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Harmonic Mitigation by Using Hybrid Series Active Power Filter

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***Abstract*: The loss of dignity in power quality causes various effects on utilities side and customer side. Voltage harmonic and current harmonics are power quality issue. This paper suggests a series active filter with a simple control technique. The series active filter decreases the terminal harmonic voltages, supplying linear or even nonlinear loads with a good quality voltage waveform. The control strategy plays vital role to improve the performance of a hybrid series active power filter (HSAPF). This paper presents the MATLAB simulation of hybrid series active power filter to lower the harmonics and improve the power quality.**

***Keywords*: Shunt passive filter, series active filter, power quality, Harmonics, Hybrid series active power filter (HSAPF)**

1. Introduction

Due to the development in the technology also the development in the smart grid, consumers demand is increases so there is a necessity of improved power quality. with the rapid increase in the non-linear load it is difficult to achieve improved power quality. Non – linear loads draw harmonic current from the utility and due to that harmonic voltage is generated. Harmonic distortion can cause problem in power distribution side and consumers side. Voltage distortion, caused by non-linear loads, failing of equipments, overheating, ageing and poverty of the performance of equipment etc., is a common phenomenon in electrical power system [1]. A inaccurate load voltage causes harmonic currents to flow at the distribution side of three phase power supply system. This harmonic components, existent at the load side, may overheat the distribution transformers at below than nominal load and thus obstruct power distribution. The traditional method for compensate the harmonic current is to used the passive filter [2]. When passive filter is connected in parallel with the load certain problems are observed, such as - series or parallel resonance , overloads owing to the harmonics to the non-linear loads etc. These filters are not suitable for variable loads and they greatly depend on the system impedance. Therefore, passive filter cannot be a better solution for harmonic compensation.

Another method to compensate harmonic possible solution is the active power filter (APF) technique. This technique initiates to draw care since 1970s. An active power filter normally contains of three phase pulse width modulation (PWM) voltage source inverter. When active filters are connected in series or in parallel with the load, it is likely to improve the harmonic compensation feature of the system. That is why from the beginning of the 1980s active power filters (APFs) are one of the common compensating techniques [3]. The APF can be connected in two manner parallel or series of the load. The first one is shunt active power filter known and the other is series active power filter [4].

New trend is to develop the shunt APF. It can be used under non sinusoidal supply voltages. But the voltages at the point of common coupling (PCC) of the APF are harmonics polluted which is due to the non-linear loads in the APF application environment. However, it is not always suitable to employ due to its higher cost and lower capacity. Moreover, it faces some problems when it is used in high-voltage grid. For the necessity of improving harmonic compensation performance, power factor improvement and decreasing the size of an active power filter, a series active power filter is used. Series active power filter is cost effective and easy to implement.

2. System Diagram of HSAPF

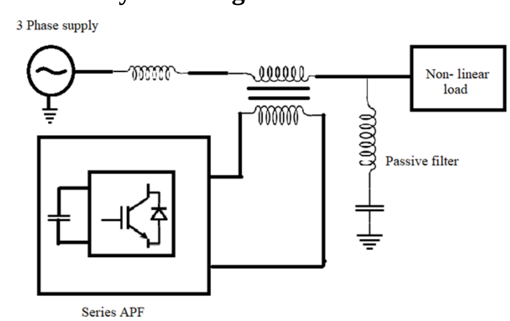

Fig. 1. Block diagram of hybrid series APF

Technical limitations of conventional APFs can be overcome with hybrid APF arrangements. They are generally the arrangement of basic APFs and passive filters. Which is shows in Fig. 1. Hybrid APFs, getting the profits of both passive filters and APFs offer better performance and cost-effective results. The idea behind this system is to successively decrease the switching noise and electromagnetic interference. The idea of hybrid APF has been offered by several researchers. In this arrangement, a less cost passive high-pass filter (HPF) is used in addition to the conventional APF. The harmonics eliminating task is divided between the two filters. The APF stops the lower order harmonics, while the HPF filters pass the higher order harmonics.

3. Control strategy

A. Compensating Current Generation Method for HAPF by Using PWM

To produce the compensating current as its reference value, the HAPF should be controlled and acted as a current source. The HAPF common method for generating compensating current by a VSI is indirect current (voltage reference) control, in which the final reference compensating current is converted into a voltage reference. Then the voltage reference is compared with a triangular carrier in order to create pulse width modulation (PWM) gate signals for switching devices of the VSI. To increase the compensation performance, combine the feedback control and feed forward control by detecting both the system source currents and load currents respectively. Actually, in order to determine the exact voltage reference from the reference compensating current for HAPF, a modeling containing the coupling LC and load voltage is essential. However, as the coupling LC is a second-order circuit, which might be complex to deduce the exact modeling, therefore, use an approximation model (multiplying the reference current by a gain) to compute the voltage reference. This approximation will induce errors to the reference signal.

4. System Diagram in MATLAB

Hybrid shunt active filter simulation is done for 3Φ, 50 Hz supply system for three phase RLC load. Matlab simulation model is shown in Fig. 2. The three phase programmable voltage source is connected to the load. It consists of the three phase transformer, series active filter, shunt passive filter. At the load side three phase R, L, C load are connected. The series active filter is connected in series while passive filter is connected in shunt.

This topology of the HSAPF is composed of a series connected active power filter (SAPF) and a shunt connected passive power filter (PPF). The PPF consists of a fifth and seventh tuned LC filter for compensation of harmonic current on the load side.

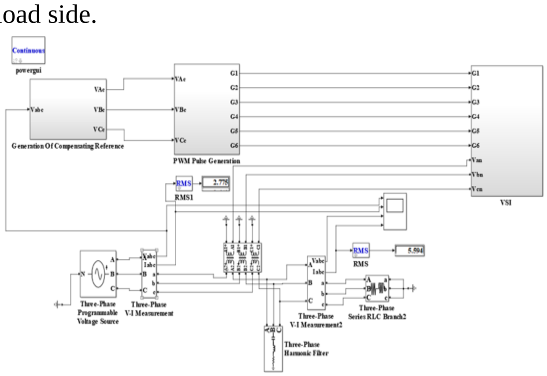

Fig. 2. Simulation model of hybrid series active power filter

5. Simulation results

In Fig. 2, shows the complete simulation diagram for Hybrid series active power filter (HSAPF). In the given figure we used three phase programmable supply. By using this we create disturbance in the system. We have to mitigate harmonic produced in the system. So, we used Hybrid series active power filter for harmonic mitigation. The waveforms for with and without filter are shown below.

A. Current and Voltage Waveform

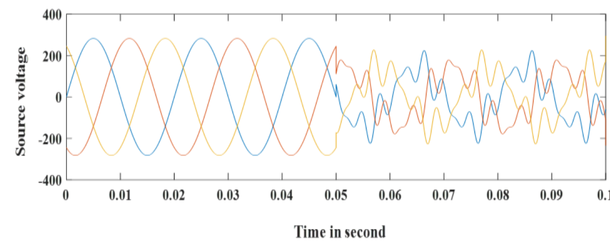

Fig. 3. Source voltage without Hybrid series active power filter

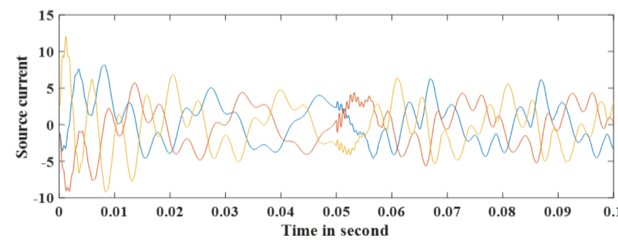

Fig. 4. Source current without Hybrid series active power filter

The waveforms of source voltage (v_{sa}, v_{sb}, v_{sc}) before compensation are given in Fig. 3. source current is non sinusoidal as shown in Fig. 4. The load current is non-sinusoidal due to the harmonics produced in system.

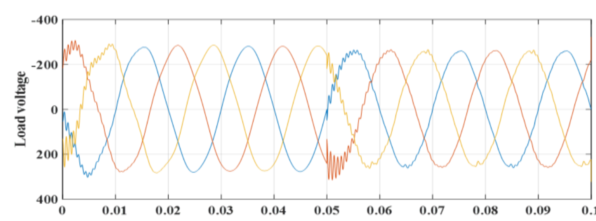

Fig. 5. Load voltage with hybrid series active power filter

In the given figure, the load voltage is constant from 0.01 to 0.05. But after 0.05 it somewhat disturb. The Fig. 5, shows the Load voltage with Hybrid series active power filter. Here, series active filter is work.

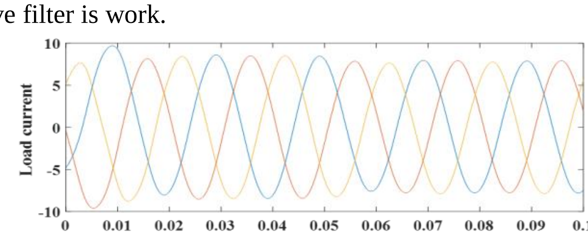

Fig. 6. Load current with Hybrid series active power filter

In the given figure, passive shunt filter is work. Fig. 6. shows Load current with Hybrid series active power filter. In the given figure, fifth and seventh order harmonic are eliminated by using single tuned passive filter. By eliminating the harmonics using filter we obtained an undisturbed sinusoidal waveform.

B. THD Responses

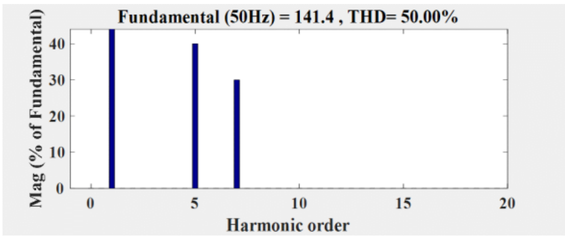

Fig. 7. THD response for source voltage without Hybrid series active power filter

Fig. 7, shows the FFT analysis for signal number 1. It shows response for without Hybrid series active power filter. The THD is approximately 50%.

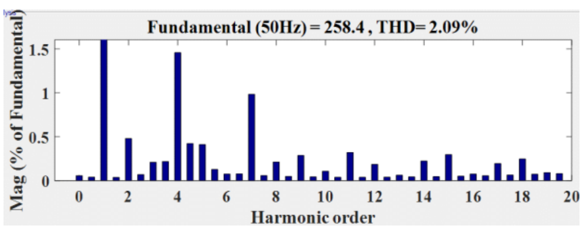

Fig. 8. THD response for load voltage with Hybrid series active power filter

Fig. 8. shows the THD response for load voltage i.e. shown for phase ‘a’. Because we used balanced three phase supply so, the THD for all three phases are same. So we show THD response for phase ‘a’. The THD response is reduced by using filter from 50% to 2%.

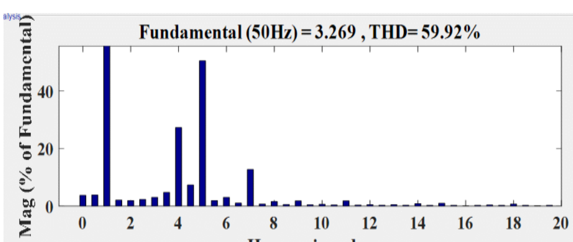

Fig. 9. THD response for source current without Hybrid series active power filter

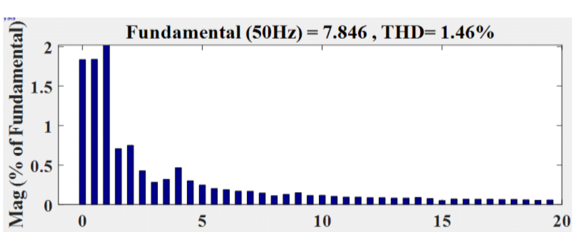

Fig. 10. THD response for load current with Hybrid series active power filter

The THD response without Hybrid series active power filter is too high. near about 60%. Fig. 9, shows the THD response for source current without Hybrid series active power filter.

The THD response is of load current with Hybrid series active power filter is reduced in Fig. 10. By using filter, we reduced THD response from 60% to 1%.

6. Conclusion

This paper proposed hybrid series active power filter to enhance the power quality in distribution system. From the obtained simulations as well as experimental results, the proposed HSAPF has been observed to provide effective current as well as voltage harmonic mitigation, reference voltage tracking behavior, and reactive power compensation with dynamically varying load conditions

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