Harmonic Reduction using Inverter based Hybrid Shunt Active Power Filter

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***Abstract* - In the recent decades the world has seen associate growth within the use of non-linear load. The Shunt Active Power Filter (SAPF) injects an acceptable compensating current at a degree of the line called as the point of common coupling (PCC) so that the harmonics present within the line are cancelled out and the sinusoidal nature of voltage and current waveforms are restored. A three phase current controlled voltage source inverter (VSI) with a DC link capacitor across it is used as an active filter. Synchronous Reference Frame (SRF) algorithm is employed to extract the harmonic components. Hysteresis band current control (HBCC) technique is employed for the generation of firing pulses to the converter. The loads draw harmonic non-linear currents and voltages among the association purpose with the utility and distribute them. The propagation of these voltages and currents within the grid affects the facility system additionally to the opposite shoppers equipment's. As a result, the power quality has become a crucial issue for each shopper and distributors of electrical power. Power filters are projected as an efficient tool for power quality improvement and reactive power compensation. In this work different harmonic effects is discussed and introduced. The different traditional and trendy harmonic resolution topologies are given. The employment of SAPF for harmonic current and reactive power compensation is studied. Shunt active power filter because the most notable and used active power filter is employed. Different studied SAPF control ways implemented in MATLAB/SIMULINK and result are tabulated and mentioned.**

Keywords - Hysteresis current controller, Hybrid filter, MATLAB/SIMULINK, PI controller, Shunt active filter, Total Harmonic Distortion, Synchronous reference frame (SRF) Controller, Voltage source Inverter .

INTRODUCTION

Harmonic and reactive power regulation and guideline are forthcoming issues and more and more being adopted in distributed power system and industries. Very important use of power electronic appliances has created power management good versatile and economical. However aspect by aspect they are resulting in power pollution owing to injection of current and voltage harmonics. Harmonics create issues within the integrated power system. The researchers and engineers have started making effort to use harmonic rules through pointers of IEEE 519-1992. Awfully before long customers have to be compelled to pay and avail the ability for prime performance, high potency energy saving reliable and compact power electronics technology. It is expected that the continual efforts by power electronics researchers and engineers can create it attainable to soak up the inflated price for finding the harmonic pollution.

The thyristor controlled reactors of varied network configurations are widely employed in industries and utility systems for harmonic mitigation and dynamic power factor issue correction. These thyristor controlled reactor operate as a variable reactance in each the inductive and electrical phenomenon domains.

By means that these two parameters two kinds of issues measure unexceptionally encountered. The first problem is the reactive power (Var) that results into poor power issues and therefore the harmonics seems owing to presence of power converter devices and nonlinear loads for instance, electrics machines unsteady industrial loads such as electric arc furnaces rolling mills converters etc.

These types of significant industrial loads unexceptionally focused in one plant and served from one network terminal and thus will be handled best by a local compensator connected to an equivalent terminal.

The main emphasis of the investigation has been on compact configurations, simplicity in control, reduced rating of components and thus finally leads to reduce the overall cost. Based on these specifications, a wide range of configurations of power quality mitigators are developed for providing a detailed exposure to the design engineer in selection of a particular configuration for a specific application under the given constraints of economy and the desired performance. Fig shows a shunt passive filter is connected the power system through common coupling point (PCC). Because of using non-linear loads, the load current characteristic is non-linear in nature. The compensating current which is the output of the shunt passive filter is injected in PCC. By this process the harmonics are eliminated and current between the sources is sinusoidal in nature. The passive filter is popular in elimination of harmonic current in power system. To control this process there are two ways i.e.

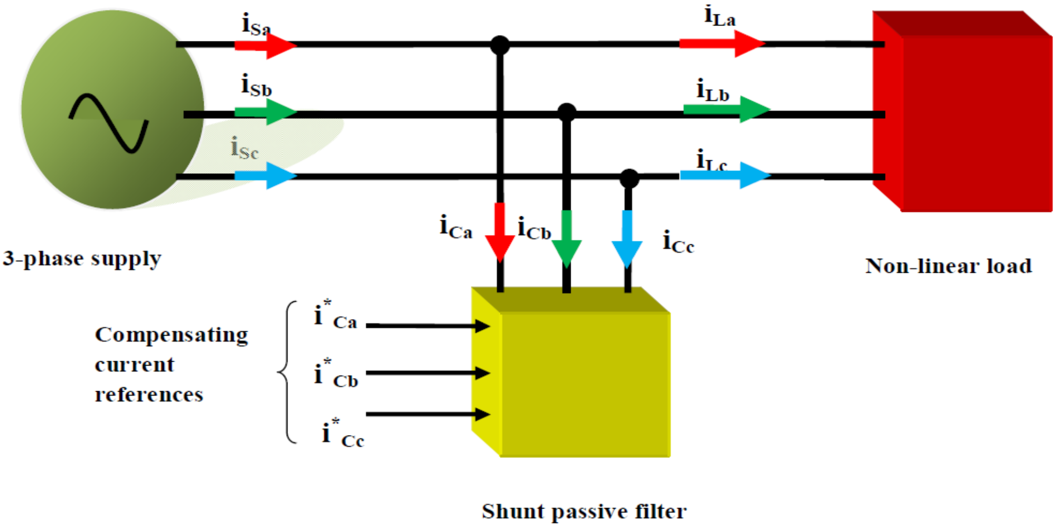

FIGURE: The classical shunt passive filter

ACTIVE POWER FILTERS

Active power filters is the device which generate the same amount of harmonic as generated by the load but 180o phase shifted. So when these harmonics are inserted into the line at the point of common coupling the load current harmonics are eliminate and utility supply becomes sinusoidal. There are basically two types of active filter: Series active filters and shunt active filters.

Below figure shows the basic scheme of shunt active power filter which compensate load current harmonics by injecting equal but opposite harmonic compensating current.

Fig. 1 Basic scheme of shunt active power fi

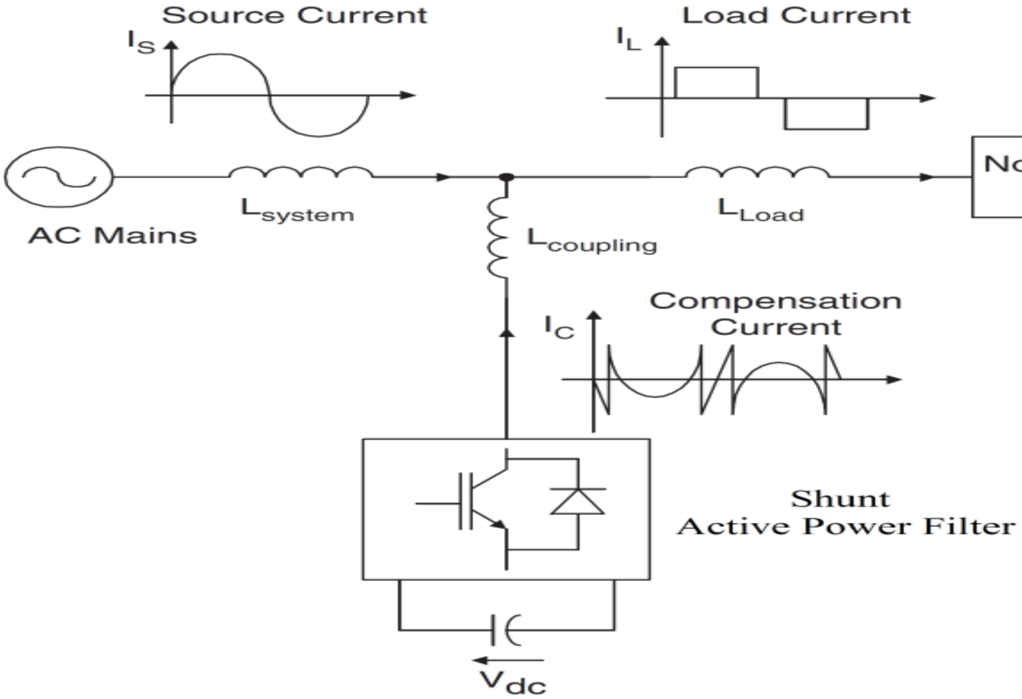

FIGURE: Basic scheme of shunt active power filter

Basically shunt active power filter operates as a current source injecting the harmonic components generated by the load but phase shifted by 180°. As shown in below figure series active power filters operate mainly as a voltage regulator and as a harmonic isolator between the nonlinear load and the utility source.

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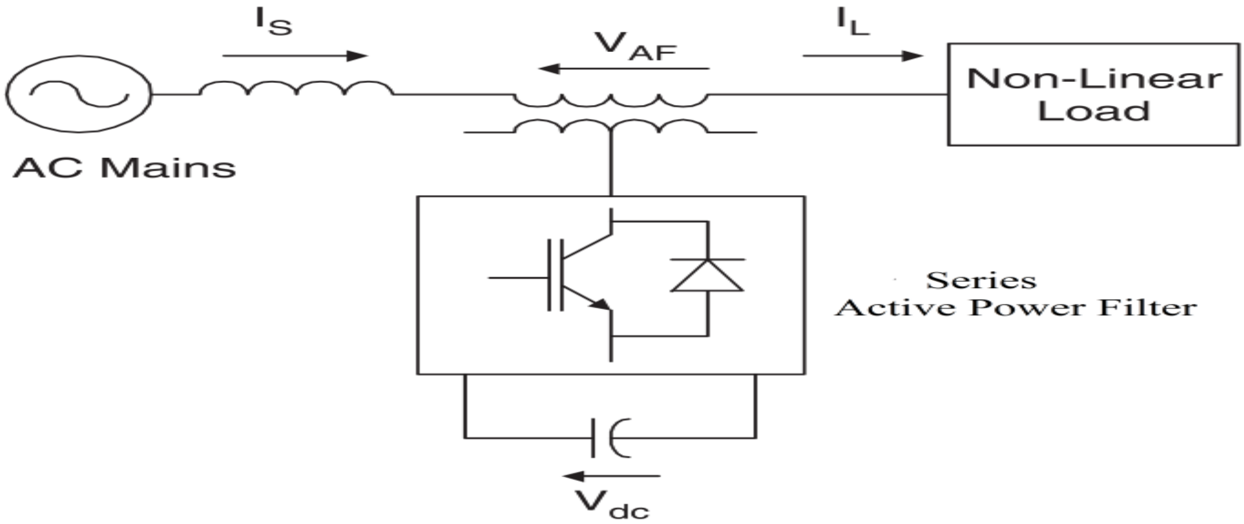

FIGURE: Basic scheme of series active power filter

The series active filter injects a voltage component in series with the supply voltage and removes harmonic components in voltage waveforms and therefore can be regarded as a controlled voltage source, compensating voltage sags and swells on the load side. Practically shunt active power filter are more effective and cheaper compared to series active power filters because most of the non- linear loads produce current harmonics. Moreover series active power filter requires adequate protection scheme. The combined series and shunt active filter is called as Unified Power Quality Conditioner

PROPOSED WORK METHODOLOGY

The shunt APLC system contains a voltage source inverter, a synchronous reference frame controller also called compensation controller and hysteresis band current controller for switching signal generation as shown in figure below.

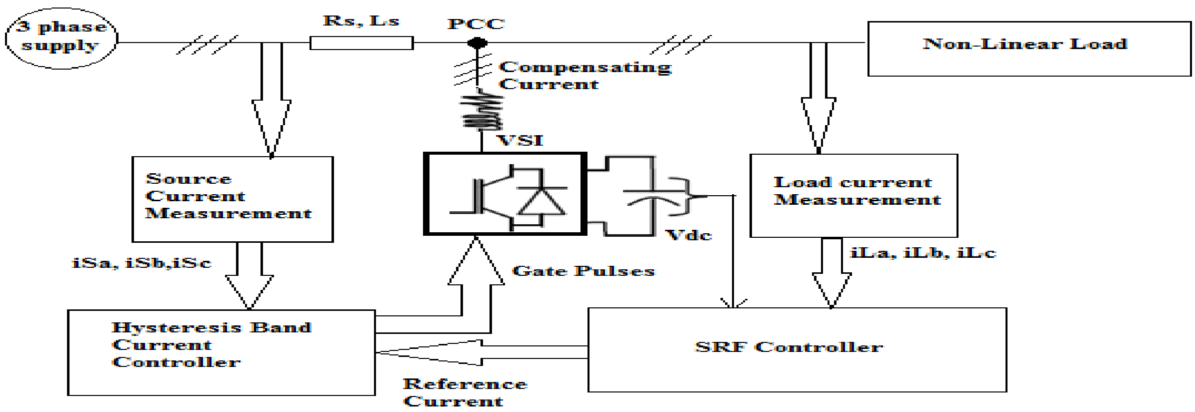

FIGURE: Shunt Active Power Line Conditioners system

Three phase supply source connected with the non-linear load. The nonlinear load current should contain fundamental component and harmonic current components. For harmonic compensation, the active filter must provide the compensation current

$$I_c\,(t) = I_l\,(t) - I_s(s)$$

At that time, source current will be in phase with the utility voltage and become sinusoidal.

Proposed control strategy

The proposed control system consists of reference current control strategy using SRF method

SRF Control strategy:

The synchronous reference frame theory is developed in time domain based reference current generation techniques. The SRF is performing the operation in steady-state or transient state as well as for generic voltage and current; it's capable of controlling the active power filters in real-time system. Another important characteristic of this theory is the simplicity of the calculations, which involves only algebraic calculation.

The block diagram of the synchronous reference frame controller is shown

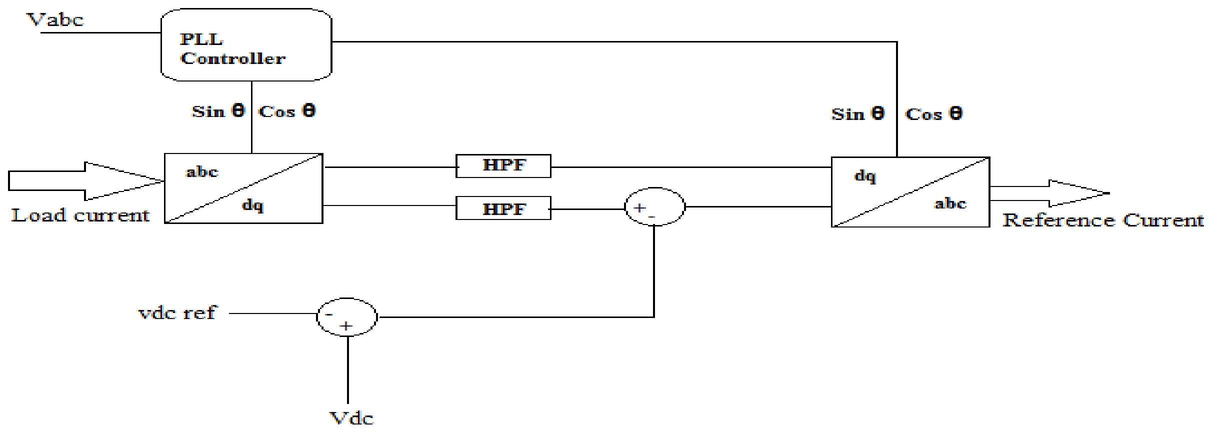

FIGURE: Synchronous reference frame controller

Basic structure of SRF methods consists of direct (d-q) and inverse $(d-q)$ park transformations, which allow the evaluation of a specific harmonic component of the input signals. The reference frame transformation is formulated from a three-phase $a-b-c$ stationery system to the two phase direct axis (d) – quadratic axis (q) rotating coordinate system. In a-b-c stationary axes are fixed on the same plane and separated from each other by 120°. These three phase space vectors stationary coordinates are easily transformed into two axis d-q rotating reference frame. This proposed algorithm derivate from a three-phase stationary coordinate load current i_{1a}, i1b, i1c are convert to id, iq rotating coordinate current as follows

$$i_d = \frac{2}{3}\left[i_{la}\sin(\omega t) + i_{lb}\sin\left(\omega t - \frac{2\pi}{3}\right) + i_{lc}\sin(\omega t + \frac{2\pi}{3})\right]$$
$$i_q = \frac{2}{3}\left[i_{la}\cos(\omega t) + i_{lb}\cos(\omega t - \frac{2\pi}{3}\right) + i_{lc}\cos(\omega t + \frac{2\pi}{3})]$$

The d-q transformation output signals depend on the load currents (fundamental and harmonic frequency components) and the performance of the phase locked loop.

The PLL circuit of rotation speed (rad/sec) of the rotating reference frame ωt set as fundamental frequency component. The PLL circuit is providing sinϴ and cosϴ for synchronization. The id-iq current passed through low pass filter (LPF) for filtered the harmonic components and allows only the fundamental frequency components. The LPF design is based on Butterworth method and the filter order is 2. The band edge frequency is selected the fundamental of 50 Hz for eliminate the higher order harmonic components. Proportional Integral (PI) controller is used to eliminate the steady state error of the DC-component of the inverter and maintains the dc-side capacitor voltage constant. The dc capacitor voltage is sensed and compared with reference voltage for calculate the error voltage. These error voltage involved the P-I gain (KP=0.1 and KI=1) for regulate the capacitance voltage in the dynamic conditions. In accordance to the PI controller output is subtracted from the direct axis (d axis) of harmonic component for eliminate the steady state error. The algorithm is further developed to the desired reference current signals in d-q rotating frame is converted back into $a-b-c$ stationery frame. The inverse transformation from $d-q$ rotating frame to $a-b-c$ stationery frame is achieved by the following equations

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$$i_{sa}^{*} = i_d \sin(\omega t) + i_q \cos(\omega t)$$
$$i_{sb}^{*} = i_d \sin(\omega t - \frac{2\pi}{3}) + i_q \cos(\omega t - \frac{2\pi}{3})$$
$$i_{sc}^{*} = i_d \sin(\omega t + \frac{2\pi}{3}) + i_q \cos(\omega t + \frac{2\pi}{3})$$

MATLAB SIMULATION DIAGRAM

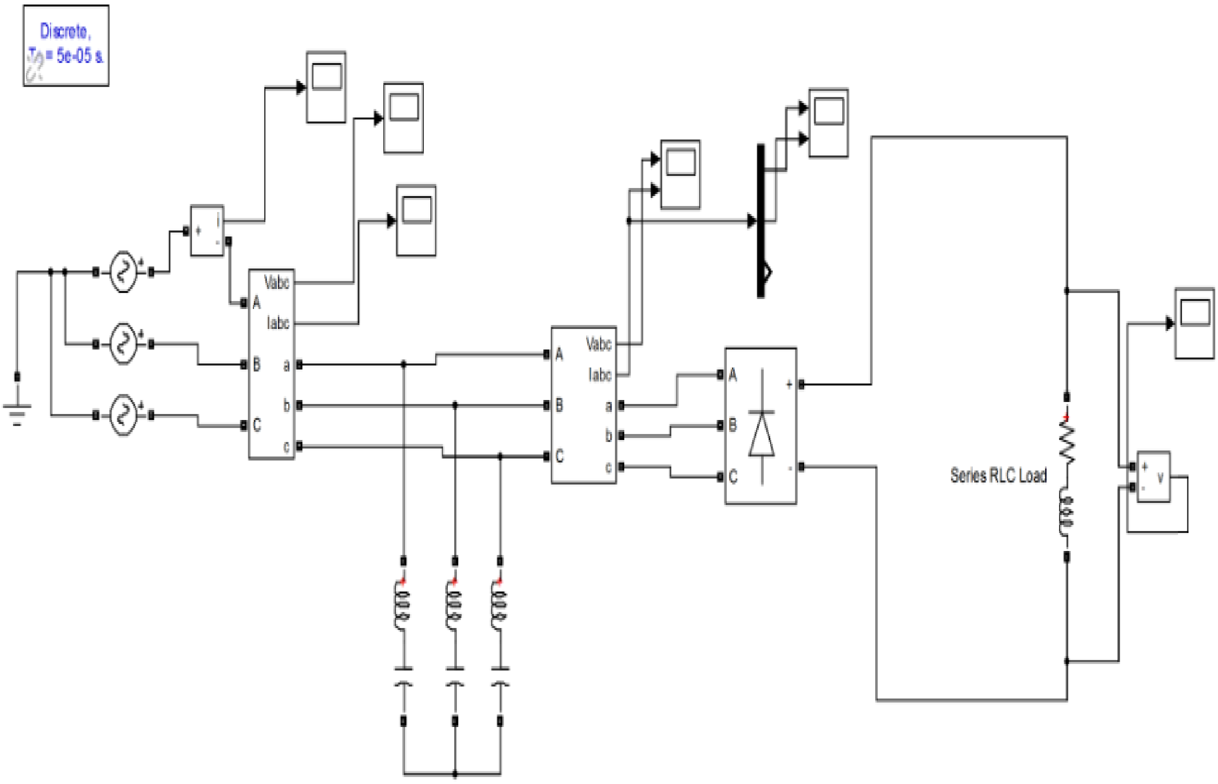

FIGURE: Simulation of passive power filter

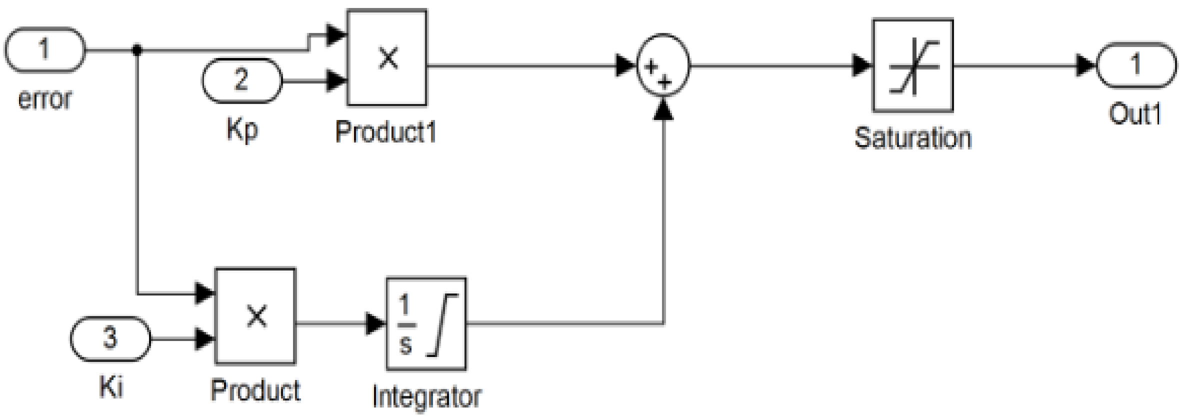

FIGURE: Internal block diagram of PI controller

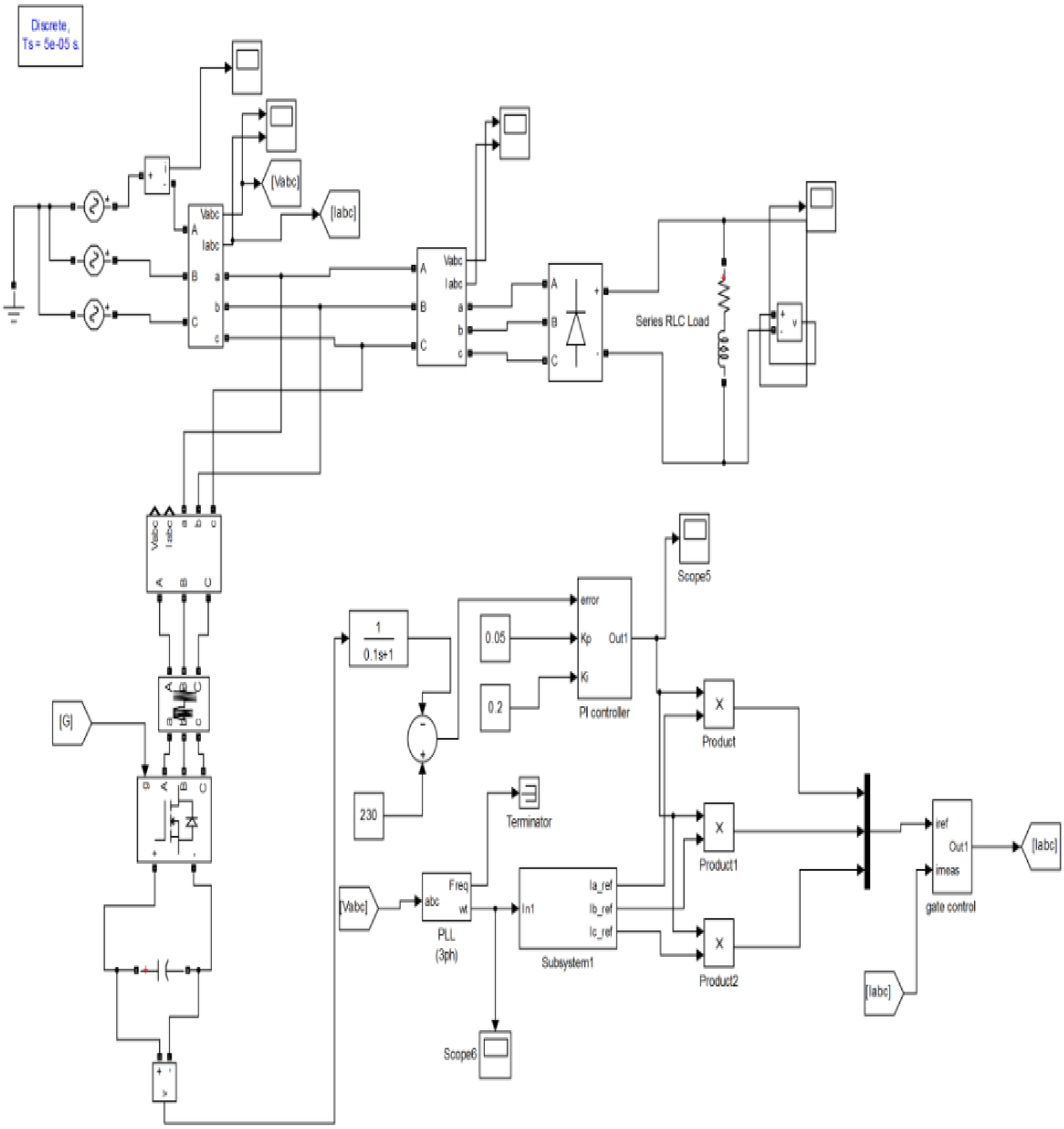

FIGURE: Simulation of PPF and SAPF

Below figure shows the waveform of supply current before compensation. It consists of fundamental current as well as the harmonic current due to the non-linear load.

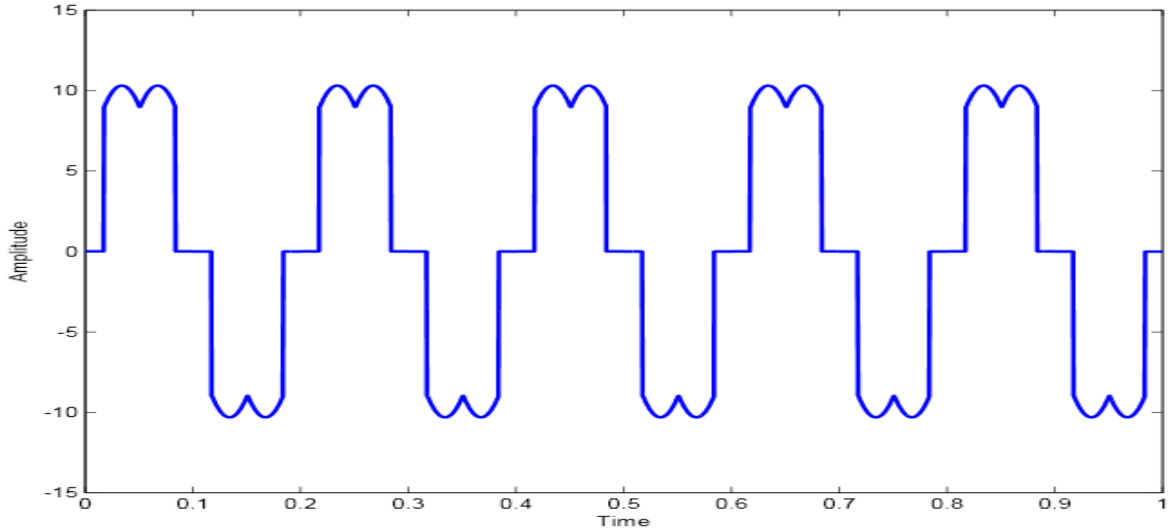

FIGURE: Supply current waveform before compensation

Below figure shows the waveform of supply current after compensation. It consists of fundamental current only. The harmonic current present in the supply current is eliminated by using the Passive Power Filter.

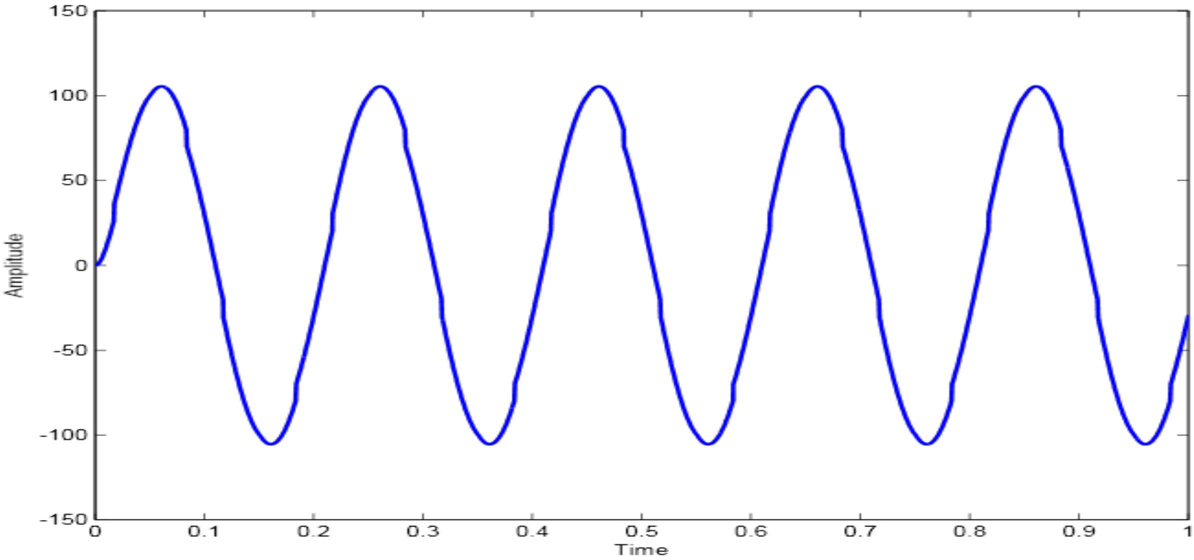

FIGURE: Supply current waveform after compensation using SAPF

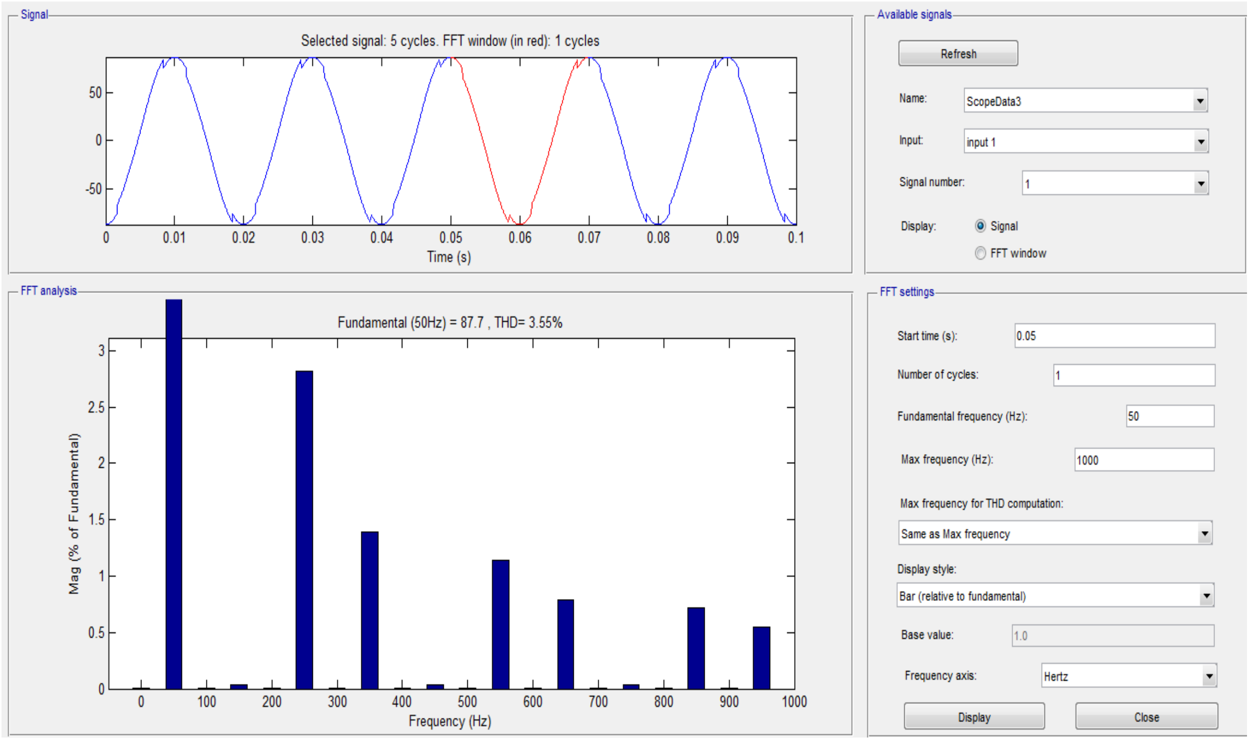

FIGURE: Spectrum analysis of supply current after compensation of PPF

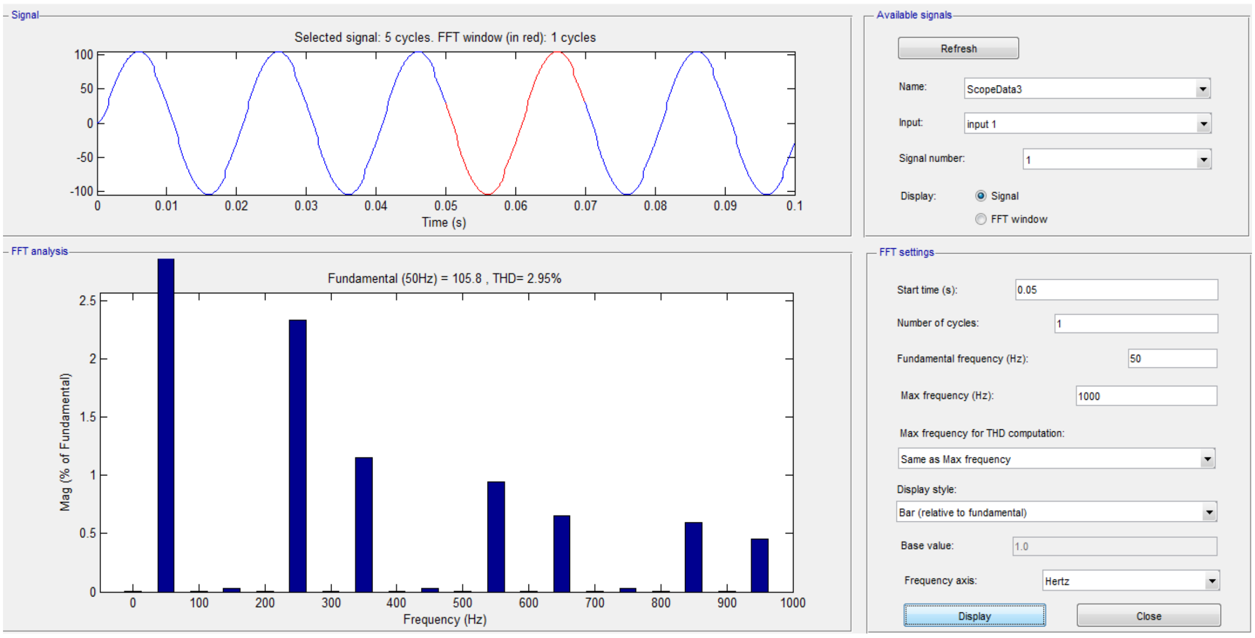

FIGURE: Spectrum analysis of supply current after compensation of combined PPF and SAPF

RESULT

From MATLAB/SIMULINK simulation of hysteresis current controller based mostly active power filter, it's found that THD of supply current is found to 3.55 % after use of filter. Reactive power needed by nonlinear load is totally stipendiary by Shunt active power filter (SAPF) and power factor at supply finish becomes nearly unity. By using combination of Shunt active power filter and Passive Power Filter controller based mostly active power filter, it is found that THD of supply current is found to 2.95 % and reactive power is also completely compensated and power factor is additionally found to be unity at the supply end.

CONCLUSION

As load conditions modification, harmonic current within the network conjointly changes. A fixed element passive filter provides inadequate or more than adequate reactive power compensation at variable load conditions. Therefore, LC components of filter are to be elite and altered supported on the harmonic content and reactive power drawn from supply. Thus associate degree adjusted an adaptive shunt passive filter is planned to fulfill these needs. The inputs to the controller are distorted load currents and voltages at PCC and therefore the controller effectively chooses appropriate element values of filter. This controller is easy to program and is flexible. This adaptive shunt passive filter is proved to be a better solution for harmonics and reactive power compensation, when compared to a traditional passive filter wherever mounted components are perpetually used.

Scope for future research

This research work can be extended to the research areas like: Power systems have evolved from isolated generators feeding their own loads to huge interconnected systems which are spread across the country. Interconnected systems are more reliable, because in case of disruption in one part of the system, power can be fed from alternate paths and thus can maintain continuity of the system. However, harmonic distortions introduced by the nonlinear loads will propagate throughout the system. This issue may be solved by installing filters of suitably designed ratings at optimal locations in the interconnected power system. The optimal allocation and rating of these filters can be determined with help of evolutionary algorithms such as Genetic Algorithm.

For sustainable growth in power system, it is needed to utilize the renewable energy resources like wind, biomass, hydel power, co-generation, etc. The integration of wind energy into existing power system generates power quality issues such as voltage transients, instability, etc. When induction generator is used as wind power generator, it requires reactive power for magnetization. When the generated active power of an induction generator is varied due to wind, the absorbed reactive power and terminal voltage of an induction generator are significantly affected. A proper control scheme in wind energy generation system is required under normal operating condition to allow the proper control over the active power production. Adaptive shunt hybrid filters are suggested for improving power quality issues, when generation rapidly changes with wind speed.

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