% |
| 3 | with shunt active filter | 2.26% |

Conclusion

The proposed shunt passive filter and active filter effectively reduces the current harmonics produced in the system due to non-linear loads. The source current T.H.D is decreased from 23.40 % to 7.50 % by using shunt passive filter. The T.H.D is further reduced to 2.26 % by using shunt active filter which is well below the harmonic limit imposed by IEEE standard-519.

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