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Smart Hybrid Active Power Filter Power Quality Improvement

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Abstract: *Filters are devices that remove undesirable or polluting particles from a required environment. Filters are used to ensure the purity of electrical power in electrical systems. Power filters are used to handle power quality concerns such as power factor, voltage stability, and harmonics. There are two types of filters: passive filters and active filters. The current waveform is injected by the active filter in response to the recognized harmonic in the unit. The active filter is made up of electronic semiconductor switching devices. It takes current from an external source (typically DC) and injects it into the system as a specified current waveform to eliminate harmonics. The ability to give signal gain through amplification and lower output impedance are two major advantages of active filters. Active harmonic filters have seen numerous adjustments and upgrades in their implementation to suit specific applications since its introduction. As a result, series and shunt active filters have been implemented to meet the application's needs. Shunt Active Power Filter as a Smart Impedance with proportional resonant (P + R) controller is presented in this work to reduce current harmonics. The results of a MATLAB simulation model are presented in this paper.*

Keywords: Smart Impedance, Shunt Active Filter, Harmonics, Power Quality, etc.

I. INTRODUCTION

The increasing use of power-electronics-based devices has significantly impacted on electric power supply quality. Harmonics in the network voltages are caused by both high-power industrial loads and home loads. Simultaneously, much of the equipment that causes the disruptions is extremely sensitive to deviations from the optimum sinusoidal line voltage. As a result, power quality issues may arise in the system or be created by the consumer. Conventional equipment is proving insufficient for mitigating power quality problems in an increasing range of applications. Passive LC filters have typically been used to reduce harmonic distortion. However, using passive filters for harmonic reduction might lead to parallel resonances with the network impedance, overcompensation of reactive power at the fundamental frequency, and a lack of flexibility in dynamic compensation of varied frequency harmonic components. Power engineers are working to offer dynamic and adaptable solutions to power quality problems as the severity of power quality issues in power networks has escalated. Active power line conditioners, also known as active filters, are capable of compensating current and voltage harmonics and reactive power, regulating terminal voltage, suppressing flicker, and improving voltage balance in three-phase systems. Active filtering has the advantage of automatically adapting to network changes and load fluctuations. They can accommodate for several harmonic orders and are unaffected by significant changes in network parameters, reducing the possibility of filter and network impedance resonance. In comparison to classic passive compensators, they also take up extremely little space.

II. LITERATURE REVIEW

The important stages of an active power filter are signal conditioning for harmonics detection, deriving compensation signal and generation of gate pulses. The reference current generation is done through feedback network of voltage sensor and current sensor. This reference current generation is further used to derive compensation signal in time domain or frequency domain based on which many control strategies are devised like instantaneous power theory, Extension Instantaneous Reactive-Power Theorem, Synchronous-Detection Theorem, Synchronous-Reference-Frame Theorem, Sine-Multiplication Theorem, synchronous dq frame, linear control technique and hysteresis control technique[1]. The PWM signals are generated by these techniques which in turn are used as gating pulses for injecting current in to the system for mitigation of harmonics [8]. Different types and configurations of active filter described in [2]. The classification of active filters is based on type of converter feeding and topology used. Each configuration has some or more characteristics over the other and hence selection of configuration shall be done for current based compensation, voltage based compensation or current and voltage based compensation [3]. Active filters are also classified on the basis of power ratings and response time, power circuit configuration and connection, compensation variable (reactive power, harmonics), balancing, control technique, reference current / voltage generation approaches [4].

The shunt active filter works on principle of current source and are suitable for inductive and rectifier loads. However the injection of current into the load may cause over current problems. On the other hand series active filter works on voltage source principle. They are particularly suited for capacitive loads. The experimental simulation results [5] show that series and shunt active filters offer good compensation characteristics. A hybrid filter is a blend of active and passive filter that can be used for harmonic mitigation, reactive power compensation and balancing the unbalanced non linear load in real time. The prime objective of hybrid filter is to reduce the power rating of active elements. A hybrid active filter is broadly categorized in three topologies namely- series active – shunt passive, shunt active – shunt passive and active power filter in series with shunt passive filter. The control techniques used for active filters are applicable for hybrid filters as well. Hybrid active power filters are better choice for nonlinear load and mitigating power quality issues [6].

III. PROPOSED HYBRID ACTIVE POWER FILTER

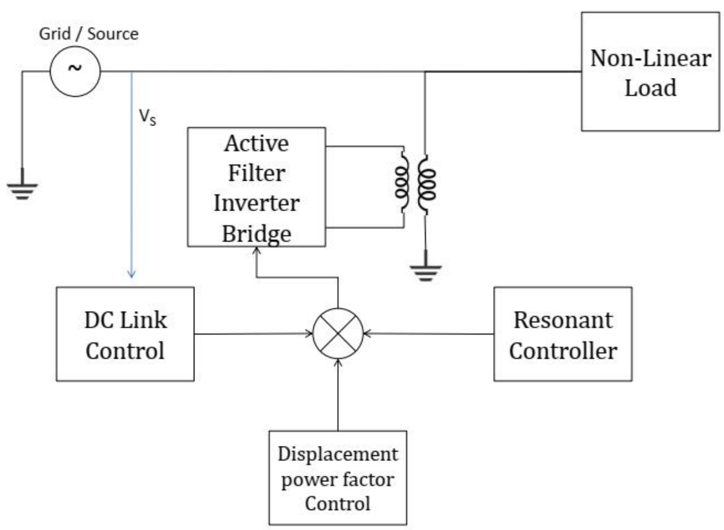

Figure 1: Block diagram of proposed shunt active power filter

The block schematic of proposed shunt active power filter is shown in figure 1. It consists of DC link voltage control, resonant controller and displacement power factor controller in the feedback control strategy.

3.1 Compensation of Harmonics

As a mathematical translation of the synchronous frame with PI controller, the proposed control system with Proportional Resonant Controller is constructed. The controller function is described as follows::

$$C(s) = k_p + \frac{k_r s}{s^2+\omega^2} \quad (1)$$

Where, k_p= proportional gain,

k_r= resonant gain,

ω = resonance frequency

The resonance frequency at high gain provides zero steady-state inaccuracy for sinusoidal reference. For dc reference, an equivalent characteristics PI controller is provided to avoid reference transformation and PLL synchronization. This is because the error signal is tracked by the reference current signal. With the help of notch filter source current harmonic I_{sh} is derived from source current I_S. Transfer function for this extraction is given as:

$$H(S) = \frac{s^2 + \omega_0^2}{s^2 + 2\omega_c s + \omega_0^2} \quad (2)$$

Where, ω_c = bandwidth of notch filter,

ω_0= resonance frequency

In this topology the harmonic current produced due to load flows through the smart impedance branch. Also harmonics due to source voltage gets blocked. Resonance between filter and source impedances is avoided because resonance damping is provided by harmonic source current feedback. Several harmonics frequencies are mitigated with multiple controllers connected in parallel, at a time:

$$C(S) = k_p + \sum_{h=3}^{21} \frac{k_r s}{s^2 + (h\omega_0)^2} \quad (3)$$

Tuning of smart impedance is done by generating voltage reference V_{afh}. And this voltage is generated by adding all P + Resonant regulators for each frequency. Tuning of this type of controller is done by various methods. Zero order hold method is used for discretization by Proportional Resonant controller.

3.2 Compensation of Displacement Power Factor

V_S the source voltage component and I_S the source current component at fundamental frequency is achieved. Phase difference between these two components is obtained from zero-crossing method. Amplitude of active filter voltage V_{af} is controlled by phase error signal which is given to capacitor in series Voltage across capacitor bank at fundamental frequency is:

$$V_C = V_S - V_{af} \quad (4)$$

Since the phase difference between V_C and V_S is not much. This is because the voltage drop at fundamental frequency is low. Hence V_S is incorporated as Displacement Power Factor control reference rather than V_C.

3.3 Control of DC Link

The DC connection voltage must be kept constant at the reference value. The active filter is used as a rectifier for pulse width modulation to achieve this goal. To do this, the voltage is sent through the coupling transformer, which should be perfectly in phase with the capacitor bank's current at the fundamental frequency. The DC link voltage becomes stable in this manner. This method also provides the filter losses. The Phase Locked Loop (PLL) method is used to generate a reference for DC link control. PLL The notch filter is used to create a fundamental frequency sinusoidal reference from the smart impedance branch current.

IV. MATLAB SIMULATION AND RESULTS

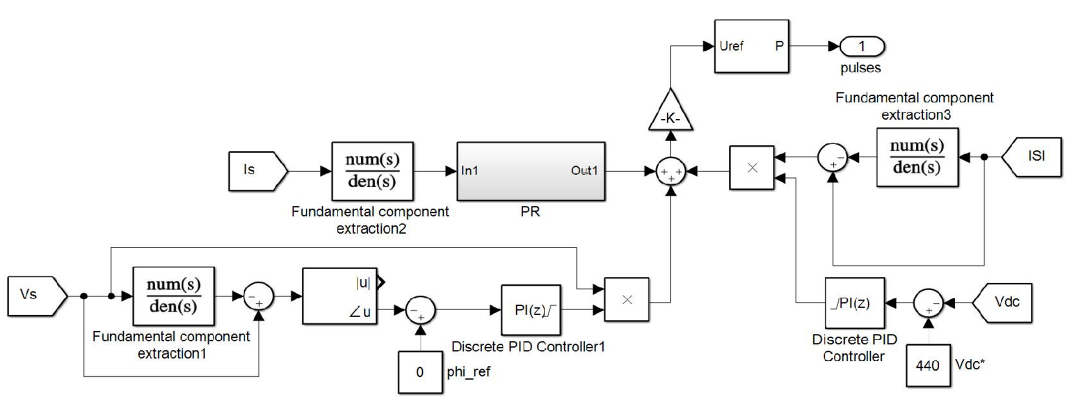

Figure 2: Control scheme of the filter

The system shown in figure 1 is simulated with MATLAB Simulink. The figure 2 shows the control scheme of the filter. The DC link control is done by PI controller. Fundamental component extraction is done by through transfer function implementation which separates fundamental component from harmonics. The proportional damps selective harmonics up to 11th order and helps in reducing damping as well as avoid resonance conditions. The output of these three controllers is combined together to generate triggering pulses for the active filter inverter bridge.

The results of MATLAB simulation are subsequently presented wherein figure 3 and figure 4 shows the waveforms and harmonics without use of filter and figure 5 and figure 6 shows waveforms and harmonics with filter.

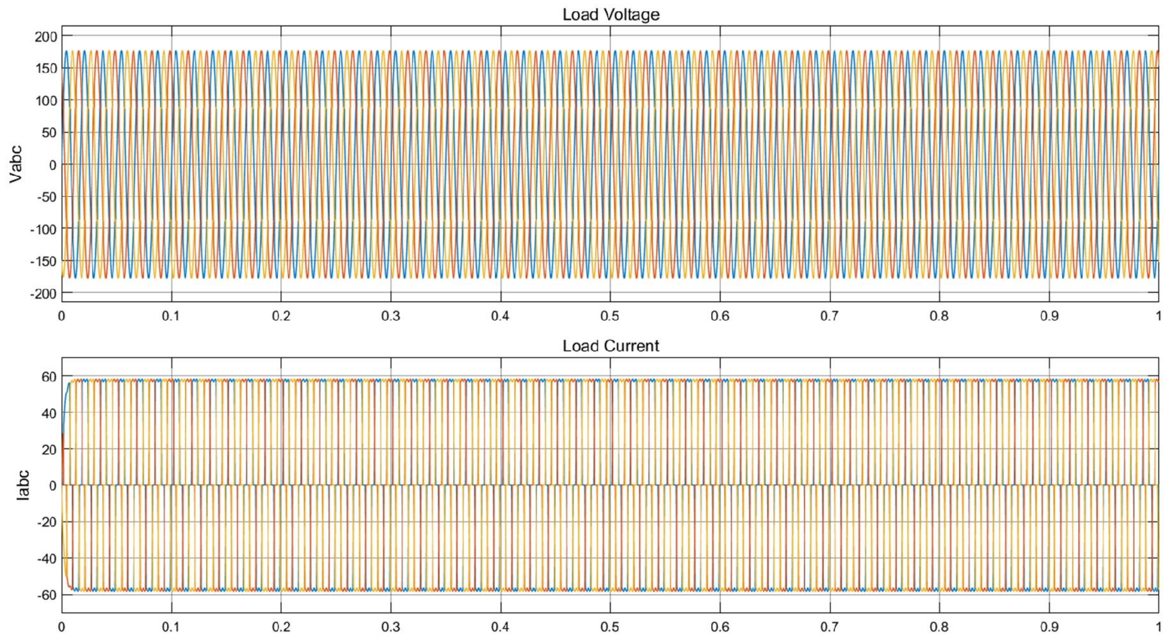

Figure 3: Voltage and Current waveforms without filter

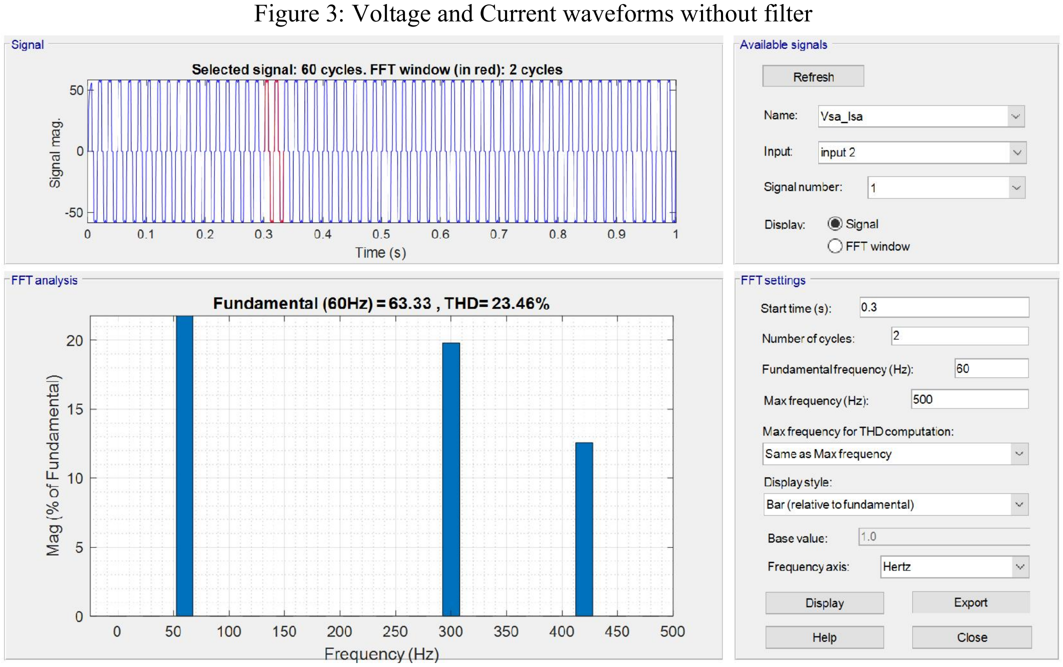

Figure 4: Harmonics without filter

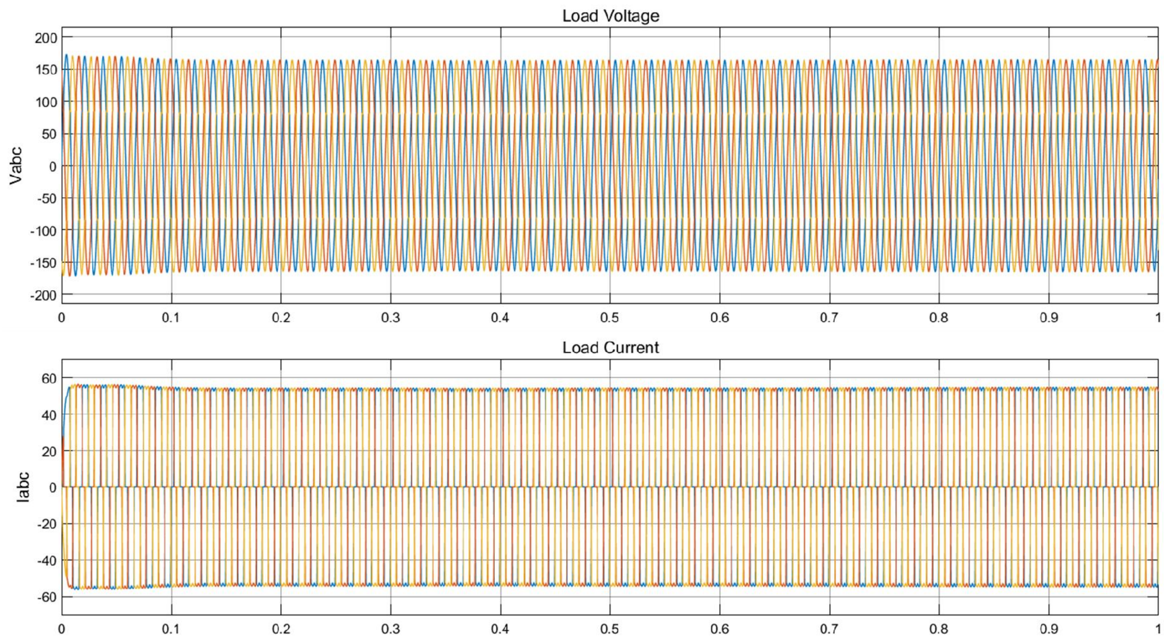

Figure 5: Voltage and current waveforms with filter

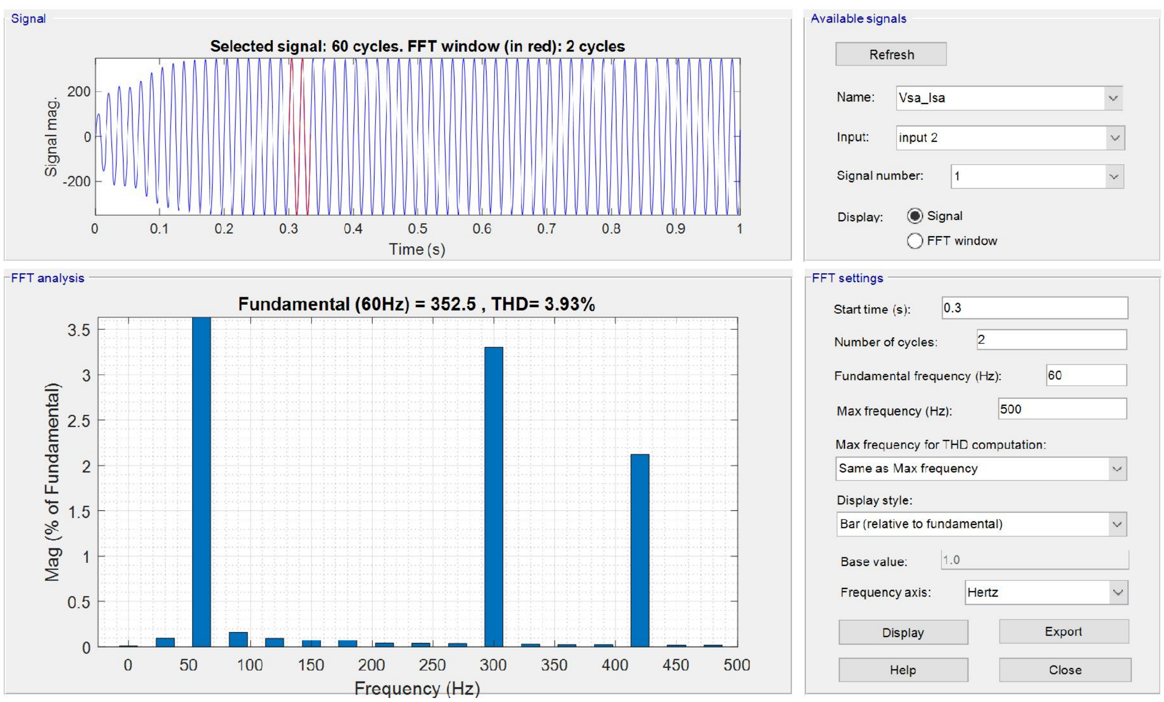

Figure 6: Harmonics with filter

V. CONCLUSION

This paper presents shunt active power filter as a smart impedance. The proportional resonance controller for shunt active power filter is discussed. The MATAB simulation of the proposed system and results for harmonics contents is presented by running the system with filter and without filter. The THD analysis clearly shows that the harmonics are reduced from 23.46% to 3.96%.

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