Modeling and Simulation of Shunt Active Power Factor using Synchronous Detection Method

Sana M.K.

Abstract—**Active power filters (APFs) provides an effective measure to eliminate the power line harmonic/reactive currents generated by nonlinear loads or by distributed energy sources that are connected to the grid. In order to mitigate the harmonics, active power filters (APFs) are used. APF overcomes the drawbacks of passive filters by using the switching mode power converter (VSI) to perform the harmonic current elimination. Active power filters are typically connected in parallel to the harmonic/reactive current sources and cancel the harmonic/reactive components in the line current so that the current flow into and from the grid is sinusoidal and in phase with the grid voltage. In this paper, a three phase shunt active power filter using synchronous detection method with a hysteresis current control technique is presented.**

Index Terms—**APF, SDM, harmonics, grid.**

I. INTRODUCTION

Our current power system, the utility grid generates, transmits, and distributes power with sinusoidal voltage waveforms. When currents flowing in the grid are sinusoidal and in-phase with the voltages, the power system operates at the highest efficiencies and features the maximum power handling capability. Unfortunately, most electronic loads draw non sinusoidal currents that introduce harmonics and reactive current into the utility grid. In recent years, as the applications of electronic equipment in industry, commercial, agriculture, and residential fields increase, harmonics in the utility grid have become a very serious power quality issue, which deteriorate the energy efficiency, reduce the power transmission capability, and cause harmful pollution to other appliances in the grid. The existence of the harmonic and reactive current is harmful to the power system itself and also to the other equipment in the neighborhood [1]. The evidences are-reducing the power handling capability of the power system because of the delivery of harmonic & reactive current, increasing the level & accelerating aging of the insulation due to the elevated peak current, lowering the energy efficiency because of the additional copper loss on the transmission line & equipment, decreasing the PF (Power Factor) for harmonics contribute reactive power flow, disturbing the neighborhood equipment with distorted voltage and EMI, and causing additional heat loss, dangerous to the safety of protection device & therefore of the whole power system[2].

Shunt active filters were proposed as a means of removing harmonic current. In an active power filter, a controller determines the harmonics that are to be eliminated. The output of this controller is the reference of three-phase current controlled inverter.

Sana M.K., VJEC, Kerala, India.

Conventionally, passive LC filters have been used to eliminate line current harmonics and to increase the load power factor[3]. However, in practical applications these passive second order filters present the following disadvantages: the source impedance strongly affects filtering characteristics, as both the harmonic and the fundamental current components flow into the filter, the capacity of the filter must be rated by taking into account both currents, when the harmonic current components increase, the filter can be overloaded, parallel resonance between the power system and the passive filter causes amplification of harmonic currents on the source side at a specific frequency, the passive filter may fall into series resonance with the power system, so that voltage distortion produces excessive harmonic currents flowing into the passive filter.

APF overcome the drawbacks of passive filters by using the switching mode power converter to perform the harmonic current elimination. Shunt active power filters are developed to suppress the harmonic currents and compensate reactive power simultaneously [4]. The power converter of active power filter is controlled to generate a compensation current, which is equal but opposite to the harmonic and reactive currents generated from the nonlinear load. Thus the main currents become sinusoidal

II. METHODOLOGY

A. Method

A three-phase uncontrolled diode bridge rectifier with resistive loading is considered as a non-linear load on three phase ac mains. This load draws non-sinusoidal currents from ac mains even though mains supplies sinusoidal currents. This causes the source current to be distorted, i.e., harmonics is introduced in the lines. In order to mitigate the harmonics, active power filters [APFs] are used. APF overcomes the drawbacks of passive filters by using the switching mode power converter [VSI] to perform the harmonic current elimination. The switching action of VSI is controlled by a hysteresis current controller [HCC]. It forces the VSI to produce compensating current which follows the actual compensating current which is equal but opposite to the harmonic and reactive currents generated from the nonlinear load. In this situation, the main current becomes sinusoidal and in-phase with main voltages.

B. Problem Identification

Non-linear loads are ones which draws non-linear currents from the source. That means whenever non-linear current draws from source, the source current will distort. As power electronic devices are non-linear in nature they also injects harmonics to the power system and hence distorts the source and therefore the total harmonic distortion (THD) will be

high. Here we are considering a three phase supply system and a three phase rectifier bridge as the non-linear load. After simulation it is found that the source current is distorted due to the harmonics injected by the load. The total harmonic distortion for the above system is found to be almost equal to 30%.

Hence our aim is to inject compensating current to rectify the source current distortion and to make the THD below 5%. This can be achieved by connecting a shunt active power filter in the system.

III. RESULTS

A. Without active filter

Figure 1 shown below represents the voltage and current graph without active power factor. The voltage and current are sinusoidal.
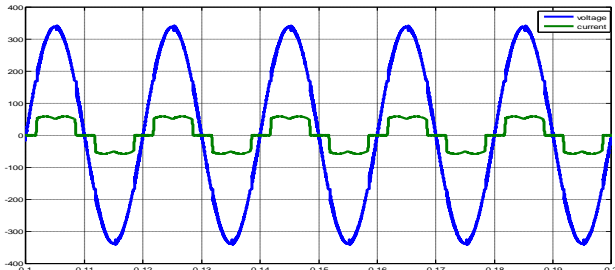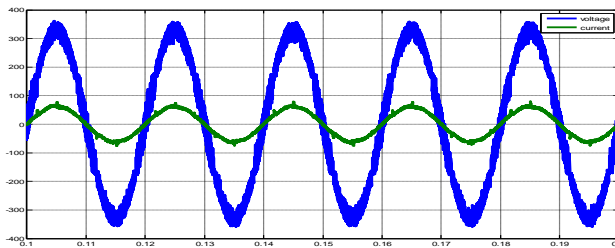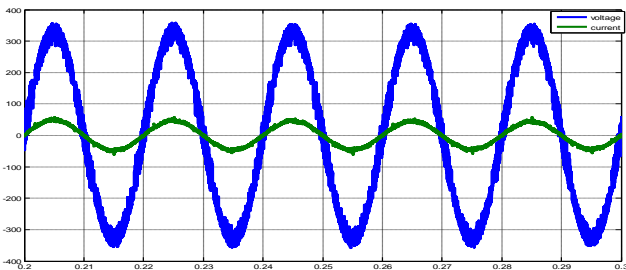
Fig. 1 Voltage and current without APF

B. With active power filter

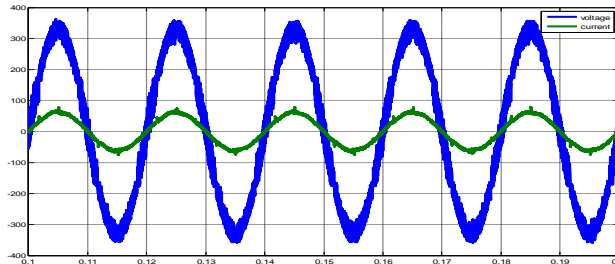##### a. With R load

b. With RL load
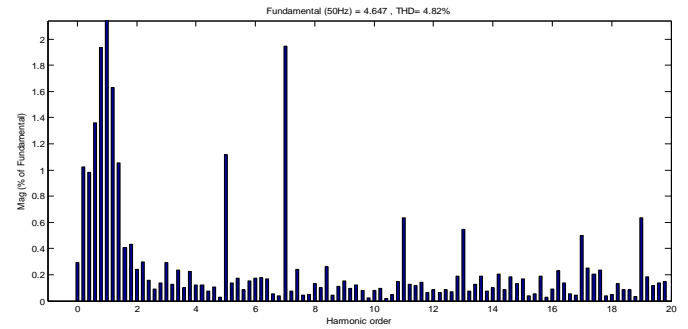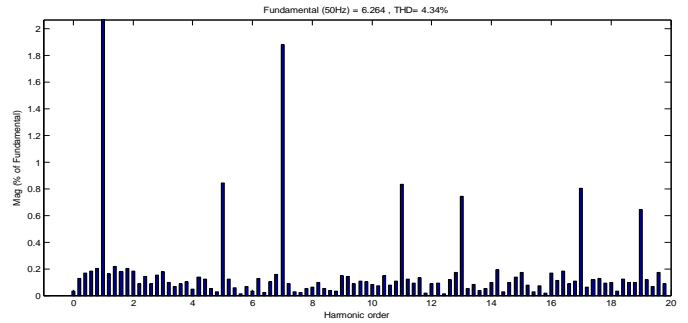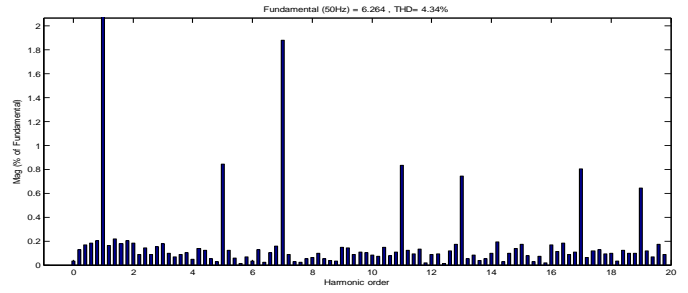
c. With RC load

Fig. 2 Voltage and current waveform (a) R load (b) RL load (c) RC load with APF

C. THD waveform

Fig. 3THD waveforms for (a) R load (b) RL load (c)RC load

Figure 3 shows the THD for three different loads: R, RL, RC loads. The THD for R load is 4.23%, RL load is 3.4% and RC load is 4.3%.

From the wave forms and THD plot of a three phase system it is clear that, if a non-linear load is connected to the supply system, it draws non-linear currents and hence distorts the source current. The source current has to be made sinusoidal. In order to obtain sinusoidal current, an active power filter is shunted across the system. It injects compensating current which is equal and 180 phases shifted to the harmonic current produced by the non-linearity.

IV. DISCUSSION

The degree of current distortion is represented by the percentage of total harmonics distortion (THD). Total harmonic distortion of a three phase system with a non-linear load was found to be 29.9%. The distorted source current is no longer a sinusoidal waveform. As per IEEE standard 519 the THD should be less than 5%. In order to reduce the harmonic distortion, a shunt active filter is connected across the system. So that the non- linear current required by the load

is compensated by the active filter. After connecting an active

Condition	Load	THD(%)
Balanced	R	4.23
Balanced	RL	3.4
Balanced	RC	4.3
Unbalanced Source	RL	4.3
Dynamic Switching	RL	4.8

power filter, the THD is obtained below 5%. THD for different condition is given below in table 1.

Table1. Comparison of THD for different condition

Load current for R, RL and RC loads were plotted and load current for RC load was found to be decreasing. However, when the compensated harmonic currents are added into the distorted line, a sinusoidal waveform is obtained.

V. CONCLUSION

Harmonic distortion has harmful effects on both distribution system equipment and on loads that the system supplies. Because of this, harmonic distortion is a main cause of supply quality degradation. To overcome the power quality problems one should make use of harmonic filters which will not only suppress harmonics but also supplies the reactive power for the improvement of power factor[5]. An active filter provides multiple functions such as harmonic filtering, damping, isolation and termination, load balancing, reactive-power control for power-factor correction and voltage regulation, voltage-flicker reduction, and/or their combinations[6-7]. A cluster of the above functions can be represented by "power conditioning." Hence, the active filter is well suited to "power conditioning" of nonlinear loads such as electric ac arc furnaces, and utility/industrial distribution feeders.

In this work, synchronous detection method using equal current division technique has been applied to a shunt active power filter to compensate for reactive and harmonic currents. A novel hysteresis control method for harmonic current compensation has been proposed. Switching losses are reduced because only two switches are controlled at any instant of time. An algorithm for determining the switches to be operated is presented. It is shown by simulation that the proposed scheme is successfully able to track the harmonic current required to be injected. Here the equal current synchronous detection method is apply to an active power filter for an unbalanced three phase load system under unbalanced three phase voltage. The simulation has been carried out in MATLAB/SIMULINK system. And the source current is made sinusoidal, successfully under balanced and unbalanced source conditions and even under dynamic condition. The total harmonic distortion caused by the non-linearity present in the load is found to less than 5% after compensation.

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