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Power Quality Improvement using Passive & Active Filters

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Abstract— *Poor quality of electric supply is normally caused by power line disturbances such as transients, notches, momentary interruptions, voltage sag and swell, over-voltage, under-voltages and harmonic distortions. Filters are used for improving the power quality. Active and Passive filters eliminate major fluctuating factors. Hybrid filters are the combination of active and passive filters. Conventional Active Filtering using PLL also reduces the harmonics. Total Harmonic Distortion (THD) can be reduced by implementing combination of active and passive filters. To design a hybrid power filter to reduce the harmonics for enhancing the quality of power. Also compare various topologies of filters to evaluate the best filter for power quality enhancement using MATLAB.*

Keywords— *Active filters, Hybrid filters, Phase lock loop (PLL) Passive Filter, Total Harmonic Distortion (THD)*

I. INTRODUCTION

Utility point of view power quality is means reliability. But from the manufacturer point of view power quality are those characteristics of power supply that enable the equipment work properly. Now the load equipment are very sensitive to PQ variation then the equipment used earlier example processor based system. Power quality is the study of voltage variation, waveform distortion and frequency variation at the load end.

A .Power Quality Problems

A brief explanation of the power quality problems is given in the following section. The term transients used in the analysis of power system variations to denote an event that is undesirable and momentary in nature. There are two main sources of transient overvoltage on utility systems viz. capacitor switching and lightning. Long-duration variations can be either overvoltage or under voltages. Short-duration voltage variations are caused by fault conditions, the energization of large loads which require high starting currents, or intermittent loose connections in power wiring. voltage imbalance is defined as the maximum deviation from the average of the three-phase voltages or currents, divided by the average of the three-phase voltages or currents, expressed in percent. Waveform distortion is defined as a steady-state deviation from an ideal sine wave of power frequency principally characterized by the spectral content of the deviation. Voltage fluctuations are systematic variations of the voltage envelope or a series of random voltage changes, the magnitude of which does not normally exceed the voltage ranges specified by ANSI C84.1 of 0.9 to 1.1 pu. Power frequency variations are defined as the deviation of the power system fundamental frequency from it specified nominal value. On modern interconnected power systems, significant frequency variations are rare. Frequency variations of consequence are much more likely to occur for loads that are supplied by a generator isolated from the utility system. Harmonics are qualitatively defined as sinusoidal waveforms having frequencies that are integer multiples of the power line frequency. In power system engineering, the term harmonics is widely used to describe the distortion for voltage or current waveforms. [1]

II. CLASSIFICATION OF FILTERS

Harmonic (voltage or current distortion) in distribution system increases with the increase of high rating nonlinear load. The filter design is becoming more and more essential for industrial distribution systems. This work examines the probability of manipulating the filter size in such a way that the total investment cost, in which undesirable voltage profile must be corrected and harmonic, must be condensed within the tolerable maximal value.

Filter can be classified as:

a) Passive filter
b) Active filter

A. Passive Filter

A passive filter is an arrangement of inductances, capacitances as well as resistances orderly in such a manner that it acts as a frequency discriminator, i.e.,it provide low impedance path for harmonics component or we can say that it allows passing of several frequencies and discards others.. It is possible to connect more than one passive filter in either shunt and/or series configuration.

1. Series Passive Filter

When only purpose of filter a particular frequency from entering in to the system the series filter is use. Fig.1 shows the series passive filter

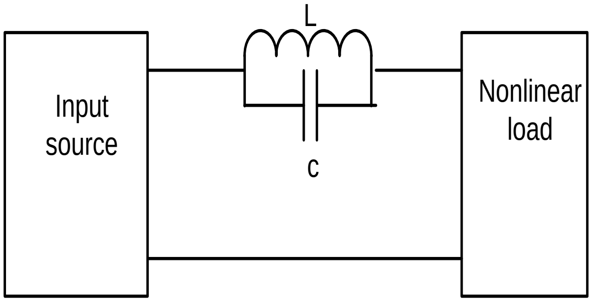

Fig.1 Series Passive Filter

2. Shunt Passive Filter

This is a commonly used filter which is mostly connected at load end. It offers low impedance path to tuned harmonics component connected to load end.But problem with these can occur when it resonate with the system and it import harmonics from other sources. It can also classified as single tuned and double tuned. Fig. 2 shows the shunt passive filter.[2]

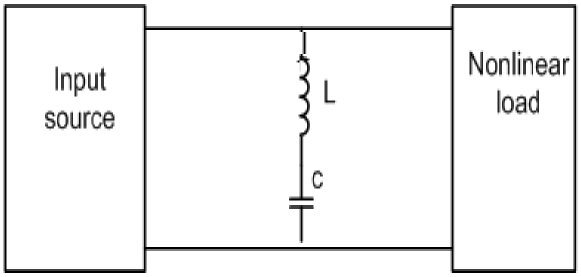

Fig.2 Shunt Passive Filter

3. Series Passive ac Reactor

This type is used to filter all harmonics frequency by varing amount. It can only improve harmonic distortion. But it can‘t create system resonance. Fig.3 shows the series passive AC reactor.

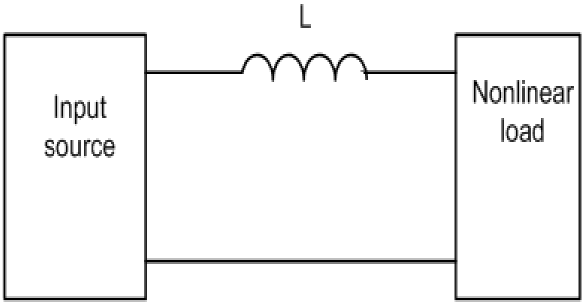

Fig.3 Series Passive ac Reactor

4. Low Pass Filter

This is used to eliminate all the Harmonics freq above the resonating frequency. Neither it creates system resonance nor it import harmonics from other source. But it draws full load current. Fig.4 shows the low pass filter.

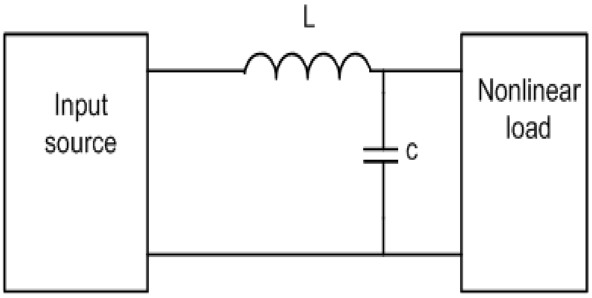

Fig.4 Low Pass Filter

B. Active Filter

The design complexity and high cost of losses of the conventional passive filters, as well as their restricted capability to eliminate inter-harmonics and non-characteristic harmonics, has encouraged the development of harmonic compensation by means of power electronic devices, and commonly referred to as active filters. Shunt active filter is used instead of passive filter because it absorbs the current harmonics dynamically by injecting equal and opposite harmonic current into the system.

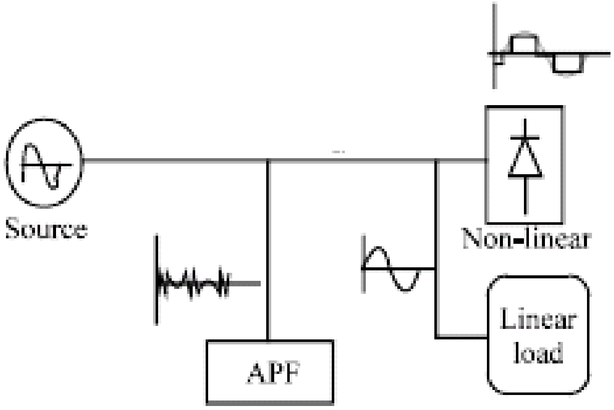

Fig.5 Active Filter

Both the views of Active Filters serve the same purpose of reactive power and harmonic compensation. Fig.5 shows the active filter.Fig.6 shows the classification of active filters based on system configuration. [3]

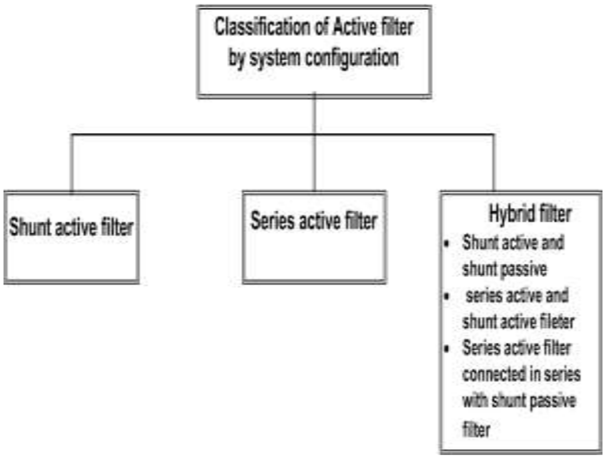

Fig.6 Classification of Active Filter

1. Shunt Active Filter

Shunt Active Filter is most widely used to eliminate current harmonics, reactive power compensation and balancing unbalanced currents. Only the control scheme makes difference either it work as an SAF or STATCOM. Fig.7 shows the shunt active filter.

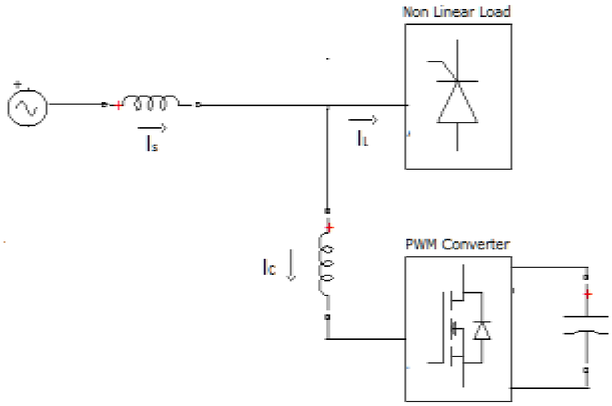

Fig.7 Shunt Active Filter

2. Series Active Filter

It is connected before the load in series with the main using matching transformer. In this filter is act as a controllable voltage source. Fig.8 shows the series active filter.

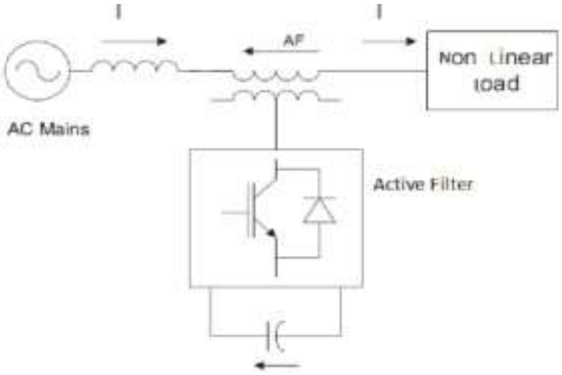

Fig.8 Series Active Filter

C. Hybrid Filter

Passive filter has a disadvantage of resonance and does not properly work for load variation. Then Active filter is used in place of passive filter, because of their good dynamic response in load and harmonic variation. Active filter also use for the compensation of more than one harmonics and reactive power compensation. But active filter has some disadvantage. Economically it is not good option for power quality improvement. For such cases hybrid filter is use. Which is the combination of both Active filter and Passive filter? Mainly used to reduce the rating of active filter. It can used with already existing passive filter. With these active filters the dynamic performance of the overall filter can be improved. [4]

III. DEVOLVEMENT OF VARIOUS FILTERS USING MATLAB

Here designing of active shunt and passive filter are presented for effective filtering of harmonics. The design of the power circuit includes the following three main parameters:

- Selection of reference value of DC side capacitor voltage,
- Selection of filter inductor, Lc.
- Selection of DC side capacitor, Cdc

The simulation analysis of Shunt Active Power Filter is performed with PLL technique and PQ theory as discussed in previous chapter. For this purpose, a SIMULINK model is developed for the Shunt Active Power Filter to investigate the performance during steady states as well as transient's condition. Here a three phase diode bridge rectifier and a controlled rectifier with RL load on its DC side is taken as the nonlinear load is use for which filtering is required. First shunt active filters are designed with PLL technique and Reactive power theory for filtering and comparison is done on their performance. Simulation is carried out for both harmonic and reactive power compensation. Then a shunt active power filter is appended to the system for better filtering. In the simulation power source with the following parameters is used:[6]

Voltage Vrms (phase to phase) = 400V

Source inductance Ls=0.5mH,

Source resistance Rs=0.1 ohms.

An inductive load with Resistance RL =30 ohms and Inductor L=40mH is connected to the DC side of rectifier is used as nonlinear load. Active filter is modeled by a MOSFET based inverter with a capacitor on its DC side which acts as an energy storage element during transients. The switches of the inverter are taken as ideal ones. A resistance is taken in series with the compensation inductance to account for the switching losses of active filter. The various parameters of the active filter are taken as Q=8KVA; Vs,rms(line to line)=400; Vdc,ref=700V; LC=3.35mH; Rc=0.5ohms; Cdc=2200uF. [7]

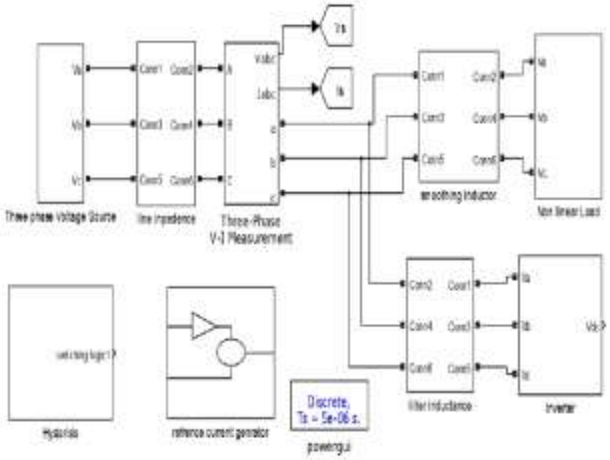

Fig.9 Block Diagram of Shunt Active Filter

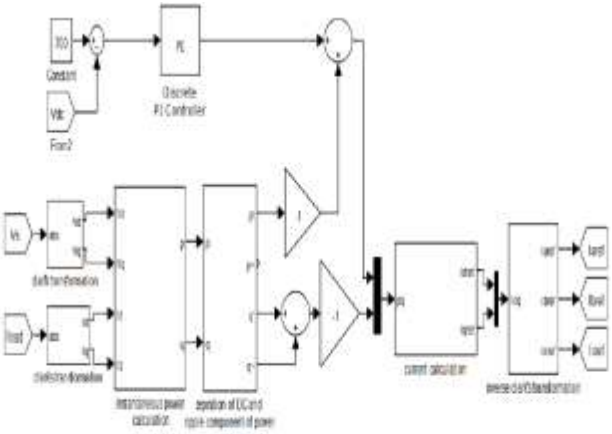

Fig.10 Control scheme with instantaneous reactive power theory for the compensation of both harmonic and reactive power

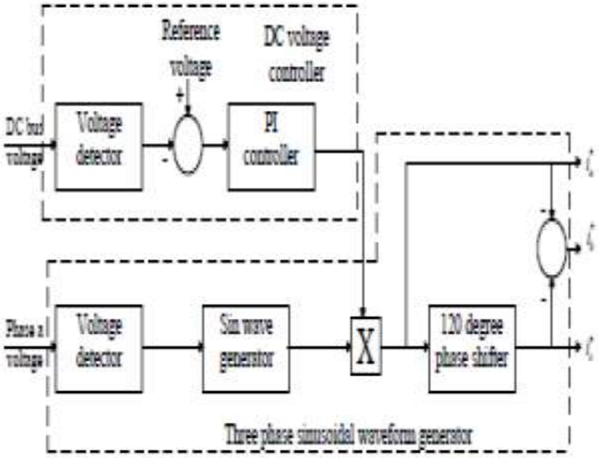

Fig .11 Control scheme with PLL technique

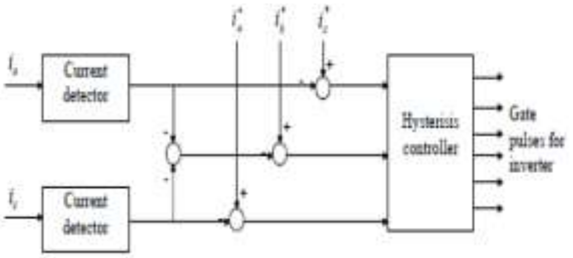

Fig .12block diagram of hysteresis controller

IV. SIMULATION RESULT FOR VARIOUS FILTERS

Rating of active filter is totally depends on the reactive power compensation. With the increase of firing angle of converter rating of active filter are also increases. It is clear from the data 4.68 KVA rating of SAF required at a firing angle of 25o which is 59% of the load KVA. And data 5.026 KVA rating of SAF required at a firing angle of 30o which is 70.6% of the load KVA. This increases the losses as well as coast.

However this problem is overcome by using hybrid filter, which is a combination of active and passive filter. Passive filter is design for reactive power compensation and simultaneously it is tuned for lower order harmonics. Harmonic spectrum of load, passive, active and Hybrid filter are shown here.

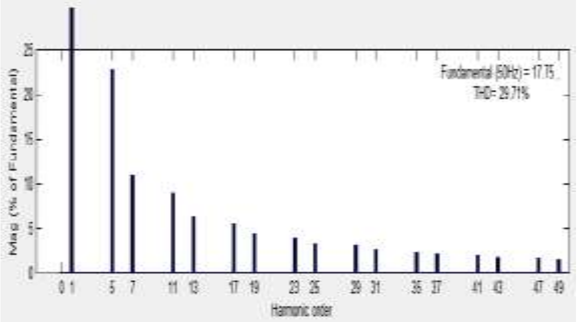

Fig.14 Harmonics spectrum of non linear load

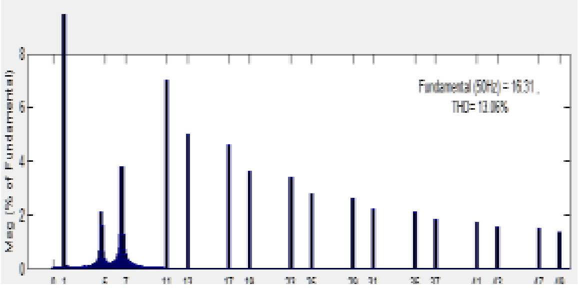

Fig.15Harmonics spectrum with passive filter only

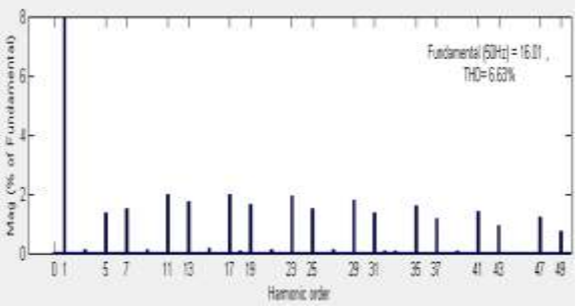

Fig .16 Harmonics spectrum with active filter only

V. PERFORMANCE COMPARISON OF VIROUS FILTERS OR CONCLUSION

Various techniques are use for filtering two of them are compared with simulating model. That shows steady state as well as dynamic response with instantaneous reactive power technique is better than conventional control (with PLL). Rating of active filter is totally depends on the reactive power compensation, with the increase of firing angle of converter rating of active filter are also increases. It is clear from the data 4.68 KVA rating of SAF required at a firing angle of 25o which is 59% of the load KVA. And data 5.026 KVA rating of SAF required at a firing angle of 30o which is 70.6% of the load KVA. This increases the losses as well as coast. Then it was observed that use of a Shunt Passive Filter along with Shunt Active Filter reduce the rating of active filter. From the simulation it is clear that for the demand of 3.7 KVAR at converter firing angle 25o, passive filter inject 3.35 kVAR and active filter inject only 0.35 KVAR. This reduces the rating of active filter. We can conclude that hybrid filter response with instantaneous reactive power technique gives better performance for reactive and harmonic compensation.

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