Simple Augmented Current Controller with OHC Technique for grid current compensation in the Distribution System

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Abstract—**This paper presents a novel control technique on four leg inverter with which the distribution grid is interconnected with the domestic houses. Most of the houses in the distribution side possess inverter for the usage of Electricity. With the advancement in Solar & wind, it will become easy to see houses, often with solar & a small Wind power system. The excess power generated can be exchanged with the Electricity Board for providing uninterruptible power supply. During this exchange there may be a deterioration in the quality of power, most often the grid current gets affected with a large harmonic distortion, and also there exists unbalanced grid currents. Thus, it is necessary to provide uninterruptible power supply with good quality of power. In spite of several controllers, the proposed augmented controller has its own reliability & quick response with Overall Harmonic Compensation (OHC) technique which relies on DSP based filter. This Augmented based control technique with OHC is demonstrated extensively with MATLAB/Simulink simulation.**

Keyword-Current controller, Distributed Generation, Distribution system, Grid interconnection, Power Quality, Renewable Energy.

I. INTRODUCTION

A Grid connected system allows us to get an uninterruptable power supply when the sun shines, water runs, or the wind is blowing. Any excess energy that is produced is fed back into the grid. When there is Scarce Renewable energy, electricity from the grid supplies the needs, eliminating the expense of electricity. The power providers allow net metering [1], an arrangement where excess electricity generated by a grid connected system turns back the electricity meter as it fed back into the grid. It is necessary to know about this interconnection to electric grid, which includes (i) Equipment required for the connection to the grid (ii) State and community codes (iii) Requirements from power provider.

It is necessary to have some additional equipment called balance of the system in order to safely transmit electricity to the loads. As per the power providers the system must include safety and power quality components [2]. These components include Switches to disconnect the system from the grid in the event of a power surge or power failure and power conditioning unit to ensure that the power exactly matches the voltage and frequency of the electricity flowing through the grid. The Institute of Electrical and Electronics Engineers (IEEE) have written a standard IEEE 1547-2003 which provides technical requirements and tests for grid connected operation. Moreover the Underwriters Laboratories (UL) have developed UL1741 to certify inverters, Converters, charge controllers and output controllers for power producing stand-alone and grid connected system [3]. UL1741 verifies that inverter complies with IEEE 1547 for grid connected applications.

One of the most important objectives of the electric utility is to supply Sinusoidal voltage with constant magnitude [4]. Maintaining this Sinusoidal supply voltage is not easy because in the distribution side, balanced load, unbalanced load, linear load, nonlinear load have their own effects on the distribution lines which make the deviation from sinusoidal voltage [5]. Another important objective of the electric utility is to supply uninterruptible green energy to the distribution side customers. This can be accomplished by interconnecting Renewable energy sources such as solar and wind. One of the most common problems while connecting this power from solar, wind to the grid is on the Interfacing unit [6]. Since the interfacing unit undergoes power electronic components it generates harmonics and deteriorates the quality of power with Grid current deterioration and load current unbalance.

Conventional solutions such as Active filters, Passive filters for reducing harmonic problems are ineffective [7-8]. In addition IEC 61000 and IEEE 519 have become restricted. In this paper Hybrid filtering (OHC) & augmented current control techniques are incorporated to overcome this mitigation problems.

This paper is arranged as follows. Section II describes the system under consideration. Section III describes the controller for grid interfacing inverter. Section IV presents the Simulation study, Section V concludes the Paper.

II. SYSTEM DESCRIPTION

Consider the system having Renewable energy source such as solar, wind in the distribution side of consumer. The generated power is utilized and stored in the Battery of the receivers in distribution system. This excess power can be fed to the grid with the help of grid interfacing unit. The Distribution side Consumer utilizes the power from Electric utility as well as from their own Renewable energy source generation. Thus the consumers possess Bidirectional power flow and bidirectional metering [9-10]. The solar can be directly fed to the battery whereas the power generated from wind must undergo power conditioning before connecting to the battery and Grid as shown in Fig 1 and 2.

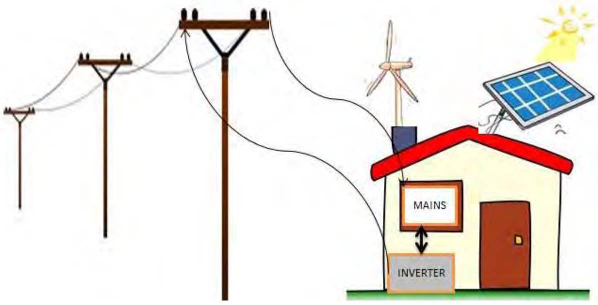


Fig.1. Schematic diagram of system description

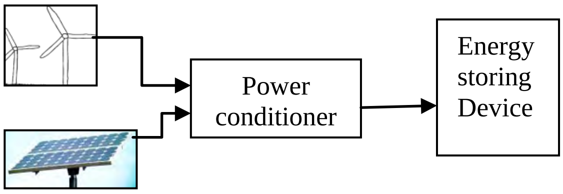


Fig.2. RES at distribution system

III.HYBRID FILTERS WITH OHC TECHNIQUE

The overall harmonic compensation (OHC) aims to provide as harmonic reference current, the entire harmonic spectrum present in the load current except the fundamental frequency [11], which is to be supplied by the utility. The OHC relies on overall harmonic detection method as in Fig.3. Therefore the main function of harmonic detection block is to filter out the fundamental frequency. This can be achieved as follows. In Stationary abc-frame by tuning Notch filters [12-13] the unwanted fundamental component are removed. This may be prone to the phase delay/deviation if not carefully designed and implemented causing improper harmonic compensation. In synchronous fundamental dq frame by using high pass filter the dc component aliasing the fundamental frequency are eliminated. The instantaneous power theory can also be used for the removal of fundamental component. Thus as per the detection, the harmonic compensation signal is generated using DSP toolbox.

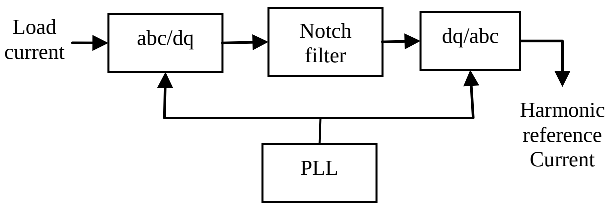


Fig.3 Illustration of generation of harmonic reference current using overall harmonic compensation method (OHC)

A. Mathematical model

The mathematical model relies on the one line diagram of distribution system as shown in the Fig.4. The voltage and the current reference have to be generated for generating the pulses for the interfacing unit.

Let I_1 be the current in grid with resistance R_1 and I_2 be the load side current with the resistance $R_L I_L$. I_{inv} is the current in the inverter. V_s are the source voltage. This model undergoes abc to dq transformation which generates reference current and voltage as per distribution line [14]. The generated current is utilized for OHC and the voltage for augmented controller which ultimately generates pulses for the interfacing unit. The transformation is further demonstrated in clark's Transformation which is utilized for the mathematical modelling of system.

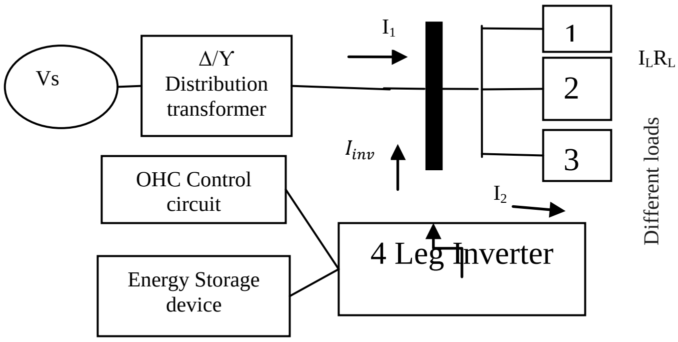


Fig.4. Schematic block diagram of proposed system

At the Point of Common coupling,

$$i_1 = i_{inv} + i_2 \tag{1}$$

$$V_1 - V_{pcc} = i_1 R_1 + L_1 \frac{di_1}{dt} \tag{2}$$

$$V_{pcc} - V_2 = i_2 R_2 L_2 \frac{di_2}{dt} \tag{3}$$

$$V_{pcc} - V_{inv} = R_{inv} I_{inv} + L_{inv} \frac{di_{inv}}{dt} \tag{4}$$

The abc to αβ0 transformation is done using clark transformation. This is done easily with abc to αβ0 transformation block in Simulink/MATLAB. The theoretical model is done as per the following equations

$$\begin{bmatrix} V_0 \\ V_\alpha \\ V_\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \\ 1 & \frac{-1}{2} & \frac{-1}{2} \\ 0 & \frac{\sqrt{3}}{2} & \frac{-\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} V_1 a \\ V_1 b \\ V_1 c \end{bmatrix} \tag{5}$$

$$\begin{bmatrix} i_0 \\ i_\alpha \\ i_\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \\ 1 & \frac{-1}{2} & \frac{-1}{2} \\ 0 & \frac{\sqrt{3}}{2} & \frac{-\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} i_2 a \\ i_2 b \\ i_2 c \end{bmatrix} \tag{6}$$

The zero sequence power is represented as additional power in the system.

$$P_Z = V_Z i_Z \tag{7}$$

Thus $[V_0 \quad V_\alpha \quad V_\beta]$ and $[i_0 \quad i_\alpha \quad i_\beta]$ are given to the controller to generate the pulses for the control activity.

This clarks transformation is utilized by the augmented controller and it transfers α, β to d and q and finally it uses the parks transformation of d,q to abc transformation. This incorporates the rapid and reliable control of power and the interfacing unit. It also incorporates rapid disturbance rejection capability.

IV. AUGMENTED CONTROLLER

The equation set shown below forms the basic algorithm which is in discretized model. The output of this module are the direct and quadrature average voltage references which are used together with two PI controllers, to calculate the average voltage references.

$$U_{Md}(t_k) = Ri_d(t_k) + \left[\frac{L}{T} - \frac{R}{2}\right]\{i_d(t_k) - i_d(t_k-1)\} - \omega L i_q(t_k) \tag{8}$$

$$U_{Mq}(t_k) = Ri_q(t_k) + \left[\frac{L}{T} - \frac{R}{2}\right]\{i_q(t_k) - i_q(t_k-1)\} - \omega L i_d(t_k) + u(t_k) \tag{9}$$

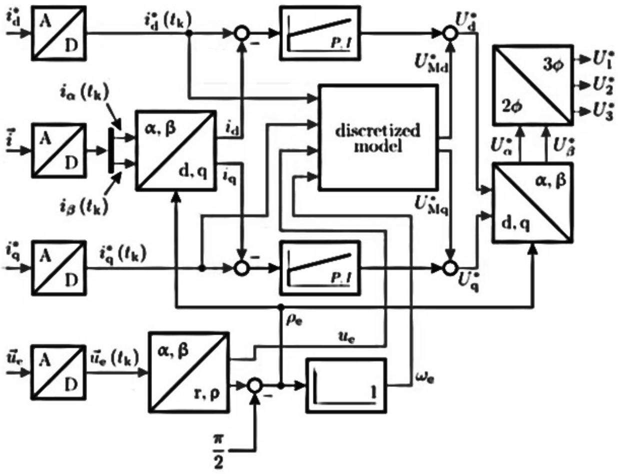


Fig.5. Structure of Augmented controller

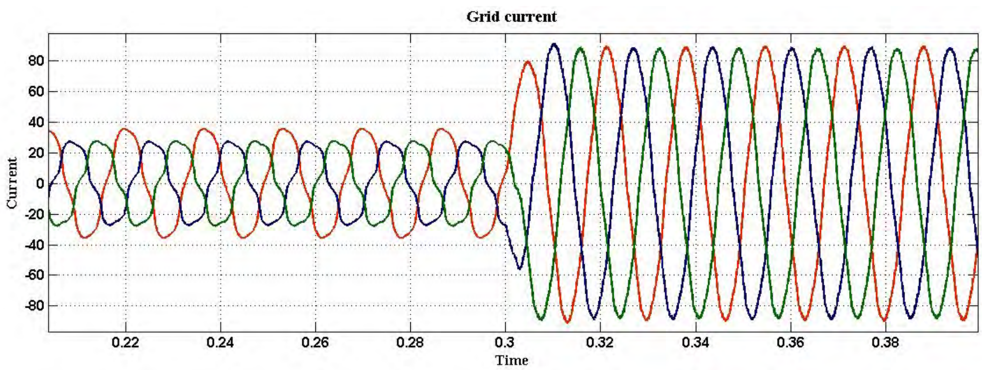
Deviations between the load parameters used in the controller and those actually present are compensated by the two PI controllers [15-16]. The dynamics which need to be handled by these PI controllers are rather limited because they relate to parameter changes due to physical environment. Hence the gains can be choosen relatively low. The discrete model uses four additional terms $Ri_d(t_k)$, $Ri_q(t_k)$, $\{i_d(t_k) - i_d\ (t_k\text{-}1)\} - \omega Li_q(t_k)$, $\{i_q(t_k) - i_q\ (t_k\text{-}1)\} - \omega Li_d(t_k) + u(t_k)$. of which the latter two are current difference equations.

Thus the input signals are discretized and transformed from α, β to d,q and finally resolving the pulses for interfacing unit using appropriate transformation.

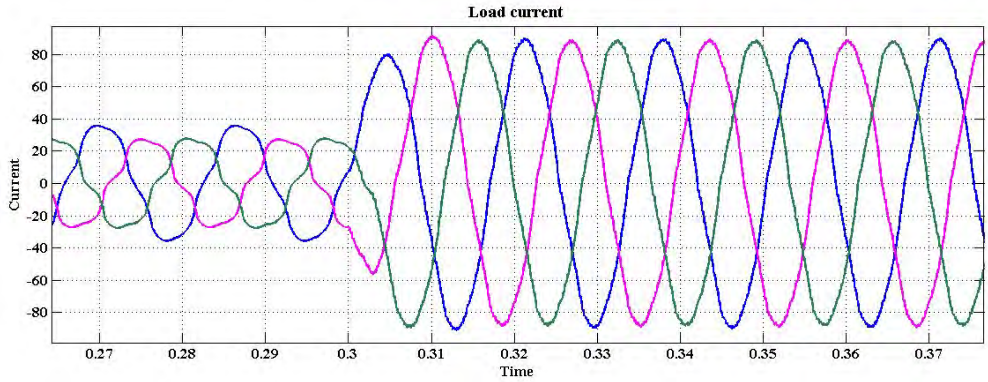
V. SIMULATION RESULTS & DISCUSSIONS

In order to verify the proposed control approach, an extensive Simulation study is carried out using MATLAB/Simulink.The quality of power is maintained despite of highly unbalanced nonlinear load at Point of common coupling. An unbalanced 3 phase 4 wire non linear load which is unbalanced and with harmonics have to be compensated. The augmented current controller and the OHC plays a part in its compensation.Initially the grid interfacing unit is not connected. At t=0.3 s the grid interfacing unit along with OHC and Augmented current controller is connected. At this stage the profile of load current changes from unbalanced non linear to sinusoidal current as shown in Fig 6. Moreover it can be noticed that the unbalanced load current gets balanced fom the figure 6(b). As the interfacing unit also supplies the load neutral current, the neutral current gets to be compensated after t=0.3 s as shown in Fig 7.

The Comparison of Various controllers and the Compensation details of proposed controller are displayed in terms of THD in Table.1. The Notch filter plays a vital role in the compensation (OHC). The harmonics are calculated using FFT analysis as shown in Fig. 8. The THD is calculated at t=0.05s, 0.1s, 0.15s, 0.2s, 0.25s, 0.3s which possess large harmonics and the THD t=0.35s, 0.4s, 0.45s, 0.5s, o.55s possess harmonics within the specified limit.



(a)



(b)

Fig.6. Simulation Results of (a) Grid current (b) Load current

Thus from the above results, it is portrayed that the interfacing unit can be effectively controlled using OHC and Augmented controller when compared to other conventional controllers [17], hence compensating the current unbalance and current harmonics. This enables the grid to supply sinusoidal and balanced power.

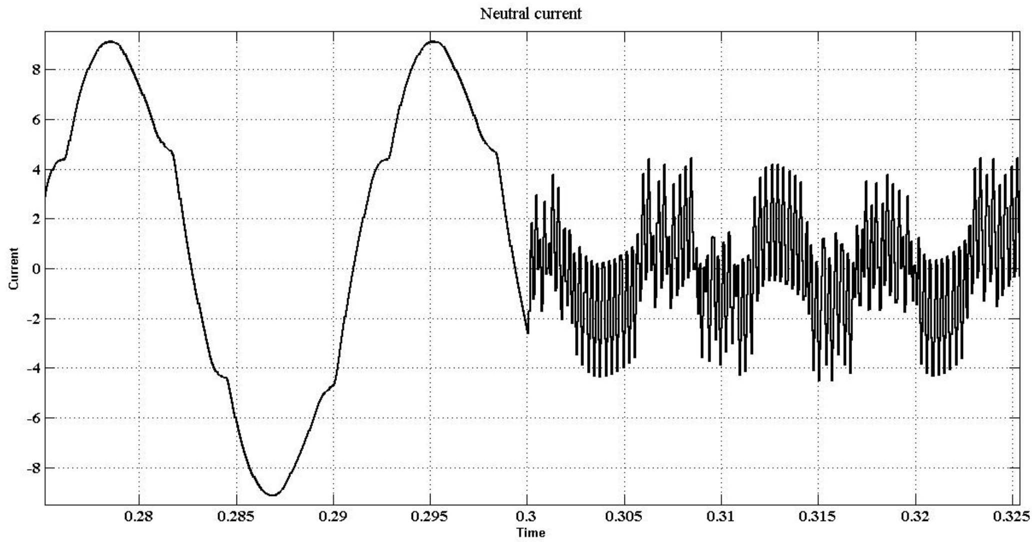
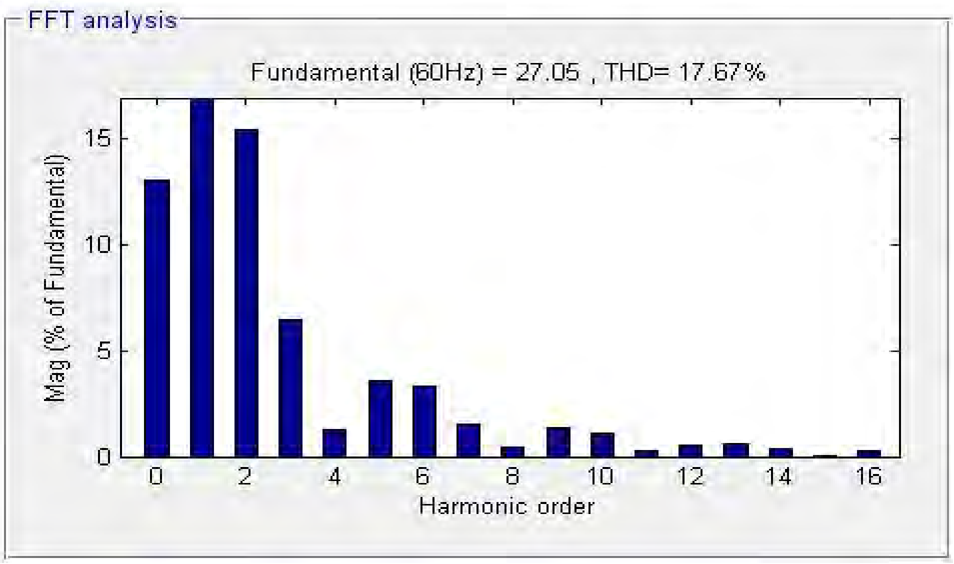


Fig.7. Neutral current forced to reach zero after t=0.3s



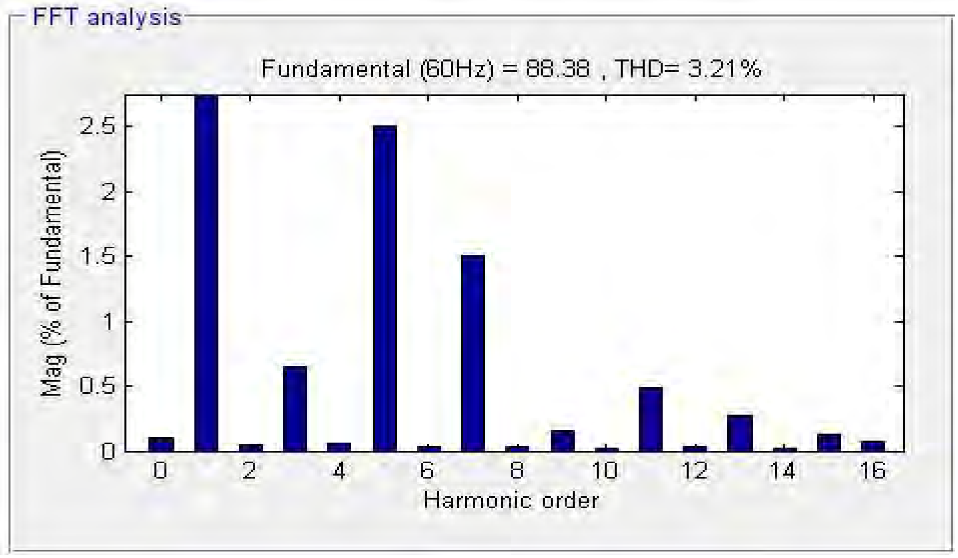


Fig.8.FFT analysis for THD calculation at t=0.05s & t=3.5s

TABLE 1. Total Harmonic Distortion of Grid current

S.No	Control Techniques	THD after compensation
1.	OHC	3.21 %
2.	PQ theory	3.29%
3.	L_{d-q} theory	3.24%
4.	SRF theory	3.32%
5.	Direct current theory	4.42%

VI. CONCLUSION

This paper has presented a novel control strategy based on OHC and Augmented current controller in order to maintain the quality of power at the coupling point and to bring down the THD for the distribution system comparatively. It has been shown that the interfacing unit is effectively utilized for maintaining the quality of power. Extensive use of MATLAB/Simulink simulation validates the proposed controller. Moreover the load neutral current is minimized from flowing into the grid. With this technique each consumer acts as power conditioner and generator with improved THD level. The rapid disturbance rejection capability and power controlling capability with high performance and reliable operation makes the controller superior than other conventional controller. Finally reducing the current harmonic capability from 18.94% to 3.21% shows its performance whose THD level is low compared to other conventional controllers.

REFERENCES

[1] Melike Erol-Kantarci, “Wireless sensor networks for cost efficient residential energy management in the smart grid” IEEE Transactions on smart grid, vol.2, pp.314-325, June 2011.

[2] M.laden Kezunovic, “Smart fault locations for smart grids”, IEEE Transactions on Smart grid, vol.2, pp.11-22, March 2011.

[3] B.K.Bose, Modern power electronics Evolution Technology and applications, Mumbai, Jaico Publishing house, 2003.

[4] A.Chandra, Mukhtiar Singh,Vinod Khadkikar, “Grid Interconnection of Renewable energy sources at the distribution level with power quality improvement features”, IEEE Transanctions on power delivery, vol.26, pp. 307-315,January 2011.

[5] W.Abbas, M.A.Saqib, “Effect of Nonlinear load distributions on Total Harmonic distortion in power systems”, in IEEE Conference publication ICEE 07,April 2007, pp. 1-6.

[6] Sheng-Yi Su, Chan-nan lu, Rung-fang chang, Guillermo Gutiérrez-Alcaraz, “Distribured Generation Interconnection Planning: A wind power case study”, IEEE Transactions on smart grid, vol.2, pp.181-189, March 2011.

[7] Frede Blaabjerg, Remus Teodorescue, Marco Liserre, Adrian V Timbus, “Overview of control and Grid Synchronisation for distributed power generation systems”, IEEE Transactions on Industrial Electronics, vol.53, pp.1398-1409,October 2006.

[8] Emanuel Serban, Helmine Serban, A control strategy for a distributed power generation Microgrid application with voltage and current controlled source converter, IEEE Transactions on power electronics, vol.25, pp.2981-2991, December 2010.

[9] Stevens, H.Raymond, “ power flow direction definitions for metering of Bidirectional power”,IEEE Transactions on power apparatus and systems, vol.102, pp.3018-3022,1983

[10] Sun, Hongjian, “ Relaying technologies for smart grid communications”, IEEE Transactions on wireless communications, Vol.19, pp.52-59, Dec 2012

[11] L.Asiminoaei, Lucian, “overall and selective compensation of harmonic currents in active filter applications”, IEEE conference publication CPE 09, May 2009, pp.153-160.

[12] Chien-Cheng Tseng, soo-chang pei, Stable IIR notch filter design with optimal pole placement, IEEE transactions in signal processing, vol.49, pp- 2673-2681, November 2001.

[13] Dash, Pradipta Kishore, “Estimation of power system frequency using adaptive notch filters”, IEEE Conference publication on Energy management and power delivery EMPD 98, march 1998, pp.143-148.

[14] M.Hartmann, " Current control of three phase rectifier systems using three independent current controllers" IEEE Transactions on Power electronics, Vol.28, pp.3988-4000, August 2013.
[15] M.Tanrioven, M. S. Alam, "Modelling control and power quality Evaluation of a PEM fuel cell based power supply system for Residential use", IEEE transactions on Industry application, vol.42, pp-1582-1589, December 2006.
[16] G.Escobar, A.Vald, Z.J.Leyva-Ramos,P.R.Martnez, "A controller for a Boost converter with Harmonic reduction", IEEE Transactions on Control system technology, vol.12, pp-717-726, Sept 2004
[17] Naimish Zaveri, Ajitsinh Chudasama, "Analysis of differenent real time reference generation techniques used for harmonic mitigation in three phase shunt active power filters", International journal of recent trends in Engineering, Vol 2, pp.123-126,November 2009.

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