Harmonic Reduction in Power Distribution Network Using Transformerless Hybrid Series Active Filter

[1]Kajal S. Tumane, [2] Dr. Vilas N. Ghate,
[1]PG Scholar, [2]Associate Professor
[1]Government college of engineering, Amravati, India,444601
[2] Government college of engineering, Amravati, India,444601

Abstract : This study focused on Power quality which play main role in Generation, Transmission and Distribution network. therefore improvement of power quality by correction of power factor and elimination of harmonics is present in nonlinear load is the main task. Energy control & power quality issues corresponding to electric transportation is main purpose of transformerless hybrid series active filter (THSeAF). In power system this proposed topology forbid or isolates the harmonic distortion of current in nonlinear load. A THSeAF is a device, which reduces current and voltage corresponding to Power Quality problem in the power distribution system, this problem may come from load side or source side. In power system Load side problems causes harmonics and source side problems cause voltage stability problems. This given strategy was planned for elimination of harmonic distortions in current with the nonlinear loads to manage the flow of utility in the absence of any large and expensive transformer. It assist to match the dc-link voltage necessary for the shunt active power filter, this arrangement uses inductor of the shunt active filter combining with capacitor in series. MATLAB/SIMULINK is use for shown simulation results.

IndexTerms - Current harmonics, electric vehicle, hybrid series active filter (HSeAF), power quality improvement, PI controller, pulse width modulator (PWM), Non-linear load, THD;

I. INTRODUCTION

In present days there is more importance of electrical energy is the most important form of energy and all are massively depend on it. Insufficient supply of electricity life cannot be imagined. At the same time the quality and continuous flow of the electric power supply is also necessary for the effective functioning of the end user equipments. Most of the commercial and industrial loads demands high quality constant power. Therefore keeping the power quality having topmost importance in todays nation. Due to devices of power electronics there is serious concern on quality of power supply. Because of electronic devices there are some power quality (PQ) problems like harmonics, flicker, voltage fluctuations, voltage rise due to network faults, lightning, switching of capacitor banks etc. due to too much use of non-linear loads like (computer, lasers, printers, rectifiers) having reactive power disturbances and harmonics in power distribution system. This is very important to reduce that type of problems as there result may increase fast in future [4,5].Traditionally for reactive power disturbances and harmonics reduction were used passive filters but they have many problems with them because of large in size, problem of resonance and effect of source impedance on implementation etc. For enhancement of power quality, Active Power Filter is used and this are classified on the basis of configuration of system.[7].A Shunt APF removes all category of current issues like current harmonics, reactive power compensation, power factor enhancement, voltage dip/rise compensates by Series APF therefore, voltage at load side is perfectly regulated.

The forecasting of future Grids related with electric vehicle charging stations has produce a serious concern on all characterstics of power quality of the power system. Simultaneously, Increased harmonics sustain from nonlinear loads like electric vehicle battery chargers [1] which definately have dangerous effect on the power system and damaged plant equipments must be considered in the development of the modern grid. similarly, increase in rms and peak-value of distorted current waveforms also increase heating & losses, also affects failure of the electrical equipment. Such phenomenon adequately reduces system performance. Furthermore, to secure the point of common coupling (PCC) from distortion of voltage using dynamic voltage restorer function is advised. A solution is taken for decreasing pollution of power electronics based loads directly connected at their source. Generally, Active power devices are of two types to overcome given power quality issues, the series active filters combined hybrid type is a first category this is developed for eliminating current harmonics created by non-linear load of the power system and the second category addressing voltage issues on sensitive loads was developed generally known as Dynamic voltage restorer (DVR), having similar configuration as of Series active filter but both categories are ultimately different from each other in their control strategy. This comparison relies on purpose of their application in the power system.

Hybrid series active filter (HSeAF) was proposed to address the above earlier mentioned issues with one combination. theoretically, they are capable to compensate current harmonics to secure a power factor correction and eliminating voltage distortions at the PCC [2]. The three phase series active filters are well researched, while limited research on present the single-phase applications of series active filters in the literature. Transformerless hybrid series Active filter (THSeAF) is a combination of Active and passive filter using absence of large and expensive transformer deals with both load current and supply voltage faults. It can save sensitive loads from power quality problems arising from the service side and at the same time can stop the disturbance being injected in to the productivity from load side. This paper presents a single phase transformerless HSeAF is energy sources, where each phase can be controlled separately and could be operated independently of other phases. This paper shows the separation of a three phase converter into single phase H-bridge converters has allowed for elimination of the costly isolation transformer and stimulate industrial application for filtering.[7,9].

Harmonics

In most of the cases, power electronic equipment causes harmonics, While switching converters of all types create harmonics because of the non linear characteristic between voltage and current across the switching device and large variety of "conventional" equipments is also produced harmonics including:

1. Transformers (over excitation leading to saturation),
2. Power generation equipments (slot harmonics),
3. Induction motors (saturated magnetics),
4. AC electric arc furnaces (arcing)

All of these devices will cause harmonic currents to flow and some devices are directly produce harmonics in voltage. Any alternating current flow through any type of circuit at different frequency will produce a voltage drop at the same frequency. Because of interrelation between flow of current and voltage drop, at any location harmonic current created & it will distort the voltage in the supply circuit. In most of the condition, Equipments are not overly sensitive to the direct impact of harmonic current flow. If, equipment heated and its function shows as RMS value of the current, which can significantly overshoot the fundamental frequency value when large harmonic components are present because harmonic currents produce harmonic voltages that are is a real power quality concern and Most equipments can operate satisfactorily as long as the distortion of voltage at the equipment terminals which do not increase.

II. SYSTEM ARCHITECTURE

A. Block Diagram

The Transformerless hybrid series active filter (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 current ensures a low impedance path for current harmonics. A dc auxiliary source is connected to inject power during voltage sags. The dc-link energy storage snetwork is shown in the fig.1,The system parameters are described in Table I. The given variable source is of 120 Vrms is connected to a 1.1 kVA non-linear load and a 998 VA linear load with a 0.46 power factor. The THSeAF is connected in series in order to inject the compensating voltage. During time of distortion also On DC side the compensator (H-bridge) auxiliary source is connected. HSeAF is mostly used for compensating distortions in current type of non-linear loads.

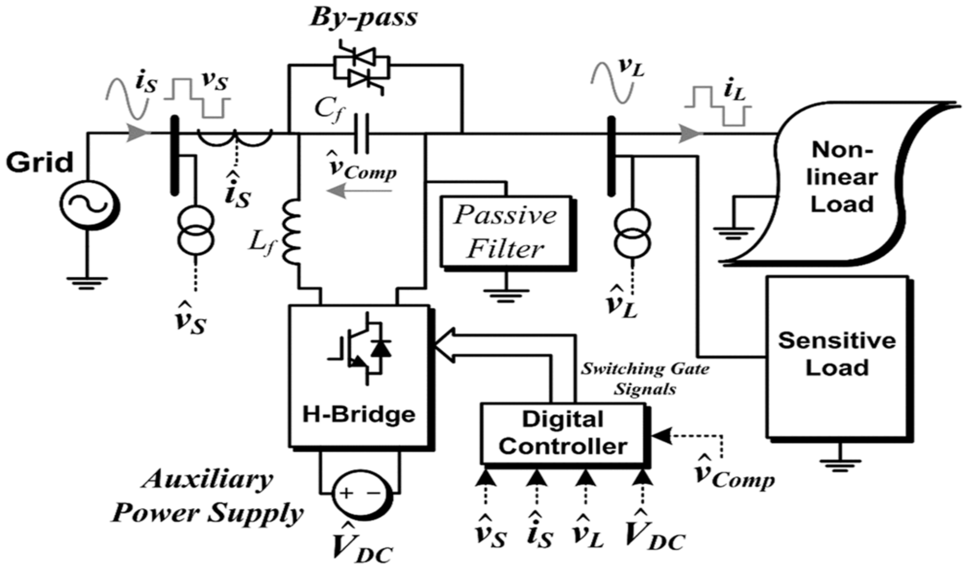


Fig 1. Electrical diagram of the THSeAF in a single phase utility

The THSeAF is bypassed and current harmonics flew directly into the smart grid. This configuration is connected to the grid with no need of a costly series injection transformer, making this topology capable of compensating source current harmonics and voltage distortion at the point of common coupling (PCC). Even if the number of switches are 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. It's aimed to point out the advantages and disadvantages of the proposed configuration over existing network configuration is clearly stated.

TABLE I
SIMULATION PARAMETER:

Symbol	Definition	Value
V_s	Line phase-to-neutral voltage	120 V_{rms}
F	System frequency	60Hz
$R_{non-linearload}$	Load resistance	11.5 ohm
$L_{non-linear\ load}$	Load inductance	20 mH
P_L	Linear load power	1 kVA
PF	Linear load powerfactor	46 %
L_f	Switching ripple filter inductance	5 mH
C_f	Switching ripple filter capacitance	2 µF
f_{PWM}	PWM frequency	5 kHz
G	Control gain for current harmonics	8 ohm
V_{DCref*}	VSI DC bus voltage of the THSeAF	70 V
PI_G	Proportional gain (Kp), Integral gain (Ki)	(10) (0.05)

B. Operation Principle

The series active filter shows a controlled voltage source (VSI). In order to prevent the source from current harmonics which drift from the nonlinear load. This series source should present low impedance for the fundamental component and high impedance for all harmonics as indicated in Fig.3. The principle of such modeling is well represented in [5].

The passive filter is important to compensfate current issues and voltage distortion and to maintain balanced voltage at load terminal. The performance of a SeAF for a current control is considered from Fig.2 of phasor equivalent circuit. The nonlinear load is nothing but a resistance representing active power consumed and generated harmonic current impedance represent nonlinear load. If source current is free from harmonics then this improves the voltage distortion at the grid side. The THSeAF acts as a low impedance path for all harmonics and open circuit for fundamental this also improves power factor. The non-linear load could be simulated by a resistance representing the active power consumed and a current source are generating current harmonics. Accordingly, the impedance Z_L shows non-linear load and the inductive load.

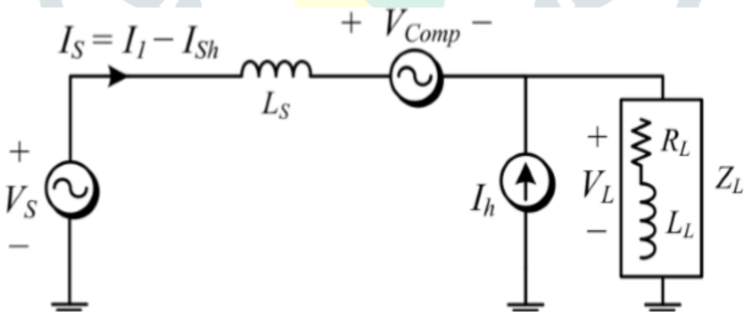


Fig. 2 THSeAF equivalent circuit for current harmonics

If gain G is large ($G \rightarrow \infty$), then the source current will became clean of any harmonics ($Ish \rightarrow 0$). That help to improving the voltage distortion at the grid side. In this approach of the THSeAF behave as high impedance open circuit for current harmonics, while the shunt high pass filter tuned at the system frequency, it creates a low-impedance path for all harmonics and open circuit for the fundamental, it also help for power factor correction.

III . CONTROL SCHEMES OF THSeAF AND PROPORTIONAL INTEGRAL (PI)

The outer-loop controller is employed wherever a capacitor replaces the DC auxiliary supply. This management strategy is well explained within the previous section. The inner-loop management strategy is predicated on Associate in nursing indirect management principle. The second PI controller employed in the outer loop, was to reinforce the effectiveness of the controller once control the DC bus. Therefore an additional correct and quicker transient response was achieved while not compromising compensation behavior of the system. In keeping with the speculation, the gain G ought to be unbroken in an exceedingly appropriate level, preventing the harmonics flows into the grid. Compensating voltage for current harmonic compensation is given by the following equation as shown,

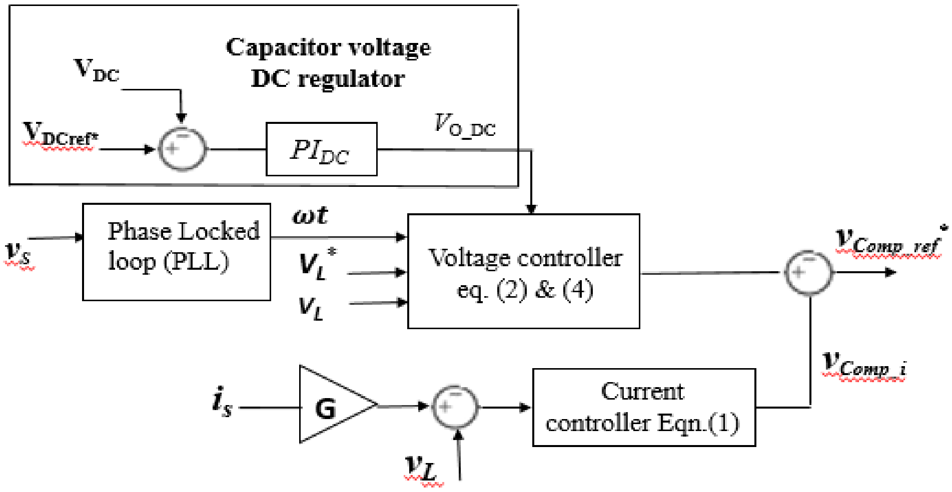


Fig.3 Control system scheme of the active part

$$V_{comp\_i}(t) = (-G\hat{i}_S + \hat{v}_L) - [|-Gi_{S1} + v_{L1}| \cdot \sin(\omega_S t - \theta)] \qquad (1)$$

Maintain voltage magnitude is

$$V_{comp\_v} = \hat{v}_L - \overset{*}{v}_L \sin(\omega_S t) \qquad (2)$$

$$V^*{}_{comp\_ref} = V_{comp\_v} - V_{comp_i} + V_{DC\_ref} \qquad (3)$$

Voltage required for DC bus is as,

$$V_{DC\_ref}(t) = V_{O\_DC} \cdot \sin(\omega_S t) \qquad (4)$$

According to the given detection formula, the compensated reference voltage V*Comp_ref is calculated. An outer loop controller is used where a capacitor can replace an DC auxiliary source. An inner loop control strategy is indirect control principle. Gain represents as the impedance for current harmonics in a suitable level to clean the grid from harmonics which are fed from non-linear loads. The second Proportional Integral (PI) controller in the outer loop is to enhance the effectiveness when regulating the DC bus. Thus, more accurate and faster response will be achieved without compromising the compression performance of the system. The gain should be kept in such a way that the current harmonics are prevented from flowing into the grid. As discussed for more accurate compensation of current harmonics, the voltage harmonics must be taken into consideration. The compensation of voltage is done to compensate the current harmonics is shown proposed simulation in Fig.5.

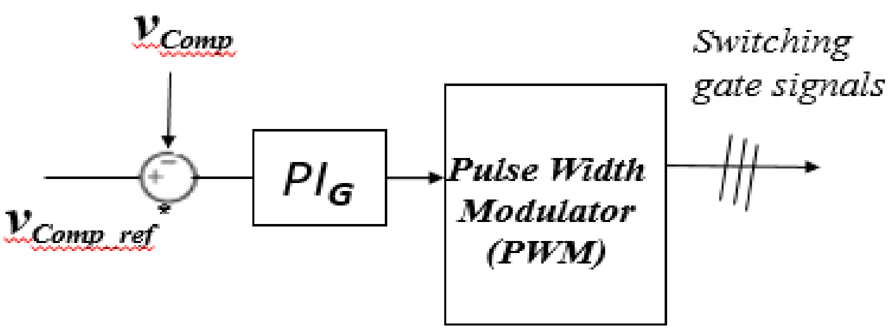
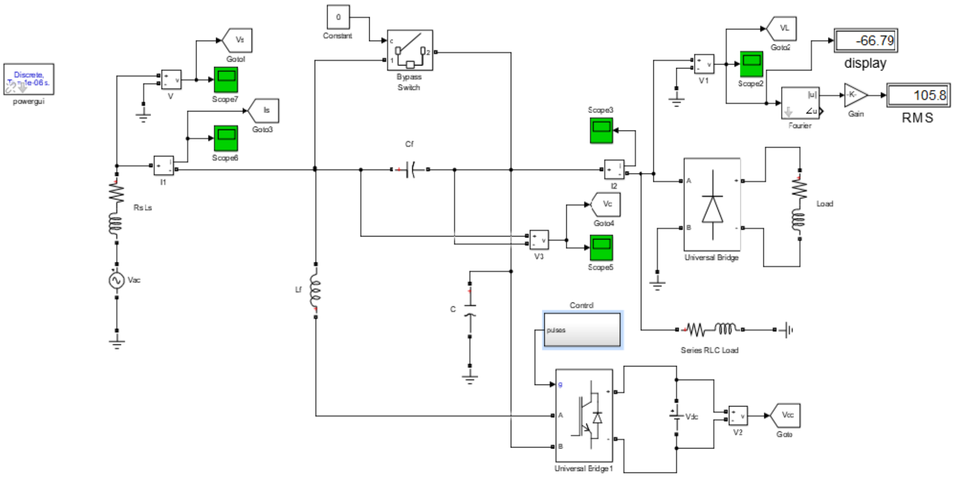


Fig.4 block diagram of THSeAF and PI controller

The complete control scheme of the proposed system THSeAF is shown in Fig.6 is implemented in MATLAB/ Simulink for real time simulations and calculation of the compensating voltage, the source voltage and load voltage along with the source current is given as the input signal to the system indirect control increases the stability of the system. The difference between the source current and fundamental components gives the source current harmonics.

Where Vdc reference is the voltage required to maintain the dc bus voltage constant. A phase locked loop PLL is used to get the reference angular frequency. The current harmonics contain fundamental components are similar to the source voltage in order to correct the power factor. This currents represents the reactive power of the load. Gain acts as resistance to the harmonics and converts current into a reactive voltage. The voltage which is generated from the loop will clean the source current from harmonics. After that, a reference signal is compared with the measured output voltage and applied to the PI controller to generate gate signals.



.Fig.5 Proposed overall simulation setup of THSeAF system

IV. RESULTS AND DISCUSSION

The performances of the hybrid series active power filter are simulated using MATLAB software. Simulink and SimPower Systems block sets are used for implementing the global system (PFC and HSeAPF). Fig. 9 shows the Simulink graph of nonlinear load (PFC) with SeAPF. Simulation results are given here for non-linear load. Fig.9 shows the source voltage and current before hybrid series active filter connection and Fig. 10 shows the load voltage and current after HSeAF connection. FFT analysis of source voltage and FFT analysis of load voltage. It may be noted that, the source voltage with no active power filter waveform gives non-sinusoidal because FFT window shows THD is as 3.8% and its fundamental value is 169.7 V. However after filter connection the source voltage has a THD is reduce to 1.37% and its fundamental value is 169.4 V. In same case load voltage FFT window reduce to 2.46%. The main reduction is with active power filter source current 14.14% which is very much reduce to 1.65% and this is clear cut improvement of using an active power filter.

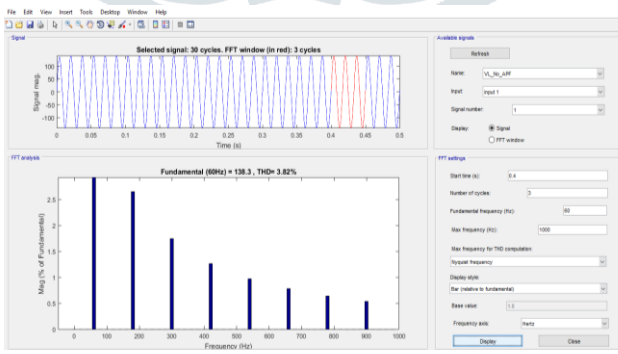


Fig.6. Before & after hybrid series active filter connection THD of Source voltage (Vs) and Source curren (Is) & load voltage (V_L)

For successful performance of HSeAPF is reference voltage. The reference voltage using instantaneous reactive power factor is presented in this paper. HSeAPF helps in reducing total harmonic distortion and maintain it to acceptable level. HSeAPF helps in improving power quality. The simulation results using MATLAB/Simulink verifies that. PI Controller can effectively and efficiently be used to control hybrid series active power filters.

V. ADVANTAGES/APPLICATION:

- No use of Transformer so, it's cost is less
- By using filters we can eliminate unwanted harmonics

- By installing filter we can improve power quality
- The Hybrid Filters are applied to large machines to eliminate frequencies
- The hybrid filters are applied to mostly grids

VI. CONCLUSION

In this paper, Transformerless hybrid series active filter (THSeAF) for power quality improvement was developed. 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 or household equipment. 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 HSeAF regulates and improves the PCC voltage. A novel THSeAF configuration with a PI controller was proposed to overcome power quality issues of a voltage fed type of non-linear load. 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.It was determine that, active compensator responds properly to the source voltage side variations by providing a constant or distortion free supply at load terminals. Furthermore, it eliminates source harmonic currents and improves power quality. Hence this system proves that by using THSeAF we can reduce the current harmonics present in the single phase system. This is less complex than other available and also cheaper as compare to other available Harmonic Compensation devices. The THSeAF is more efficient if compared to other systems.

VII. FUTURE SCOPE

The purpose of this system is to improve the power quality by compensating harmonic current and the control strategy is designed to prevent current harmonic distortions of non linear loads to flow into the utility and corrects the power factor. In future one can use Fuzzy logical controller which is automatic controller gives speed of response.This paper helps to reduce noise and gives actual output power help to charge battery properly. The modeling and analysis of the control algorithm simulated. The dc voltage regulation and its considerations are explained and the voltage and current harmonic detection method is explicitly described to evaluate the configuration and the control approach using simulation.

REFERENCES

[1] 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.

[2] A. Javadi, H. Fortin Blanchette, and K. Al-Haddad, "A novel transformerless hybrid series active filter," *in IECON 2012 - 38th Annual Conference on IEEE Ind. Electron. Society*, Montreal, 2012, pp. 5312-5317.

[3] 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.

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

[5] 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.

[6] 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.

[7] Alireza Javadi, Kamal Al-Haddad “A Single Phase Active Device for Power Quality Improvement of Electrified Transportation”, *IEEE Transactions on Industrial electronics*, Vol. 62, No. 5, May 2015

[8] D. Sixing, L. Jinjun, and L. Jiliang, "Hybrid Cascaded H-bridge Converter for Harmonic Current Compensation," *IEEE Trans. Power Electron*, vol. 28, pp. 2170-2179, 2013. [9] 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, pp. 6645-6654, 2014.

[10] Varschavsky, J. Dixon, M. Rotella, Mora, x, and L. n, "Cascaded Nine-Level Inverter for Hybrid-Series Active Power Filter, Using Industrial Controller," *IEEE Trans. Ind. Electron.*, vol. 57, pp. 27612767, 2010.

[11] Salmero, x, P. n, Litra, and S. P. n, "A Control Strategy for Hybrid Power Filter to Compensate Four-Wires Three Phase Systems," *IEEE Trans. Power Electron.*, vol. 25, pp. 1923-1931, 2010.