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# IMPROVEMENT OF POWER QUALITY BY USING A ROBUST HYBRID SERIES ACTIVE POWER FILTER

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**ABSTRACT:** In this paper, Design of Hybrid series active filter (HSAF) for Harmonic reduction and reactive power compensation in single phase systems is represented. The HSAF consists of the series combination of two single tuned LC filters which are tuned to 3rd and 5th harmonics and an active filter. Discrete Fourier transformation is used as the control technique. Simulation results using MATLAB shows the effectiveness of control technique. On getting the simulation results the value of THD is very low (2.75%), which is very negligible. So the power quality is said to be improved.

Keywords: Hybrid series active filter, active filter, harmonic reduction, reactive power compensation, Discrete Fourier transformation, power quality.

**I. INTRODUCTION** With the wide use of power electronic equipments and nonlinear loads, the power quality has been lost in distribution system. Current harmonics cause serious harmonic problems in distribution feeders for sensitive consumers. Some technology solutions have been reported in order to solve power quality problems. Initially, lossless passive filters have been used to mitigate harmonics and for compensation of reactive power at nonlinear loads. However, passive filters have the drawbacks of fixed compensation, large size and resonance with the supply system. Active filers have been explored in shunt and series configurations to compensate different types of nonlinear loads; nevertheless, they have some demerits. As a case in point, their power rating is sometimes close to load, and thus it becomes a costly option for power quality improvement. Many analysts have classified various types of nonlinear loads and have suggested different filter options for their compensation. In response to these factors, a series of hybrid filters has been evolved and widely used in practice as a cost effective solution for the compensation of nonlinear loads. Mainly shunt active filters consisting of voltage-fed pulse width modulated (PWM) inverters using IGBT or GTO thyristors are operating successfully in all over the world. These filters provided the required harmonic filtering, reactive power compensation, and etc [1-2]. The most important technology for the power quality improvement is the detecting method of harmonics to decrease the capacity of the various energy storage components. Different control methods are presented in recent publications for this type of active filters [3-16].The control method presented in this thesis is depends upon the calculation of the real part of the fundamental load current while this is helpful in some configurations such as hybrid series active filter, since it cannot compensate reactive power completely and needs many complicate calculations. The active power filter proposed in this thesis uses a dc capacitor voltage closed- loop control and used a modified phase-locked loop for extraction of the reference current. In the cited references, the computation involves various control parameters or needs complex calculations. Also, the dynamic performance of the compensator is not desire in the case of fast-changing loads. The least compensation current control method presented in [9] is based on detection of the harmonics and reactive current of the active power filter. In [10], genetic algorithm and extended analysis optimization techniques were applied for switched capacitor active filters. The combined genetic algorithm/conventional analysis control methods [11] have been considered as a recent control approach. These control methods have a common demerit of concerning the global stability of the closedloop system. In [12], the control technique is based on the calculation of average power; this wants to know some information regarding system and requires some intense calculation. The sliding-mode control technique proposed in [13] solves the stability problem; however, the calculation technique for compensation of current reference is complex and switching rate is variable. In [14], a digital repetitive control approach is presented to obtain high gain for the current loop; nevertheless, the control strategy in this method is based on a linearized replica of the active filter and does not direct to global stability. A deadbeat control strategy is presented in [15] for the current loop of single-phase active filters. Even though this process has a rapid current control due to the deadbeat nature, it dependence on parameters is a basic drawback. Furthermore, the call for prediction of the current reference requires adaptive signal processing techniques, complicating the execution of this technique. Passivity based controllers [16] based on phasor models of system dynamics have also been projected in an attempt to improve the stability properties of active filters.

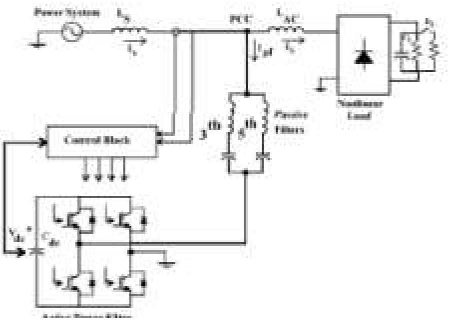


**FIG : SYSTEM CONFIGURATION**

## PROPOSED SYSTEM

Harmonic voltage source in series with an impedance ZNon−Linear or by its Norton equivalent modeled with a harmonic current source in parallel to the impedance. The Th´evenin's model and the Norton equivalent circuit are depicted in Fig. 4. In this paper, the common Norton equivalent is chosen to followmajor related papers. The principle of such modeling is documented in [30]. In this paper, the approach to achieve optimal behavior during the time the grid is perturbed is implemented on the controller. The use of a passive filter ismandatory to compensate current issues and maintaining a constant voltage free of distortions at the load terminals. The nonlinear load is modeled by a resistance

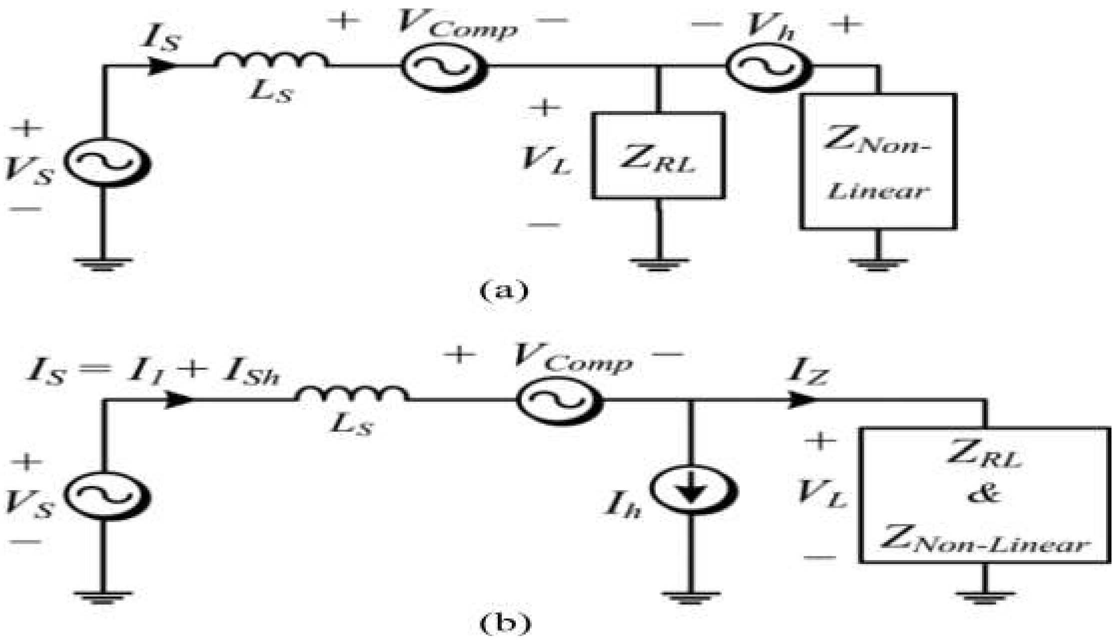


Fig.Single-phase equivalent phasor model for VSC type of loads. (a) Th´evenin's model. (b) Norton equivalent.representing the active power consumed and a current sourcegenerating harmonics current.

Accordingly, the impedance ZL is the equivalent of the nonlinear(ZNon−linear ) and the linear load (ZRL). The series activefilter, whose output voltage Vcomp is considered as an idealcontrolled voltage source is generating a voltage based on thedetecting source current, load voltage, and also the source voltageto achieve optimal results as of (4). This established hybridapproach gives good result and is quite less sensitive to thevalue of the gain G to achieve low level of current harmonics.The gain G is proportional to the current harmonics (Ish) flowingto the grid. Assuming the grid contains voltage distortions,the equivalent circuit for the fundamental and harmonics are

$$V_S = V_{s1} + V_{sh} \tag{1}$$

$$V_L = V_{L1} + V_{Lh} = Z_L I_Z = Z_L (I_S - I_h) \tag{2}$$

$$I_S = I_{S1} + I_{Sh} = I_Z + I_h \tag{3}$$

$$V_{Comp} = +G I_{Sh} - V_{Lh} + V_{Sh} \tag{4}$$

where IZ represents the load current in ZL shown in Fig. 4.Using Kirchhoff's law, the following equation is depicted forboth the fundamental and harmonics:

$VS = ZS\ IS + VComp + VL$ (5)

$VL1 = ZL\ IS1,\ VLh = ZL\ (ISh - Ih\ ).$ (6)

By substituting the fundamental of (6) into (5), the sourcecurrent at fundamental frequency is obtained:

$IS1 = VS1ZS + ZL$ . (7)

By substituting (4) into (5) for the harmonic components, theharmonic source current is reached as follows:

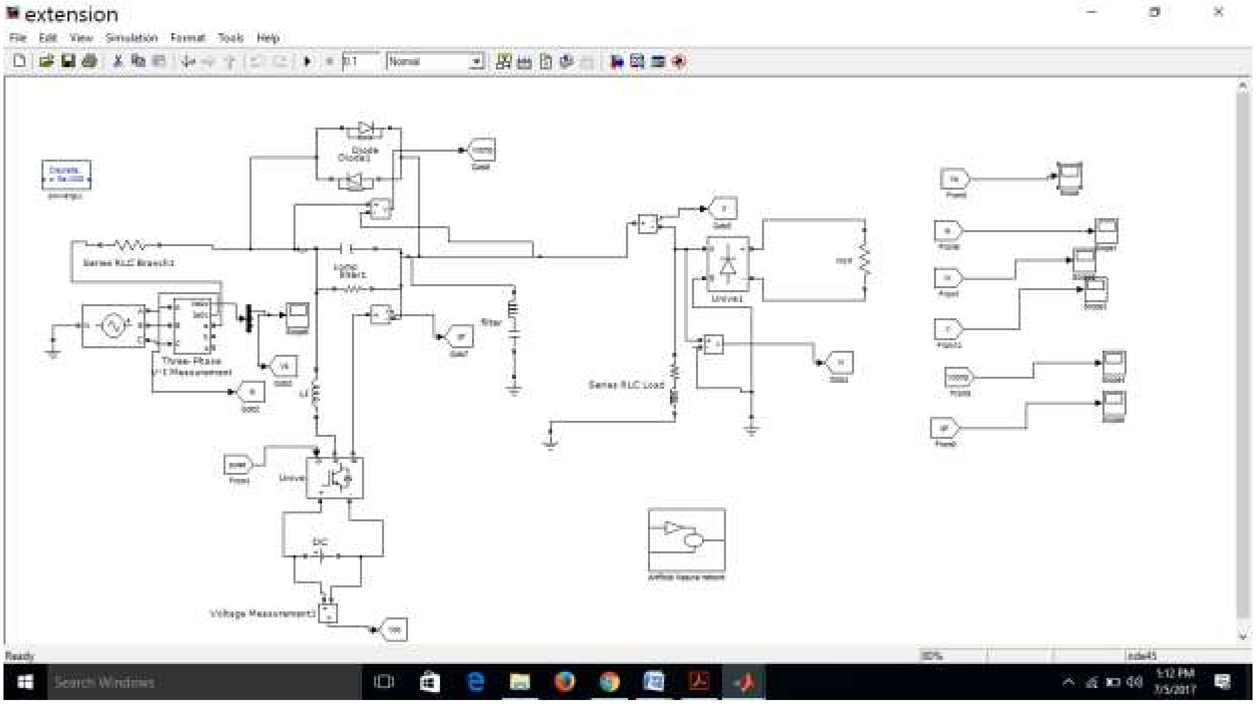
$VSh = ZS\ ISh + GISh - VLh + VSh + VLh \rightarrow ISh = 0.$ (8)

By introducing (8) into the harmonic component of the load PCC voltage (6), the following equation is achieved:

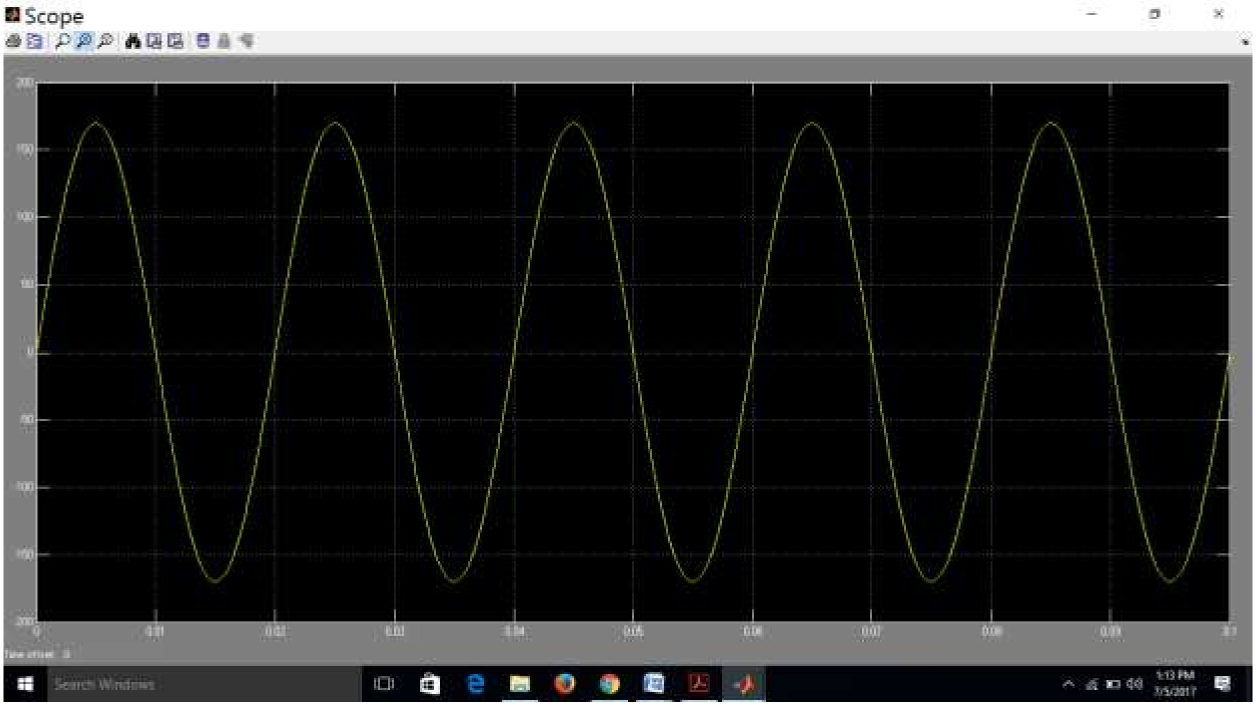
$VLh = -ZL\ Ih$ . (9)

Consequently, under this approach even in presence of source voltage distortions, the source current will remain clean of any harmonic components. To some extent in this approach, the filter behaves as high impedance likewise an open circuit for current harmonics, while the shunt high-pass filter tuned at the system frequency could create a low-impedance path for all harmonics and open circuit for the fundamental component. This argument explains the need of a hybrid configuration to create an alternative path for current harmonics fed from a current source type of nonlinear loads. The rating of the compensator is designed based on the required power consumers desire to restore during sags in the grid supply. For the 1.6-kVA load, in order to restore a 40% voltage sag, and at the same time, compensating source current harmonics and correcting the PF following sizing is suggested. The auxiliary supply should be designed accordingly as: $SDCsource = 1.6 \times 40\% = 650$ VA. The converter should transfer the load RMS current and have the following characteristics: $IConverter = IL = 1.6$ kVA/120 Vrms = 13 Arms . The nominal voltage of the converter is then $VConverter = 650$ VA/13Arms = 50 Vrms . The dc bus voltage is then required to be $VDCsource > 70$ Vdc and the more dc voltage is, the compensationwill have a better performances. The bank of series-resonant tuned shunt passive filters, assuming a 20% of fifth harmonic component, should have the following parameters: VSPF = 120 Vrms with a rated current of ISPF = 2.6 A. To have an optimized design, a primary study of the nonlinear load characteristic is required, and then, the same design process should be taken for the other tuned branches if required.

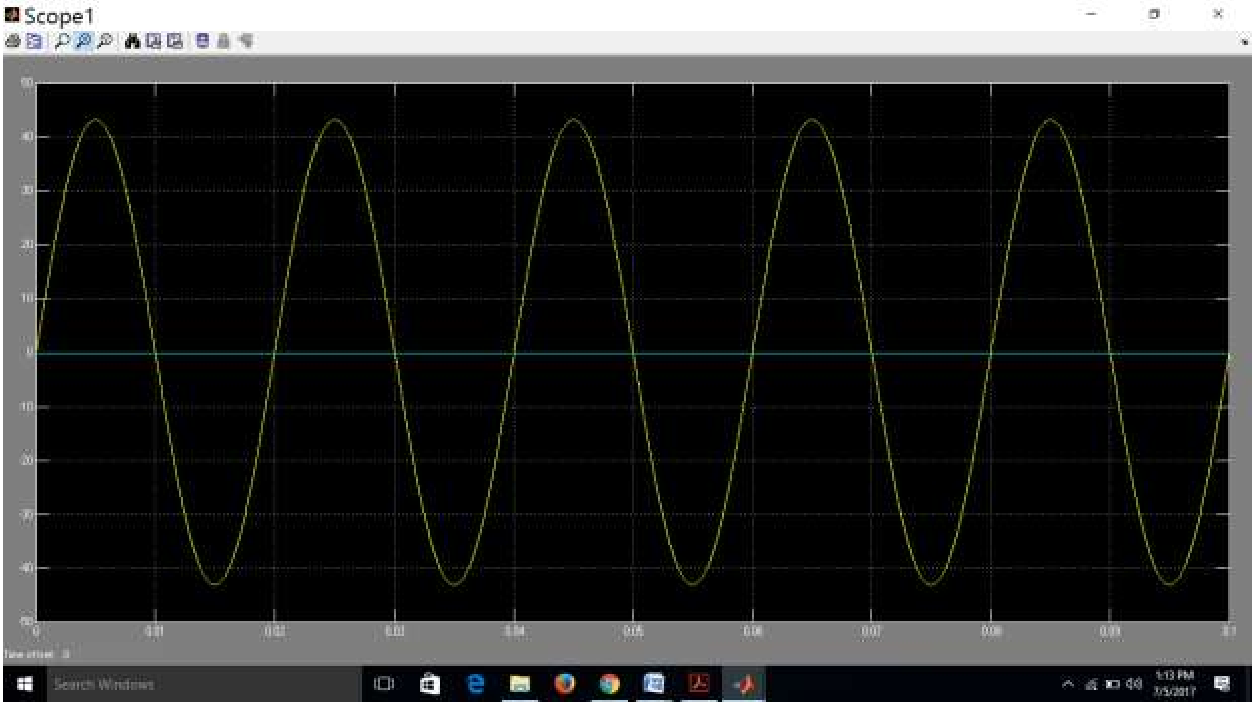
Simulation circuit:



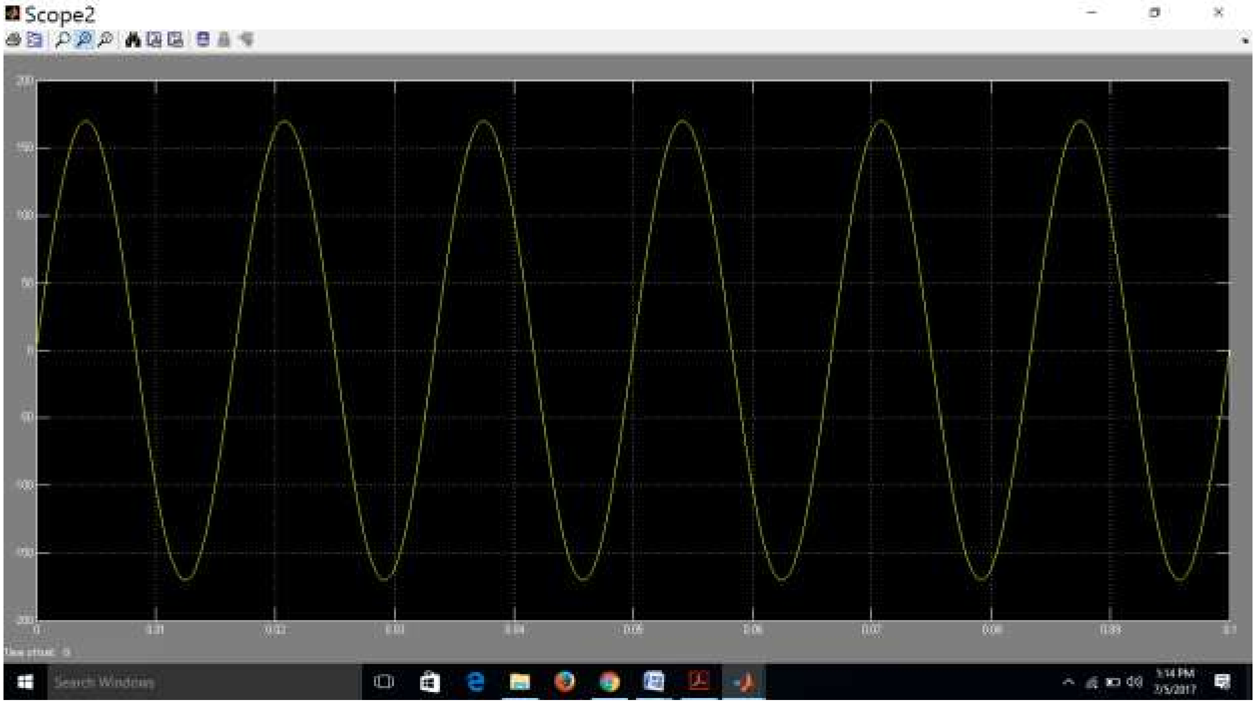
Source voltage:



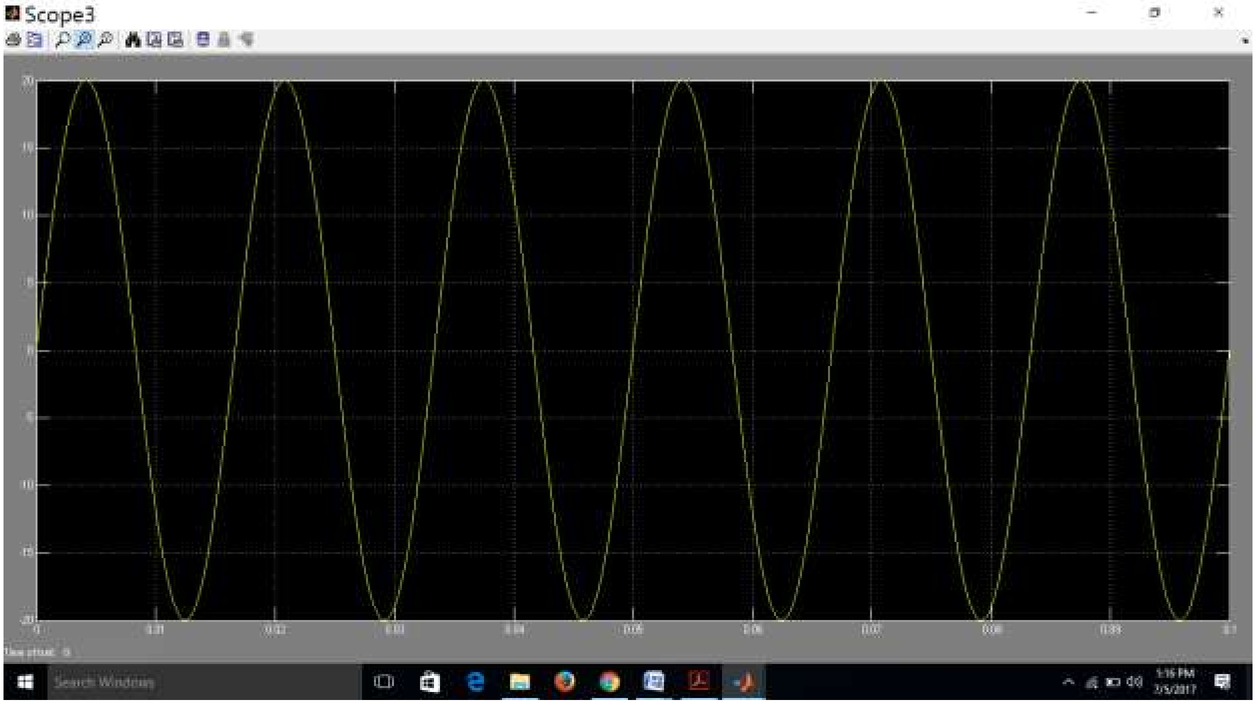
Source current:



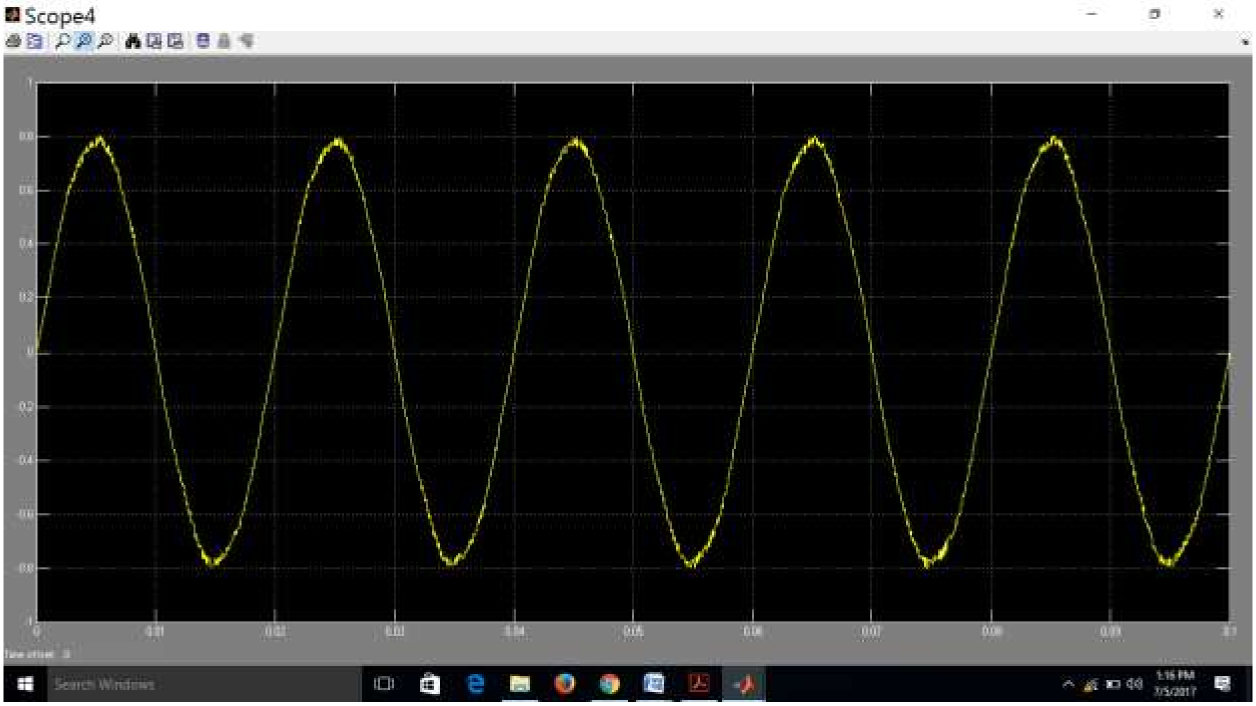
Voltage across non linear load:



Current at load:



Voltage compensation:



Current at h bridge:

# CONCLUSION

In this paper, a novel THSeAF configuration with a slidingmodecontroller was proposed and tested to overcome powerquality issues of a voltage fed type of nonlinear load. The theoreticalmodeling has been realized and simulated for furtherdevelopments. A second-order SMC is developed and adaptedfor practical real-time implementations. A notch harmonic detection is implemented and tested to extract harmonic componentof a polluted signal. The stability of the controller is also described and analyzed using Lyaponov criteria. It has beendemonstrated that the proposed configuration along with thecontrol approach is able to feature reactive power exchange withthe utility as well. With regard to the control approach and takingadvantage of the proposed robust structure, a harmonic-freevoltage is delivered across the residential terminals. The wholesystem is implemented on a real-time simulator to ensure feasibilityof the developed controller. It is worthy to mention thatthis topology does not make use of a bulky transformer, whichis mandatory for series active/hybrid filters topologies; it hasa natural feature of limiting short-circuit current during faultycondition. It also replaces the function of UPS/UPQC deviceswith much less reactive and semiconductor components. Resultsof the laboratory implementation have demonstrated thatthis active compensator responds to abrupt variations in the gridvoltage by providing a constant and distortion-free supply to theload while eliminating grid current harmonics contributing tothe improvement of the grid’s power quality.

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