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Improvement of Power Quality by using control strategy of series active filter

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Abstract - ***Harmonic current received from the supply voltage source by the non-linear load results in the distortion of supply voltage waveform.The distorted voltage and current may possibly cause conductors to overheat and may reduce the efficiency. So that reduction of harmonics is very essential in today's life. For that purpose series Active filters are used to adjust the supply voltage fluctuations by injecting voltage in phase at the point of common coupling (PCC). This in phase voltage is free from harmonics and able to compensate the reactive power. In this paper control strategy is discussed and Simulation waveforms have been carried out on the MATLAB SIMULINK platform with series active filter and results are presented.***

Key Words**: Series active filter, PCC, Power Quality, Reactive power, harmonics.**

1. INTRODUCTION

Power quality describes the strength of electric power which is provided to consumer devices. Power quality is the problem manifested in disruption of voltage, current, or frequency variation that causes failure or an improper operation of user's equipment. Power quality is the reliability issue as for as the users point of view. [1] Harmonics produced by non linear loads can produce detrimental effect on the systems equipment.

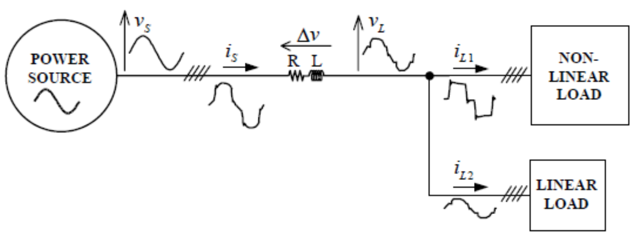

Fig.1.1 – Power system with non-linear load.

The existence of harmonics in power lines results in various power losses in the electrical system. These losses generate interference in communication systems and breakdown of electronic equipments, which are sensitive as they include many microelectronic systems, which work under low energy levels. Due to these problems, issue arises in power quality delivered to the end consumers. So, for the better operation of the system it should be free from harmonics. There are many types of filters such as active filter, high pass filter, low pass The existence of harmonics in power lines results in various power losses in the electrical system. These losses generate interference in communication systems and breakdown of electronic equipments, which are sensitive as they include many microelectronic systems, which work under low energy levels. Due to these problems, issue arises in power quality delivered to the end consumers. So, for the better operation of the system it should be free from harmonics. There are many types of filters such as active filter, high pass filter, low pass filter, passive filter etc.[2]In high pass filter there are some disadvantages due to resistance connection in parallel to the conductor, so at tuned frequency filtering effectiveness cannot be achieve and thus filtering losses increased. Passive filters can be used for current harmonics compensation but it has some limitations such as fixed compensation, large size, bulkiness and resonance problem etc. So in these paper series active filter is discussed. [3]

2. NECESSITY FOR HARMONIC COMPENSATION

The performance of Active power filters in this recent electronic age has become an ever more essential element to the electric network. With the advancement of power electronic devices between consumer and industry, there by utilities are in pressured for giving high power quality. Some Power electronic devices like computers, fluorescent light printers, faxes, and mainly other office equipment may generate create harmonics. Such types of device are commonly defined as nonlinear loads. Such loads produce harmonics by representing current distortion rather than a smooth sinusoidal waveform. The major issues associated with the harmonics supplied to nonlinear loads are severe overheating and reduction in efficiency. With the Increase in temperature the operation of generators and transformers may damage the insulation material of its windings. If this heat continues occur than it may cause flash over through the conductors. This may results in permanently damage of device and results in blackout with the loss of generation. The available solution to this problem is to mount active filters for separate nonlinear load in the power system network. However they are uneconomical, but the installation of active power filters proves crucial solution for power quality problems in power system networks for harmonics compensation.

3. POWER QUALITY PROBLEMS

Power quality problem exists if there is variation in voltage, current or frequency deviation that causes failure or disoperation of customer's equipment. Some power quality problems are: voltage sag, voltage swell, flicker, voltage imbalance, transient, over voltage and under voltage etc.[4]

Another problem is harmonics which is produced due to non linear load.

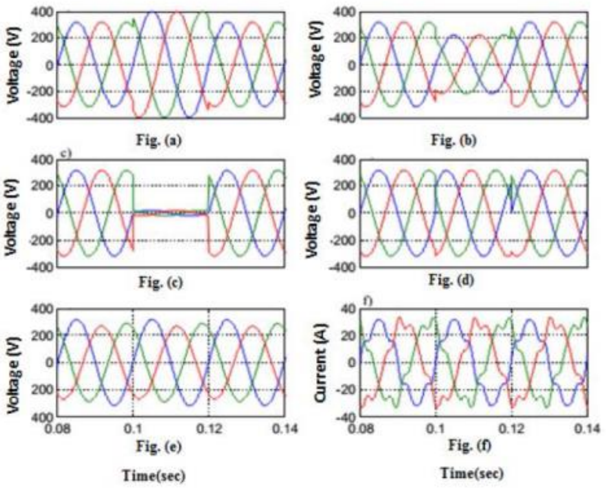

Fig.3.1 Power quality problems (a) Voltage swells (b) Voltage sags (c) Voltage interruption (d) Frequency variation (e) Voltage unbalance. (f) Harmonics

4. SOLUTION TO POWER QUALITY PROBLEMS

An appropriate solution to power quality problems are presented by active power filters. The available active power filters are: shunt active filter, series active filter and hybrid active filter. In these filters cost of shunt active power filter is comparatively high and they are not suitable for a bulky system. Series active power filters are used to mitigate voltage harmonics, and to maintain balance and control the terminal voltage of the load or line. It is also used to reduce negative-sequence voltage [5]. It has the ability of reducing voltage and current harmonics at a reasonable cost.

5. SERIES ACTIVE POWER FILTER

Series active power filters compensate current harmonics caused by non-linear loads by providing a high impedance path to the current harmonics. The high impedance required by the series active power filter is formed by the generation of voltage of same frequency in order to eliminate current harmonic component. Compensation of current harmonic and voltage unbalance are achieved by generating the suitable voltage waveforms with the three phases PWM voltage-source inverter. Voltage unbalance is correct by compensate the fundamental frequency and zero sequence voltage components of the system. [6]

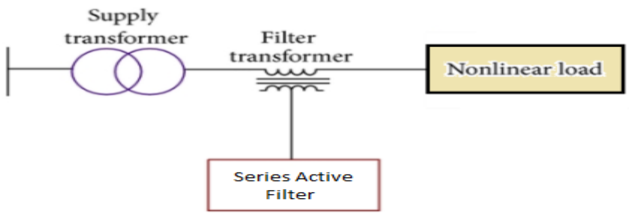

Fig. 5.1 Series Active Power Filter

6. CONTROL SCHEME FOR SERIES APF

A simple algorithm is developed to control the series filters. The control strategy is based on the origin of Unit Vector Templates (UVT) from the distorted supply. The series filter is forced by injecting voltages (**Vc_a, Vc_b, Vc_c**), which cancel out the distortions available in the supply voltages (**Vs_a, Vs_b, Vs_c**), and thus making the voltages perfectly balanced and sinusoidal at the load terminal (VLa, VLb, VLc). The control strategy for the series APF is shown in Fig.6. As the supply voltage is unbalanced or distorted, a phase locked loop (PLL) is employed to achieve synchronization with the supply. Three phase unbalanced supply voltages are sensed and set to the PLL which gives angle (ωt) i.e. varying from 0 to 2*π radian, corresponding to zero crossings of the fundamental (positive-sequence) of phase A. The sensed supply voltage is multiplied with some suitable value of gain before it is given as an I/p to PLL. The angle (ωt) output from the PLL is used to calculate the supply in phase, and 120^0 displaced three unit vectors (U_a, U_b, U_c) using equation.

U_a= sinωt; U_b= sin(ωt-120^0); U_c= sin(ωt+120^0)

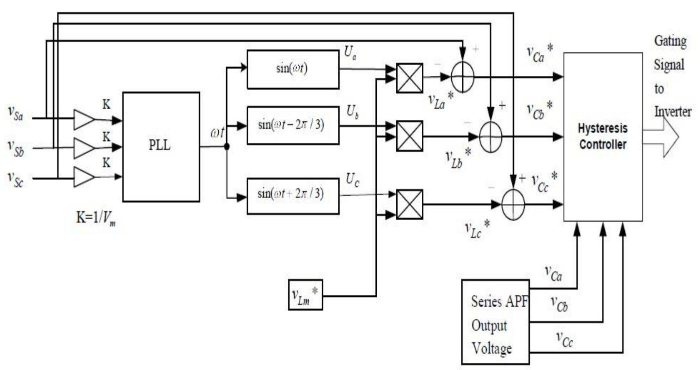

Fig. 6.1 Control Scheme Of Series APF

In order to maintain distortion less load voltage, the value of load voltage must be equal to the calculated value of reference voltage. To generate injected voltages, the supply voltage signals are compared with these reference signals and then these signals are delivered to the hysteresis voltage controller along with the sensed series active power filter output voltages. The output of the hysteresis controller controls the six switches of the Voltage source inverter of series active filter. The output of the hysteresis controller generates the switching signals and the voltage at the load becomes the required sinusoidal reference voltage. Therefore, the injected voltage applied to the series transformer through the ripple filter mitigates the harmonics and voltage unbalance present in the supply voltage.[7]

7. SIMULATIONS AND RESULTS

In these section Series active filter is shown. The developed simulation model of series APF is shown in fig. 7.1. To analyze the performance of series APF during voltage sag conditions, the voltage supply source is considered sinusoidal and contains no harmonics as shown in fig 7.2.

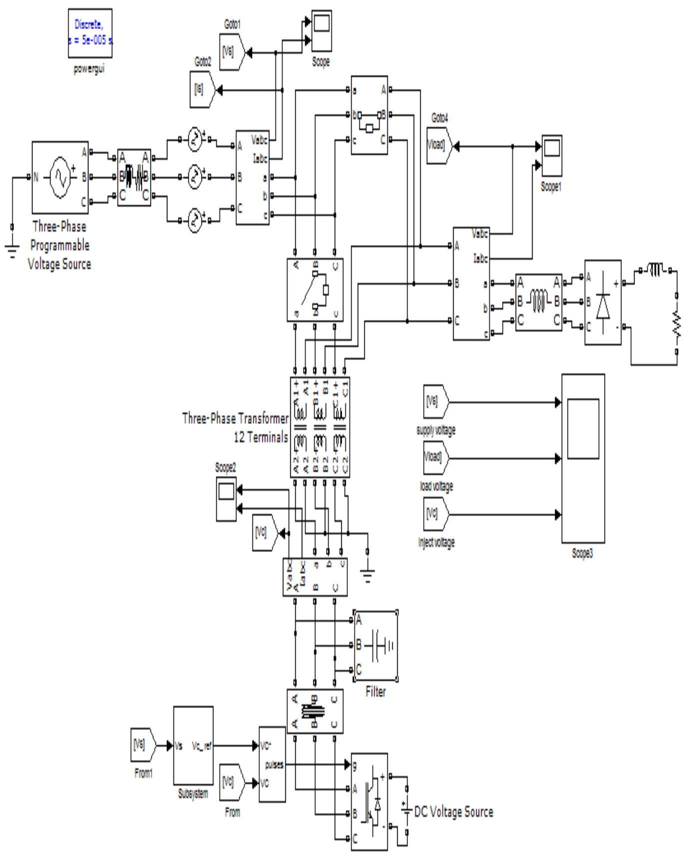

Fig.7.1 Simulation of Series Active Power Filter

At instant 0.1 sec. sag (25%) is introduced to the supply voltage .This sag lasts till the instant 0.3 sec. During the voltage sag condition, the series inverter injects an in-phase voltage (25%) equals to the difference between the desired load voltage and actual source voltage, as seen from Fig. 7.4 Thus, it helps to maintain the load voltage profile (Fig. 7.3) at desired level such that the sag in source voltage does not appear at the load terminal. The desired load voltage (V_{Lm}) is assumed to be 310.2867 volts which is calculated as:

$$V_{Lm}= V_{L-L}* \sqrt{2/3};$$

Where V_{L-L} is the line voltage equal to 380 volts. To analyze the harmonic compensating ability of series APF, the distortion in utility voltages are introduced intentionally by injecting a 5th (20%) and 7th (15%) order voltage harmonics.

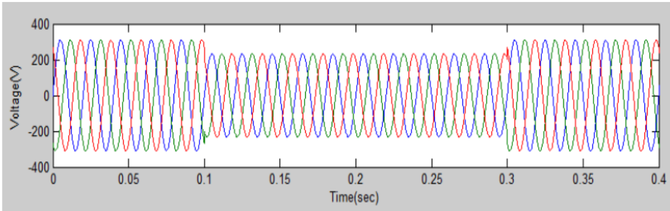

Fig.7.2 Source voltage

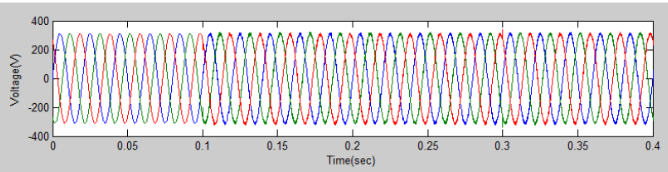

Fig.7.3 Load voltage

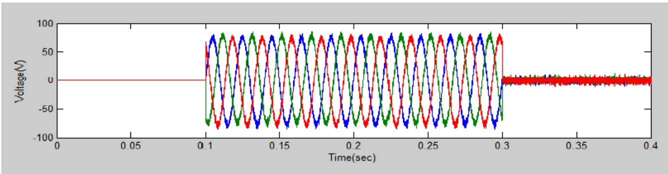

Fig. 7.4 Injected voltage

The resultant highly distorted source voltage waveform shown in Fig. 7.5 has THD of 25% as the THD information of source voltage for phase-A is shown in Fig. 7.8. Such a extremely distorted voltage may be problematic for many sensitive loads. The series APF is put into operation at 0.1 sec. The series APF starts mitigating voltage harmonics instantly by injecting sum of 5th and 7th harmonics, hence provide distortion free load voltage (Fig. 7.6). The voltage injected by series APF is shown in Fig. 7.7. Here load voltage THD is improved up to 25 % to 1.82% of load voltage is shown in Fig. 7.9

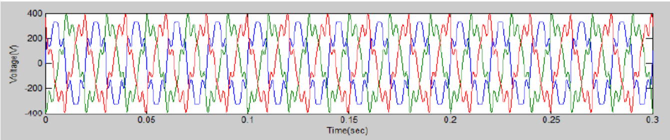

Fig. 7.5 Distorted source voltage

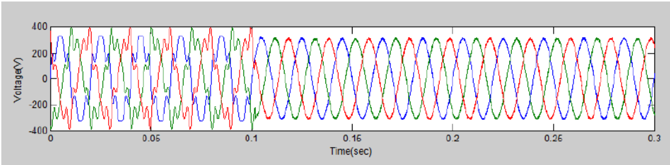

Fig. 7.6 Load voltage before and after compensation

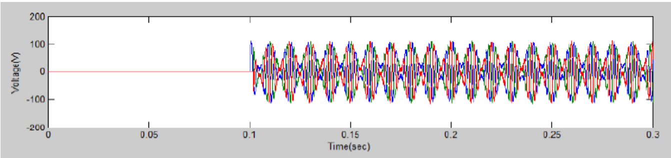

Fig. 7.7 Inject voltage

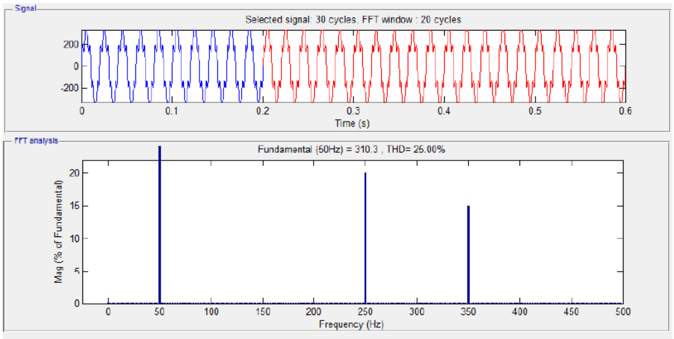

Fig.7.8 Source voltage THD

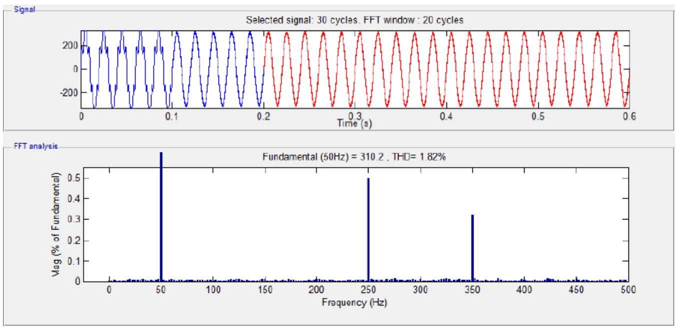

Fig. 7.9 Load voltage THD with series APF

8. CONCLUSION

This paper presents simulation results of series active power filter. Different power quality problems, causes and their consequences and the available solution have been discussed briefly. The performances of the model have been found to be satisfactory for load harmonic and reactive power compensation, mitigation of voltage sag and swells. A simple control technique, extraction of unit vector template has been used to model the control scheme for series APF. This scheme utilizes phase locked loop (PLL) and a hysteresis band controller to generate the reference signals for series APF. By using hysteresis band controller the simulation model has been developed in MATLAB platform. The performance of the model has been studied under non-linear load. It is noticed that source current and load voltage THD levels are maintained below 5 %, the THD limit is trying to impose by IEEE 519-1992.

9. FUTURE SCOPE

The Series APF model as developed can be modified to be more effective in eliminating power quality related problems in power system. The various paths in which the presented work can be extended are listed below:

- A laboratory prototype can be made for the developed model.
- The control strategy used here can be modified for three-phase four-wire system below unbalance load.

Nowadays, generation of electricity from renewable sources has improved very much. Utilizing wind energy and solar energy as a renewable source to generate electricity has developed rapidly. Series APF can be combined with one or several distribution generation (DG) system to provide good quality power to the consumers.

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