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A New Power Quality Improvement In Single Phase Active Devices For Electrified Transportation

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Abstract: *A transformerless hybrid series active filter is proposed to enhance the power quality in single-phase systems with critical loads. This paper assists the energy management and power quality issues related to electric transportation and focuses on improving electric vehicle load connection to the grid. The control strategy is designed to prevent current harmonic distortions of nonlinear loads to flow into the utility and corrects the power factor of this later. While protecting sensitive loads from voltage disturbances, sags, and swells initiated by the power system, ridded of the series transformer, the configuration is advantageous for an industrial implementation. This polyvalent hybrid topology allowing the harmonic isolation and compensation of voltage distortions could absorb or inject the auxiliary power to the grid. Aside from practical analysis, this paper also investigates on the influence of gains and delays in the real-time controller stability. The simulations and experimental results presented in this paper were carried out on a 2-kVA laboratory prototype demonstrating the effectiveness of the proposed topology.*

Index Terms: Current harmonics, electric vehicle, hybrid series active filter (HSeAF), power quality, real-time control.

I. INTRODUCTION

THE forecast of future Smart Grids associated with electric vehicle charging stations has created a serious concern on all aspects of power quality of the power system, while widespread electric vehicle battery charging units [1], [2] have detrimental effects on power distribution system harmonic voltage levels [3]. On the other hand, the growth of harmonics fed from nonlinear loads like electric vehicle propulsion battery chargers [4], [5], which indeed have detrimental impacts on the power system and affect plant equipment, should be considered in the development of modern grids. Likewise, the increased rms and peak value of the distorted current waveforms increase heating and losses and cause the failure of the electrical equipment. Such phenomenon effectively reduces system efficiency and should have properly been addressed [6], [7].

Moreover, to protect the point of common coupling (PCC) from voltage distortions, using a dynamic voltage restorer (DVR) function is advised. A solution is to reduce the pollution of power electronics-based loads directly at their source. Although several attempts are made for a specific case study, a generic solution is to be explored. There exist two types of active power devices to overcome the described power quality issues. The first category are series active filters (SeAFs), including hybrid-type ones. They were developed to eliminate current harmonics produced by nonlinear load from the power system. SeAFs are less scattered than the shunt type of active filters [8], [9]. The advantage of the SeAF compared to the shunt type is the inferior rating of the compensator versus the load nominal rating [10]. However, the complexity of the configuration and necessity of an isolation series transformer had decelerated their industrial application in the distribution system. The second category was developed in concern of addressing voltage issues on sensitive loads. Commonly known as DVR, they have a similar configuration as the SeAF. These two categories are different from each other in their control principle. This difference relies on the purpose of their application in the system. The hybrid series active filter (HSeAF) was proposed to address the aforementioned issues with only one combination. Hypothetically, they are capable to compensate current harmonics, ensuring a power factor (PF) correction and eliminating voltage distortions at the PCC [11], [12]. These properties make it an appropriate candidate for power quality investments.

The three-phase SeAFs are well documented [13], [14], whereas limited research works reported the single-phase applications of SeAFs in the literature. In this paper, a single-phase transformerless HSeAF is proposed and capable of cleaning up the grid-side connection bus bar from current harmonics generated by a nonlinear load [15]. With a smaller rating up to 10%, it could easily replace the shunt active filter [16]. Furthermore, it could restore a sinusoidal voltage at the load PCC. The advantage of the proposed configuration is that nonlinear harmonic voltage and current producing loads could be effectively compensated. The transformerless hybrid series active filter (THSeAF) is an alternative option to conventional power transferring converters in distributed generation systems with high penetration of renewable energy sources, where each phase can be controlled separately and could be operated independently of other phases [17]. This paper shows that the separation of a three-phase converter into single-phase Hbridge converters has allowed the elimination of the costly

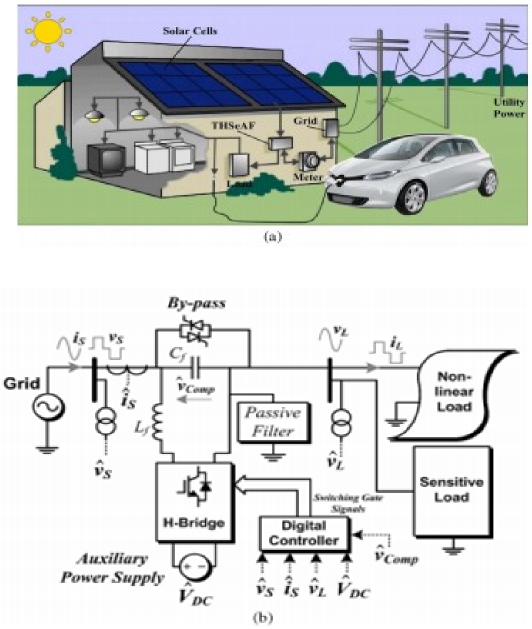

Fig1: (a) Schematic of a single-phase smart load with the compensator installation. (b) Electrical diagram of the THSeAF in a single-phase utility.

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isolation transformer and promotes industrial application for filtering purposes. The setup has shown great ability to perform requested compensating tasks for the correction of current and voltage distortions, PF correction, and voltage restoration on the load terminal [18]. This paper is organized as follows. The system architecture is introduced in the following section. Then, the operation principle of the proposed configuration is explained. The third section is dedicated to the modeling and analysis of the control algorithm implemented in this work. The dc voltage regulation and its considerations are briefly explained, and the voltage and current harmonic detection method is explicitly described. To evaluate the configuration and the control approach, some scenarios are simulated. Experimental results performed in the laboratory are demonstrated to validate simulations. This paper is summarized with a conclusion and appendix where further mathematical developments are demonstrated.

II. POWER QUALITY

The contemporary container crane industry, like many other industry segments, is often enamored by the bells and whistles, colorful diagnostic displays, high speed performance, and levels of automation that can be achieved. Although these features and their indirectly related computer based enhancements are key issues to an efficient terminal operation, we must not forget the foundation upon which we are building. Power quality is the mortar which bonds the foundation blocks. Power quality also affects terminal operating economics, crane reliability, our environment, and initial investment in power distribution systems to support new crane installations.

To quote the utility company newsletter which accompanied the last monthly issue of my home utility billing: 'Using electricity wisely is a good environmental and business practice which saves you money, reduces emissions from generating plants, and conserves our Natural resources.' As we are all aware, container crane performance requirements continue to increase at an astounding rate. Next generation container cranes, already in the bidding process, will require average power demands of 1500 to 2000 kW – almost double the total average demand three years ago. The rapid increase in power demand levels, an increase in container crane population, SCR converter crane drive retrofits and the large AC and DC drives needed to power and control these cranes will increase awareness of the power quality issue in the very near future.

III. HARMONICS

The typical definition for a harmonic is "a sinusoidal component of a periodic wave or\ quantity having a frequency that is an integral multiple of the fundamental frequency." [1]. Some references refer to "clean" or "pure" power as those without any harmonics. But such clean waveforms typically only exist in a laboratory. Harmonics have been around for a long time and will continue to do so. In fact, musicians have been aware of such since the invention of the first string or woodwind instrument. Harmonics (called "overtones" in music) are responsible for what makes a trumpet sound like a trumpet, and a clarinet like a clarinet.

Electrical generators try to produce electric power where the voltage waveform has only one frequency associated with it, the fundamental frequency. In the North America, this frequency is 60 Hz, or cycles per second. In European countries and other parts of the world, this frequency is usually 50 Hz. Aircraft often uses 400 Hz as the fundamental frequency. At 60 Hz, this means that sixty times a second, the voltage waveform increases to a maximum positive value, then decreases to zero, further decreasing to a maximum negative value, and then back to zero. The rate at which these changes occur is the trigometric function called a sine wave, as shown in figure 1. This function occurs in many natural phenomena, such as the speed of a pendulum as it swings back and forth, or the way a string on a voilin vibrates when plucked.

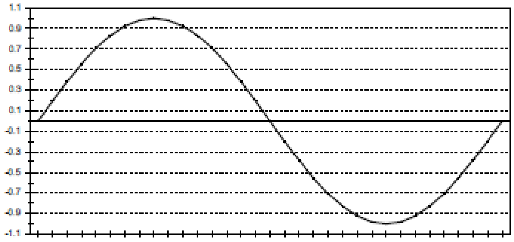

Fig2. Sine wave

VI. SYSTEM ARCHITECTURE

A. System Configuration The THSeAF shown in Fig. 1 is composed of an H-bridge converter connected in series between the source and the load. A shunt passive capacitor ensures a low impedance path for current harmonics. A dc auxiliary source could be connected to inject power during voltage sags. The dc-link energy storage

TABLE I
CONFIGURATION PARAMETERS

Symbol	Definition	Value
v_s	Line phase-to-neutral voltage	120 Vrms
f	System frequency	60 Hz
$R_{non\text{-}linear\ load}$	Load resistance	11.5 Ω
$L_{non\text{-}linear\ load}$	Load inductance	20 mH
P_L	Linear load power	1 kVA
PF	Linear load power factor	46 %
Lf	Switching ripple filter inductance	5 mH
Cf	Switching ripple filter capacitance	2 µF
T_S	dSPACE Synchronous sampling time	40 µs
f_{PWM}	PWM frequency	5 kHz
G	Control gain for current harmonics	8 Ω
V_{DCref}*	VSI DC bus voltage of the THSeAF	70 V
PI_G	Proportional gain (K_p), Integral gain (K_i)	0.025(4*), 10 (10*)

* Adopted value for the experimental setup

system is described in [19]. The system is implemented for a rated power of 2200 VA. To ensure a fast transient response with sufficient stability margins over a wide range of operation, the controller is implemented on a dSPACE/dsp1103. The system parameters are identified in Table I. A variable source of 120 Vrms is connected to a 1.1-kVA nonlinear load and a 998-VA linear load with a 0.46 PF.

The THSeAF is connected in series in order to inject the compensating voltage. On the dc side of the compensator, an auxiliary dc-link energy storage system is installed. Similar parameters are also applied for practical implementation. HSeAFs are often used to compensate distortions of the current type of nonlinear loads. For instance, the distorted current and voltage waveforms of the nonlinear system during normal operation and when the source voltage became distorted are depicted in Fig. 2. The THSeAF is bypassed, and current harmonics flowed directly into the grid. As one can

TABLE II
SINGLE-PHASE COMPARISON OF THE THSeAF TO PRIOR HSeAFs

Definition	Proposed THSeAF	[21]	[22]	[12]
Injection Transformer	Non	2 per phase	1 per phase	1 per phase
# of semiconductor devices	4	8	4	4
# of DC link storage elements	1+Aux. Pow.	1	2	1+Aux. Pow.
AF rating to the load power	10-30%	10-30%	10-30%	10-30%
Size and weight, regarding the transformer, power switches, drive circuit, heat sinks, etc.	The Lowest	High	Good	Good
Industrial production costs	The Lowest	High	Low	Low
Power losses, including switching, conducting, and fixed losses	Low	Better	Low	Low
Reliability regarding independent operation capability	Good	Low	Good	Good
Harmonic correction of Current source load	Good	Good	Good	Low
Voltage Harmonic correction at load terminals	Good	Better	Good	Good
Power factor correction	Yes	Yes	Yes	No
Power injection to the grid	Yes	No	No	Yes

perceive, even during normal operation, the current harmonics (with a total harmonic distortion (THD) of 12%) distort the PCC, resulting in a voltage THD of 3.2%. The behavior of the system when the grid is highly polluted with 19.2% of THD is also illustrated. The proposed configuration could be solely connected to the grid with no need of a bulky and costly series injection transformer, making this topology capable of compensating source current harmonics and voltage distortion at the PCC. Even if the number of switches has increased, the transformerless configuration is more cost-effective than any other series compensators, which generally uses a transformer to inject the compensation voltage to the power grid.

The optimized passive filter is composed of 5th, 7th, and highpass filters. The passive filter should be adjusted for the system upon load and government regulations. A comparison between different existing configurations is given in Table II. It is aimed to point out the advantages and disadvantages of the proposed configuration over the conventional topologies. To emphasize the comparison table fairly, the equivalent single phase of each configuration is considered in the evaluation. Financial production evaluation demonstrated a 45% reduction in component costs and considerable reduction in assembly terms as well.

B. Operation Principle

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The SeAF represents a controlled voltage source (VSI). In order to prevent current harmonics iLh to drift into the source, this

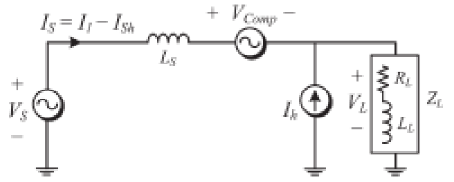

Fig. 3. THSeAF equivalent circuit for current harmonics.

series source should present low impedance for the fundamental component and high impedance for all harmonics as shown in Fig. 3.

The principle of such modeling is well documented in [20]. The use of a well-tuned passive filter is then mandatory to perform the compensation of current issues and maintaining a constant voltage free of distortions at the load terminals. The behavior of the SeAF for a current control approach is evaluated from the phasor's equivalent circuit shown in Fig. 3. The nonlinear load could be modeled by a resistance representing the active power consumed and a current source generating current harmonics. Accordingly, the impedance ZL represents the nonlinear load and the inductive load. The SeAF operates as an ideal controlled voltage source (V comp) having a gain (G) proportional to the current harmonics (Ish) flowing to the grid (Vs)

$$V_{\text{comp}} = G.I_{sh} - V_{Lh}. \qquad (1)$$

This allows having individual equivalent circuit for the fundamental and harmonics

$$V_{\text{source}} = V_{s1} + V_{sh}, \qquad V_L = V_{L1} + V_{Lh}. \qquad (2)$$

The source harmonic current could be evaluated

$$V_{sh} = -Z_s.I_{sh} + V_{\text{comp}} + V_{Lh} \qquad (3)$$
$$V_{Lh} = Z_L(I_h - I_{sh}). \qquad (4)$$

Combining (3) and (4) leads to (5)

$$I_{sh} = \frac{V_{sh}}{(G - Z_s)}. \qquad (5)$$

If gain G is sufficiently large (G → ∞), the source current will become clean of any harmonics (Ish → 0). This will help improve the voltage distortion at the grid side. In this approach, the THSeAF behaves as high-impedance open circuit for current harmonics, while the shunt high-pass filter tuned at the system frequency creates a low-impedance path for all harmonics and open circuit for the fundamental; it also helps for PF correction.

V. MODELING AND CONTROL OF THE SINGLE-PHASE THSeAF

A. Average and Small-Signal Modeling

Based on the average equivalent circuit of an inverter [23], the small-signal model of the proposed configuration can be obtained as in Fig. 4. Hereafter, d is the duty cycle of the upper switch during a switching period, whereas v¯ and ¯i denote the average values in a switching period of the voltage and current

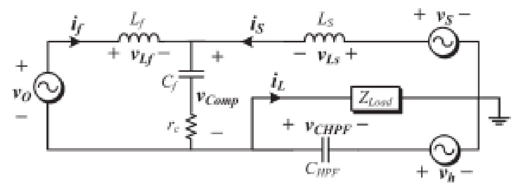

Fig4: Small-signal model of transformerless HSeAF in series between the grid and the load

of the same leg. The mean converter output voltage and current are expressed by (6) and (7) as follows:

$$\bar{v}_O = \underbrace{(2d-1)}V_{\text{DC}} \qquad (6)$$

where the (2d − 1) equals to m, the

$$\bar{i}_{\text{DC}} = m\bar{i}_f. \qquad (7)$$

Calculating the Thévenin equivalent circuit of the harmonic current source leads to the following assumption:

$$\bar{v}_h(j\omega) = \frac{-j\bar{i}_h}{C_{HPF} \cdot \omega_h}. \qquad (8)$$

If the harmonic frequency is high enough, it is possible to assume that there will be no voltage harmonics across the load.

The state-space small-signal ac model could be derived by a linearized perturbation of the averaged model as follows:

$$\dot{x} = Ax + Bu. \qquad (9)$$

Hence, we obtain

$$\frac{d}{dt}\begin{bmatrix} \bar{v}_{Cf} \\ \bar{v}_{CHPF} \\ \bar{i}_S \\ \bar{i}_f \\ \bar{i}_L \end{bmatrix} = \begin{bmatrix} 0 & 0 & \frac{1}{C_f} & \frac{1}{C_f} & 0 \\ 0 & 0 & \frac{1}{C_{HPF}} & 0 & -1/C_{HPF} \\ -1/L_S & -1/L_S & -r_c/L_S & -r_c/L_S & 0 \\ -1/L_f & 0 & -r_c/L_f & -r_c/L_f & 0 \\ 0 & \frac{1}{L_L} & 0 & 0 & -R_L/L_L \end{bmatrix}$$
$$\times \begin{bmatrix} \bar{v}_{Cf} \\ \bar{v}_{CHPF} \\ \bar{i}_S \\ \bar{i}_f \\ \bar{i}_L \end{bmatrix} + \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ \frac{1}{L_S} & 0 & \frac{1}{L_S} \\ 0 & \frac{m}{L_f} & 0 \\ 0 & 0 & -1/L_L \end{bmatrix} \times \begin{bmatrix} \bar{v}_S \\ V_{\text{DC}} \\ \bar{v}_h \end{bmatrix}. \qquad (10)$$

Moreover, the output vector is

$$y = Cx + Du \tag{11}$$

or

$$\begin{bmatrix} \bar{v}_{\text{comp}} \\ \bar{v}_L \end{bmatrix} = \begin{bmatrix} 1 & 0 & r_c & r_c & 0 \\ 0 & 1 & 0 & 0 & 0 \end{bmatrix} \times \begin{bmatrix} \bar{v}_{Cf} \\ \bar{v}_{CHPF} \\ \bar{i}_S \\ \bar{i}_f \\ \bar{i}_L \end{bmatrix} + \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & -1 \end{bmatrix} \times \begin{bmatrix} \bar{v}_S \\ V_{\text{DC}} \\ \bar{v}_h \end{bmatrix}. \tag{12}$$

By means of (10) and (12), the state-space representation of the model is obtained as shown in Fig. 4. The transfer function of the compensating voltage versus the load voltage, TV _CL(s), and the source current, TCI (s), are developed in the Appendix. Meanwhile, to control the active

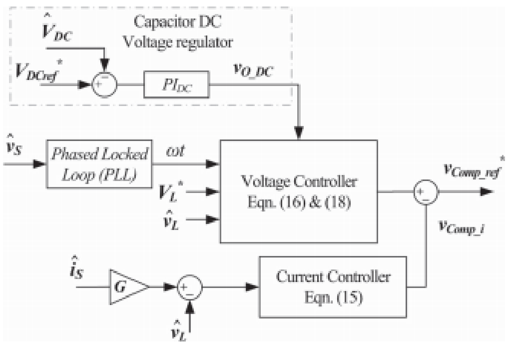

Fig5: Control system scheme of the active part.

part independently, the derived transfer function should be autonomous from the grid configuration. The transfer function TV m presents the relation between the output voltages of the converter versus the duty cycle of the first leg converter's upper switch

$$T_V(s) = \frac{V_{\text{comp}}}{V_O} = \frac{r_C C_f s + 1}{L_f C_f s^2 + r_C C_f s + 1} \tag{13}$$

$$T_{Vm}(s) = \frac{V_{\text{comp}}}{m} = V_{DC} \cdot T_V(s). \tag{14}$$

The further detailed derivation of steady-state transfer functions is described in Section V.

A dc auxiliary source should be employed to maintain an adequate supply on the load terminals. During the sag or swell conditions, it should absorb or inject power to keep the voltage magnitude at the load terminals within a specified margin. However, if the compensation of sags and swells is less imperative, a capacitor could be deployed. Consequently, the dc-link voltage across the capacitor should be regulated as demonstrated in Fig. 5.

B. Voltage and Current Harmonic Detection

The outer-loop controller is used where a capacitor replaces the dc auxiliary source. This control strategy is well explained in the previous section. The inner-loop control strategy is based on an indirect control principle. A fast Fourier transformation was used to extract the magnitude of the fundamental and its phase degree from current harmonics. The control gain G representing the impedance of the source for current harmonics has a sufficient level to clean the grid from current harmonics fed through the nonlinear load.

The second proportional integrator (PI) controller used in the outer loop was to enhance the effectiveness of the controller when regulating the dc bus. Thus, a more accurate and faster transient response was achieved without compromising the compensation behavior of the system. According to the theory, the gain G should be kept in a suitable level, preventing the harmonics from flowing into the grid [22], [24]. As previously discussed, for a more precise compensation of current harmonics, the voltage harmonics should also be considered. The compensating voltage for current harmonic compensation is obtained from

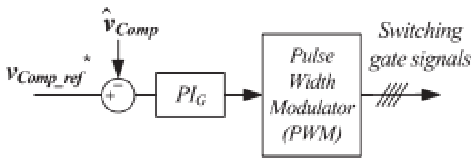

Fig6: Block diagram of THSeAF and PI controller

$$v_{\text{comp\_}i}(t) = (-G\hat{i}_S + \hat{v}_L) - [| - G i_{S1} + v_{L1}| \cdot \sin(\omega_S t - \theta)]. \tag{15}$$

Hereby, as voltage distortion at the load terminals is not desired, the voltage sag and swell should also be investigated in the inner loop. The closed-loop equation (16) allows to indirectly maintain the voltage magnitude at the load side equal to V ∗ L as a predefined value, within acceptable margins

$$v_{\text{comp\_}v} = \hat{v}_L - V_L^* \sin(\omega_S t). \tag{16}$$

The entire control scheme for the THSeAF presented in Fig. 5 was used and implemented in MATLAB/Simulink for real-time simulations and the calculation of the compensating voltage. The real-time toolbox of dSPACE was used for compilation and execution on the dsp-1103 control board. The source and load voltages, together with the source current, are considered as system input signals. According to Srianthumrong et al. [25], an indirect control increases the stability of the system. The source current harmonics are obtained by extracting the fundamental component from the source current

$$v_{\text{com\_ref}}^* = v_{\text{comp\_}v} - v_{\text{comp\_}i} + v_{\text{DC\_}ref} \tag{17}$$

where the $v_{\text{DC\_}ref}$ is the voltage required to maintain the dc bus voltage constant

$$v_{\text{DC\_}ref}(t) = V_{O\_\text{DC}} \cdot \sin(\omega_S t). \tag{18}$$

A phase-locked loop was used to obtain the reference angular frequency (ωs). Accordingly, the extracted current harmonic contains a fundamental component synchronized with the source voltage in order to correct the PF. This current represents the reactive power of the load. The gain G representing the resistance for harmonics converts current into a relative voltage. The generated reference voltage vcomp_i required to clean the source current from harmonics is described in

(15). According to the presented detection algorithm, the compensated reference voltage v∗ Comp_ref is calculated. Thereafter, the reference signal is compared with the measured output voltage and applied to a PI controller to generate the corresponding gate signals as in Fig. 6.

C. Stability Analysis for Voltage and Current Harmonics

The stability of the configuration is mainly affected by the introduced delay of a digital controller. This section studies the impact of the delay first on the inclusive compensated system according to works cited in the literature. Thereafter, its effects on the active compensator is separated from the grid. Using purely inductive source impedance (see Fig. 4) and Kirchhoff's law for harmonic frequency components, (19) is derived. The delay time of the digital controller, large gain G, and the high stiffness of the system seriously affect the stability of the closed-loop controlled system.

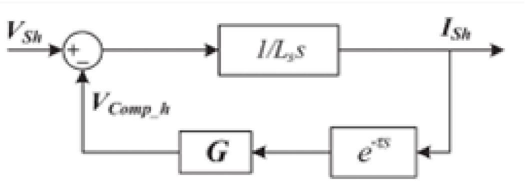

Fig7: Control diagram of the system with delay.

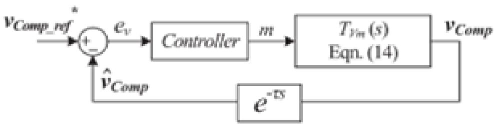

Fig8: Closed-loop control diagram of the active filter with a constant delay time τ.

VI.SIMULATIONS RESULTS:

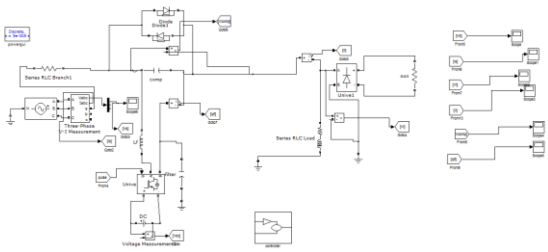

Fig9: Electrical diagram of the THSeAF in a single-phase utility

The proposed transformerless-HSeAF configuration was simulated in MATLAB/Simulink using discrete time steps of T s = 10 µs. A dSPACE/dsp1103 was used for the fast control prototyping. To ensure an error-free and fast implementation, the complete control loop was executed every 40 µs. The parameters are identified in Table I. The combination of a single-phase nonlinear load and a linear load with a total rated power of 2 kVA with a 0.74 lagging PF is applied for laboratory experiments and simulations. For experiments and simulations, a 2-kVA 120-Vrms 60-Hz variable source is used. THSeAF connected in series to the system compensates the current harmonics and voltage distortions. The complete experimental system is demonstrated in Fig. 10.

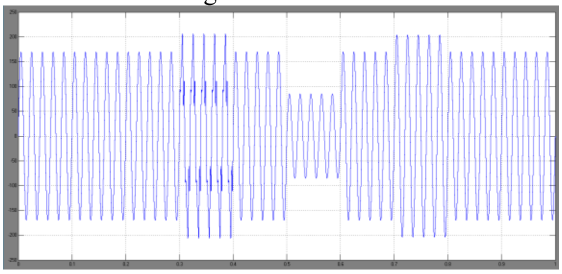

Fig10: Source Voltage(Vs)

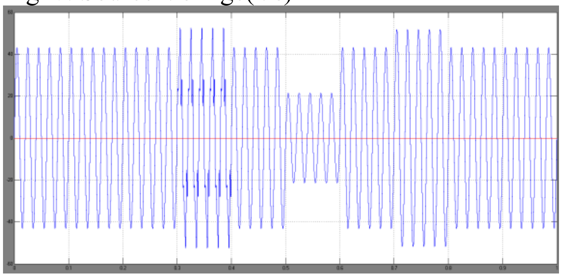

Fig11: Source Current

A gain G =8Ω equivalent to 1.9 p.u. was used to control current harmonics. As mentioned earlier, the capability of operation with low dc voltage is considered as one of the main advantages of the proposed configuration. For this experiment, it is maintained at 130 Vdc. During a grid's voltage distortion, the compensator regulates the load voltage magnitude, compensates current harmonics, and corrects the PF. The simulated results of the THSeAF illustrated in Fig. 11 demonstrates improvement in the source current THD.

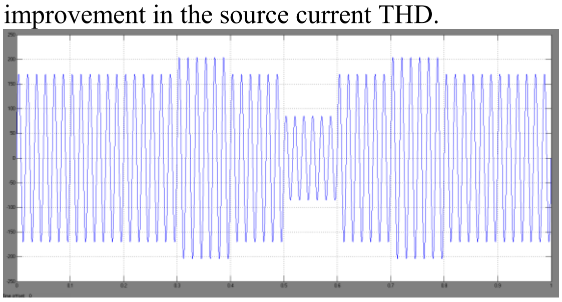

Fig12: Load Voltage

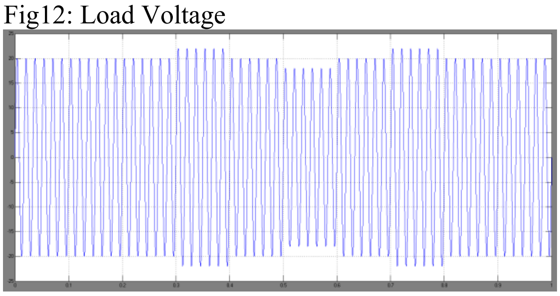

Fig13: Load Current

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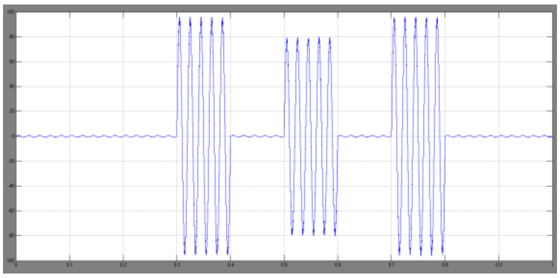

Fig14: active-filter voltage *V*Comp,

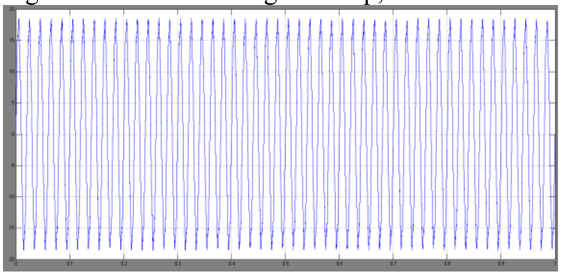

Fig15: harmonics current of the passive filter *i*PF.

The load terminal voltage VL THD is 4.3%, while the source voltage is highly distorted (THD VS = 25%). The grid is cleaned of current harmonics with a unity power factor (UPF) operation, and the THD is reduced to less than 1% in normal operation and less than 4% during grid perturbation. While the series controlled source cleans the current of harmonic components, the source current is forced to be in phase with the source voltage. The series compensator has the ability to slide the load voltage in order for the PF to reach unity. Furthermore, the series compensator could control the power flow between two PCCs.

VII. CONCLUSION

In this paper, a transformerless HSeAF for power quality improvement was developed and tested. The paper highlighted the fact that, with the ever increase of nonlinear loads and higher exigency of the consumer for a reliable supply, concrete actions should be taken into consideration for future smart grids in order to smoothly integrate electric car battery chargers to the grid. The key novelty of the proposed solution is that the proposed configuration could improve the power quality of the system in a more general way by compensating a wide range of harmonics current, even though it can be seen that the THSeAF regulates and improves the PCC voltage. Connected to a renewable auxiliary source, the topology is able to counteract actively to the power flow in the system. This essential capability is required to ensure a consistent supply for critical loads. Behaving as high-harmonic impedance, it cleans the power system and ensures a unity PF. The theoretical modeling of the proposed configuration was investigated. The proposed transformerless configuration was simulated and experimentally validated. It was demonstrated that this active compensator responds properly to source voltage variations by providing a constant and distortion-free supply at load terminals. Furthermore, it eliminates source harmonic currents and improves the power quality of the grid without the usual bulky and costly series transformer.

REFERENCES

[1] L. Jun-Young and C. Hyung-Jun, “6.6-kW onboard charger design using DCM PFC converter with harmonic modulation technique and two-stage dc/dc converter,” IEEE Trans. Ind. Electron., vol. 61, no. 3, pp. 1243–1252, Mar. 2014.

[2] R. Seung-Hee, K. Dong-Hee, K. Min-Jung, K. Jong-Soo, and L. ByoungKuk, “Adjustable frequency duty-cycle hybrid control strategy for fullbridge series resonant converters in electric vehicle chargers,” IEEE Trans. Ind. Electron., vol. 61, no. 10, pp. 5354–5362, Oct. 2014.

[3] P. T. Staats, W. M. Grady, A. Arapostathis, and R. S. Thallam, “A statistical analysis of the effect of electric vehicle battery charging on distribution system harmonic voltages,” IEEE Trans. Power Del., vol. 13, no. 2, pp. 640–646, Apr. 1998.

[4] A. Kuperman, U. Levy, J. Goren, A. Zafransky, and A. Savernin, “Battery charger for electric vehicle traction battery switch station,” IEEE Trans. Ind. Electron., vol. 60, no. 12, pp. 5391–5399, Dec. 2013.

[5] Z. Amjadi and S. S. Williamson, “Modeling, simulation, control of an advanced Luo converter for plug-in hybrid electric vehicle energy-storage system,” IEEE Trans. Veh. Technol., vol. 60, no. 1, pp. 64–75, Jan. 2011.

[6] H. Akagi and K. Isozaki, “A hybrid active filter for a three-phase 12-pulse diode rectifier used as the front end of a medium-voltage motor drive,” IEEE Trans. Power Del., vol. 27, no. 1, pp. 69–77, Jan. 2012.

[7] A. F. Zobaa, “Optimal multiobjective design of hybrid active power filters considering a distorted environment,” IEEE Trans. Ind. Electron., vol. 61, no. 1, pp. 107–114, Jan. 2014.

[8] D. Sixing, L. Jinjun, and L. Jiliang, “Hybrid cascaded H-bridge converter for harmonic current compensation,” IEEE Trans. Power Electron., vol. 28, no. 5, pp. 2170–2179, May 2013.

[9] M. S. Hamad, M. I. Masoud, and B. W. Williams, “Medium-voltage 12-pulse converter: Output voltage harmonic compensation using a series APF,” IEEE Trans. Ind. Electron., vol. 61, no. 1, pp. 43–52, Jan. 2014.

[10] J. Liu, S. Dai, Q. Chen, and K. Tao, “Modelling and industrial application of series hybrid active power filter,” IET Power Electron., vol. 6, no. 8, pp. 1707–1714, Sep. 2013.

[11] A. Javadi, H. Fortin Blanchette, and K. Al-Haddad, “An advanced control algorithm for series hybrid active filter adopting UPQC behavior,” in Proc. 38th Annu. IEEE IECON, Montreal, QC, Canada, 2012, pp. 5318–5323.

[12] O. S. Senturk and A. M. Hava, “Performance enhancement of the singlephase series active filter by employing the load voltage waveform reconstruction and

line current sampling delay reduction methods," IEEE Trans. Power Electron., vol. 26, no. 8, pp. 2210–2220, Aug. 2011.

[13] A. Y. Goharrizi, S. H. Hosseini, M. Sabahi, and G. B. Gharehpetian, "Three-phase HFL-DVR with independently controlled phases," IEEE Trans. Power Electron., vol. 27, no. 4, pp. 1706–1718, Apr. 2012.

[14] H. Abu-Rub, M. Malinowski, and K. Al-Haddad, Power Electronics for Renewable Energy Systems, Transportation, Industrial Applications. Chichester, U.K.: Wiley InterScience, 2014.

[15] S. Rahmani, K. Al-Haddad, and H. Kanaan, "A comparative study of shunt hybrid and shunt active power filters for single-phase applications: Simulation and experimental validation," Math. Comput. Simul., vol. 71, no. 4–6, pp. 345–359, Jun. 19, 2006.

[16] W. R. Nogueira Santos et al., "The transformerless single-phase universal active power filter for harmonic and reactive power compensation," IEEE Trans. Power Electron., vol. 29, no. 7, pp. 3563–3572, Jul. 2014.

[17] A. Javadi, H. Fortin Blanchette, and K. Al-Haddad, "A novel transformerless hybrid series active filter," in Proc. 38th Annu. IEEE IECON, Montreal, QC, USA, 2012, pp. 5312–5317.

[18] H. Liqun, X. Jian, O. Hui, Z. Pengju, and Z. Kai, "High-performance indirect current control scheme for railway traction four-quadrant converters," IEEE Trans. Ind. Electron., vol. 61, no. 12, pp. 6645–6654, Dec. 2014.

[19] E. K. K. Sng, S. S. Choi, and D. M. Vilathgamuwa, "Analysis of series compensation and dc-link voltage controls of a transformerless selfcharging dynamic voltage restorer," IEEE Trans. Power Del., vol. 19, no. 3, pp. 1511–1518, Jul. 2004.

[20] H. Fujita and H. Akagi, "A practical approach to harmonic compensation in power systems-series connection of passive and active filters," IEEE Trans. Ind. Appl., vol. 27, no. 6, pp. 1020–1025, Nov./Dec. 1991.

[21] A. Varschavsky, J. Dixon, M. Rotella, and L. Mora, "Cascaded nine-level inverter for hybrid-series active power filter, using industrial controller," IEEE Trans. Ind. Electron., vol. 57, no. 8, pp. 2761–2767, Aug. 2010.

[22] X. P. n. Salmero and S. P. n. Litra, "A control strategy for hybrid power filter to compensate four-wires three-phase systems," IEEE Trans. Power Electron., vol. 25, no. 7, pp. 1923–1931, Jul. 2010.

[23] B. Singh, A. Chandra, and K. Al-Haddad, Power Quality Problems and Mitigation Techniques. Chichester, U.K.: Wiley, 2015.

[24] P. Salmeron and S. P. Litran, "Improvement of the electric power quality using series active and shunt passive filters," IEEE Trans. Power Del., vol. 25, no. 2, pp. 1058–1067, Apr. 2010.

[25] S. Srianthumrong, H. Fujita, and H. Akagi, "Stability analysis of a series active filter integrated with a double-series diode rectifier," IEEE Trans. Power Electron., vol. 17, no. 1, pp. 117–124, Jan. 2002.

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