International Journal for Innovative Engineering and Management Research
A Peer Revieved Open Access International Journal
www.ijiemr.org

GRID-VOLTAGE REGULATION AS A STATCOM BY USING IUPQC CONTROLLER

G ANNAPURNAMMA

Assistant Professor, Department of Electrical and Electronics Engineering, Siddhartha Institute of Technology and Sciences, Narapally, Hyderabad, Telangana, India

ABSTRACT: This paper presents an improved controller for the dual topology of the unified power quality conditioner (iUPQC) extending its applicability in power-quality compensation, as well as in microgrid applications. By using this controller, beyond the conventional UPQC power quality features, including voltage sag/swell compensation, the iUPQC will also provide reactive power support to regulate not only the load-bus voltage but also the voltage at the grid-side bus. In other words, the I UPQC will work as a static synchronous compensator (STATCOM) at the grid side, while providing also the conventional UPQC compensations at the load or micro grid side. Experimental results are provided to verify the new functionality of the equipment.

Keywords: iUPQC, micro grids, power quality, static synchronous compensator (STATCOM), unified power quality conditioner (UPQC).

I. INTRODUCTION

CERTAINLY, power-electronics devices have brought about great technological improvements. However, the increasing number of power-electronics-driven loads used generally in the industry has brought about uncommon power quality problems. In contrast, power-electronicsdriven loads generally require ideal sinusoidal supply voltage in order to function properly, whereas they are the most responsible ones for abnormal harmonic currents level in the distribution system. In this scenario, devices that can mitigate these drawbacks have been developed over the years. Some of the solutions involve a flexible compensator, known as the unified power quality conditioner (UPQC) [1]– [7] and the static synchronous compensator (STATCOM) [8]–[13]. The power circuit of a UPQC consists of a combination of a shunt active filter and a series active filter connected in a back-to-back configuration. This combination allows the simultaneous compensation of the load current and the supply voltage, so that the compensated current drawn from the grid and the compensated supply voltage delivered to the load are kept balanced and sinusoidal. The dual topology of the UPQC, i.e., the iUPQC, was presented in [14]–[19], where the shunt active filter behaves as an acvoltage source and the series one as an ac-current source, both at the fundamental frequency. This is a key point to better design the control gains, as well as to optimize the LCL filter of the power converters, which allows improving

International Journal for Innovative Engineering and Management Research
A Peer Revieved Open Access International Journal
www.ijiemr.org

significantly the overall performance of the compensator [20]. The STATCOM has been used widely in transmission networks to regulate the voltage by means of dynamic reactive power compensation. Nowadays, the STATCOM is largely used for voltage regulation [9], whereas the UPQC and the iUPQC have been selected as solution for more specific applications [21]. Moreover, these last ones are used only in particular cases, where their relatively high costs are justified by the power quality improvement it can provide, which would beMN unfeasible by using conventional solutions. By joining the extra functionality like a STATCOM in the iUPQC device, a wider scenario of applications can be reached, particularly in case of distributed generation in smart grids and as the coupling device in grid-tied microgrids. In [16], the performance of the iUPQC and the UPQC was compared when working as UPQCs. The main difference between these compensators is the sort of source emulated by the series and shunt power converters. In the UPQC approach, the series converter is controlled as a no sinusoidal voltage source and the shunt one as a no sinusoidal current source. Hence, in real time, the UPQC controller has to determine and synthesize accurately the harmonic voltage and current to be compensated. On the other hand, in the iUPQC approach, the series converter behaves as a controlled sinusoidal current source and the shunt converter as a controlled sinusoidal voltage source. This means that it is not necessary to determine the harmonic voltage and current to be compensated, since the harmonic voltages appear naturally across the series current source and the harmonic currents flow naturally into the shunt voltage source. In actual power converters, as the switching frequency increases, the power rate capability is reduced. Therefore, the iUPQC offers better solutions if compared with the UPQC in case of high-power applications, since the iUPQC compensating references are pure sinusoidal waveforms at the fundamental frequency. Moreover, the UPQC has higher switching losses due to its higher switching frequency.

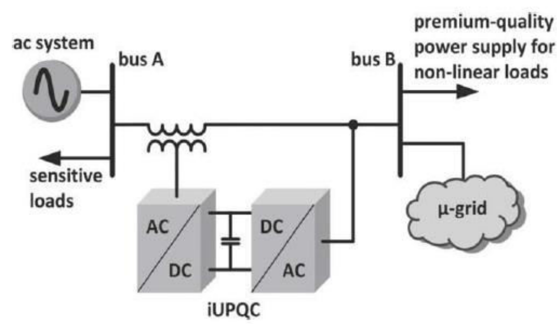
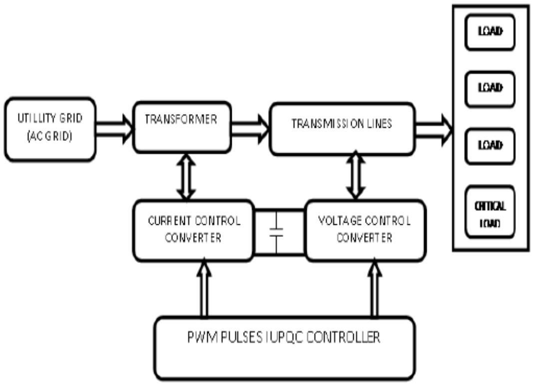


Fig. 1. Example of applicability of iUPQC.

This paper proposes an improved controller, which expands the iUPQC functionalities. This improved version of iUPQC controller includes all functionalities of those previous ones, including the voltage regulation at the loadside bus, and now providing also voltage regulation at the grid-side bus, like a STATCOM to the grid. Experimental results are provided to validate the new controller design. This paper is organized in five sections. After this introduction, in Section II, the iUPQC applicability is explained, as well as the novel feature of the proposed controller. Section III presents the proposed controller and an analysis of the power flow in steady state. Finally, Sections IV and V provide the experimental results and the conclusions, respectively.

International Journal for Innovative Engineering and Management Research
A Peer Revieved Open Access International Journal
www.ijiemr.org

II. BLOCK DIAGRAM



Fg.2.General block diagram

Mainly three significant control approaches for IUPQC can be found to control the sag on the system: 1) active power control approach in which an in-phase voltage is injected through series inverter , popularly known as IUPQC-P; 2) reactive power control approach in which a quadrature voltage is injected, known as UPQC-Q; and 3) a minimum VA loading approach in which a series voltage is injected at a certain angle, which is known as VA min. The VA loading in IUPQC-VA min is determined on the basis of voltage sag, may not be at optimal value. The voltage sag/swell on the system is one of the most important power quality problems in distribution.

III. MODULE DESCRIPTION

A. Unified Power Quality Conditioner (UPQC)

A Unified Power Flow Controller (or UPFC) is an electrical device for providing fast-acting reactive power compensation on high-voltage electricity transmission networks. It uses a pair of three-phase controllable bridges to produce current that is injected into a transmission line using a series transformer. The controller can control active and reactive power flows in a transmission line. The UPFC uses solid state devices, which provide functional flexibility, generally not attainable by conventional thyristor controlled systems. The UPFC is a combination of a static synchronous compensator (STATCOM) and a static synchronous series compensator (SSSC) coupled via a common DC voltage link. The main advantage of the UPFC is to control the active and reactive power flows in the transmission line. If there are any disturbances or faults in the source side, the UPFC will not work. The UPFC operates only under balanced sine wave source. The controllable parameters of the UPFC are reactance in the line, phase angle and voltage. The UPFC concept was described in 1995 by L. Gyugyi of Westinghouse. [1] The UPFC allows a secondary but important function such as stability control to suppress power system oscillations improving the transient stability of power system.

B. Static Synchronous Compensator (STATCOM)

A static synchronous compensator (STATCOM), also known as a "static synchronous condenser" ("STATCON"), is a regulating device used on alternating current electricity transmission networks. It is based on a power electronics voltage-source converter and can act as either a source or sink of reactive AC power to an electricity network. If connected to a source of power it can also provide active AC power. It is a member of the FACTS family of devices. It is inherently modular and electable. Usually a STATCOM is installed to support electricity networks that have a poor power factor and often poor voltage regulation.

There are however, other uses, the most common use is for voltage stability. A STATCOM is a voltage source converter (VSC)- based device, with the voltage source behind a reactor. The voltage source is created from a DC capacitor and therefore a STATCOM has very little active power capability. However, its active power capability can be increased if a suitable energy storage device is connected across the DC capacitor. The reactive power at the terminals of the STATCOM depends on the amplitude of the voltage source. For example, if the terminal voltage of the VSC is higher than the AC voltage at the point of connection, the STATCOM generates reactive current; conversely, when the amplitude of the voltage source is lower than the AC voltage, it absorbs reactive power. The response time of a STATCOM is shorter than that of a static VAR compensator (SVC), mainly due to the fast switching times provided by the IGBTs of the voltage source converter. The STATCOM also provides better reactive power support at low AC voltages than an SVC, since the reactive power from a STATCOM decreases linearly with the AC voltage (as the current can be maintained at the rated value even down to low AC voltage).

C. Power Quality

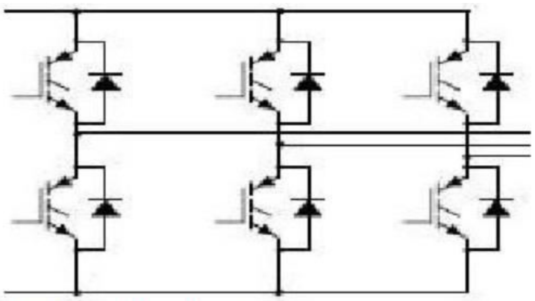
Power quality determines the fitness of electric power to consumer devices. Synchronization of the voltage frequency and phase allows electrical systems to function in their intended manner without significant loss of performance or life. The term is used to describe electric power that drives an electrical load and the load's ability to function properly. Without the proper power, an electrical device (or load) may malfunction, fail prematurely or not operate at all. There are many ways in which electric power can be of poor quality and many more causes of such poor quality power. The electric power industry comprises electricity generation (AC power), electric power transmission and ultimately electric power distribution to an electricity meter located at the premises of the end user of the electric power. The electricity then moves through the wiring system of the end user until it reaches the load. The complexity of the system to move electric energy from the point of production to the point of consumption combined with variations in weather, generation, demand and other factors provide many opportunities for the quality of supply to be compromised. While "power quality" is a convenient term for many, it is the quality of the voltage—rather than power or electric current—that is actually described by the term. Power is simply the flow of energy and the current demanded by a load is largely uncontrollable.

D. Series Inverter And Shunt Inverter

The circuit is basically an extension of the H-bridge-style single-phase inverter, by an additional leg. The control strategy is similar to the control of the single-phase inverter, except that the reference signals for the different legs have a phase shift of 120° instead of 180° for the single-phase inverter. Due to this phase shift, the odd triple harmonics

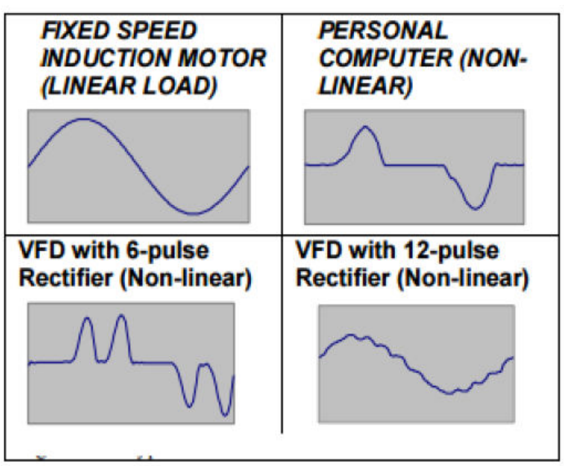
International Journal for Innovative Engineering and Management Research
A Peer Revieved Open Access International Journal
www.ijiemr.org

(3rd, 9th, 15th, etc.). To compensate for this voltage reduction, the fact of the harmonics cancellation is sometimes used to boost the amplitudes of the output voltages by intentionally injecting a third harmonic component into the reference waveform of each phase leg.



Fg.4.Series and shunt Inverter.

E. Non-Linear Load. A load is considered non-linear if its impedance changes with the applied voltage. The changing impedance means that the current drawn by the non-linear load will not be sinusoidal even when it is connected to a sinusoidal voltage. These non-sinusoidal currents contain harmonic currents that interact with the impedance of the power distribution system to create voltage distortion that can affect both the distribution system equipment and the loads connected to it.



Fg.5.Non-linear load.

IV. RESULT ANALYSIS

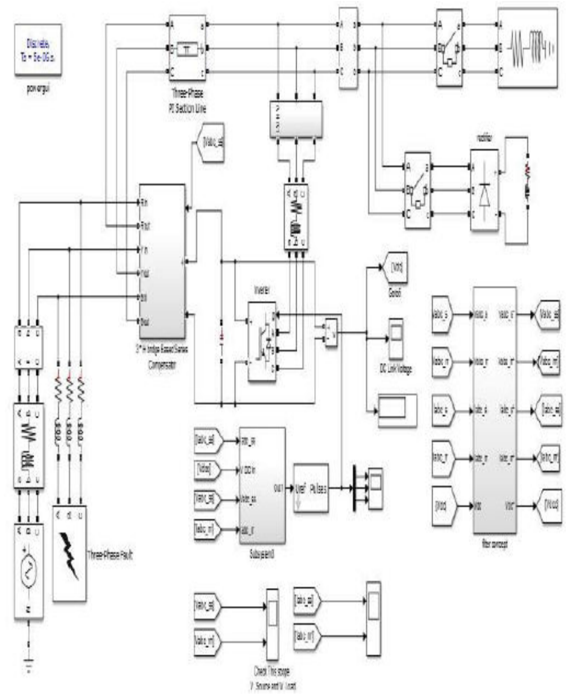


Fig.6. Simulation Diagram.

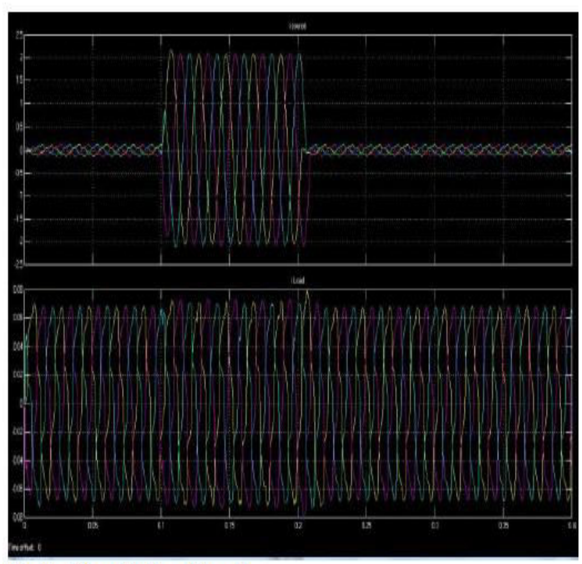


Fig.7. Simulation Graph.

In figure 7 and 8 shows the simulation diagram and graph of the compensate voltage during power quality proplem. In the graph results shows the exact output waves of the series and shunt converter. The simulation and experimental results confirm to verify the feasibility of the proposed converter. The simulation and output waveform s are done by MATLAB software.

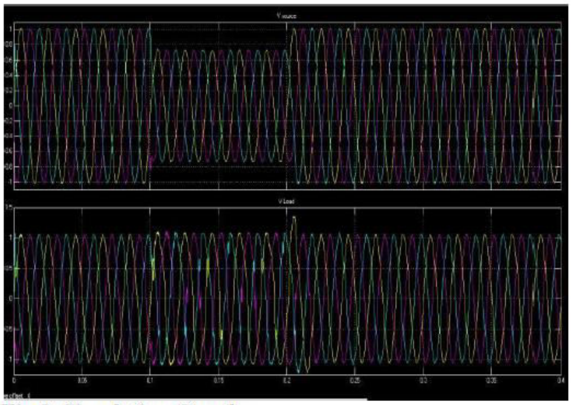


Fig.8. Simulation Graph.

IV. CONCLUSION

In the improved iUPQC controller, the currents synthesized by the series converter are determined by the average active power of the load and the active power to provide the dc-link voltage regulation, together with an average reactive power to regulate the grid-bus voltage. In this manner, in addition to all the power-quality compensation features of a conventional UPQC or an iUPQC, this improved controller also mimics a STATCOM to the grid bus. This new feature enhances the applicability of the iUPQC and provides new solutions in future scenarios involving smart grids and microgrids, including distributed generation and energy storage systems to better deal with the inherent variability of renewable resources such as solar and wind power. Moreover, the improved iUPQC controller may justify the costs and promotes the iUPQC applicability in power quality issues of critical systems, where it is necessary not only an iUPQC or a STATCOM, but both, simultaneously. Despite the addition of one more power-quality compensation feature, the grid-voltage regulation reduces the inner-loop circulating power inside the iUPQC, which would allow lower power rating for the series converter. The experimental results verified the improved iUPQC goals. The grid-voltage regulation was achieved with no load, as well as when supplying a three-phase nonlinear load. These results have demonstrated a suitable performance of voltage regulation at both sides of the iUPQC, even while compensating harmonic current and voltage imbalances.

REFERENCES

[1] K. Karanki, G. Geddada, M. K. Mishra, and B. K.Kumar, ―A modified three-phase four-wire UPQC topology with reduced DC-link voltage rating,‖ IEEE Trans. Ind. Electron., vol. 60, no. 9, pp. 3555–3566, Sep. 2013.

[2] V. Khadkikar and A. Chandra, ―A new control philosophy for a unified power quality conditioner (UPQC) to coordinate load-reactive power demand between shunt and series inverters,‖ IEEE Trans. Power Del., vol. 23, no. 4, pp. 2522–2534, Oct. 2008.

[3] K. H. Kwan, P. L. So, and Y. C. Chu, ―An output regulation-based unified power quality conditioner with Kalman filters,‖ IEEE Trans. Ind. Electron., vol. 59, no. 11, pp. 4248–4262, Nov. 2012.

[4] A. Mokhtatpour and H. A. Shayanfar, ―Power quality compensation as well as power flow control using of unified power quality conditioner,‖ in Proc APPEEC, 2011, pp. 1–4.

[5] J. A. Munoz et al., ―Design of a discrete-time linear control strategy for a multicell UPQC,‖ IEEE Trans. Ind. Electron., vol. 59, no. 10, pp. 3797–3807, Oct. 2012.
[6] V. Khadkikar and A. Chandra, ―UPQC-S: A novel concept of simultaneous voltage sag/swell and load reactive power compensations utilizing series inverter of UPQC,IEEE Trans. Power Electron., vol. 26, no. 9, pp. 2414–2425, Sep. 2011.
[7] V. Khadkikar, ―Enhancing electric power quality using UPQC: A comprehensive overview,‖ IEEE Trans. Power Electron., vol. 27, no. 5, pp. 2284–2297, May 2012.
[8] L. G. B. Rolim, ―Custom power interfaces for renewable energy sources,‖ in Proc. IEEE ISIE, 2007, pp. 2673–2678.
[9] N. Voraphonpiput and S. Chatratana, ―STATCOM analysis and controller design for power system voltage regulation,‖ in Proc. IEEE/PES Transmiss. Distrib. Conf. Exhib.—Asia Pac., 2005, pp. 1–6.
[10] J. J. Sanchez-Gasca, N. W. Miller, E. V. Larsen, A. Edris, and D. A. Bradshaw, ―Potential benefits of STATCOM application to improve generation station performance,‖ in Proc. IEEE/PES Transmiss. Distrib. Conf. Expo., 2001, vol. 2, pp. 1123–1128.
[11] A. P. Jayam, N. K. Ardeshna, and B. H. Chowdhury, ―Application of STATCOM for improved reliability of power grid containing a wind turbine,‖ in Proc. IEEE Power Energy Soc. Gen. Meet.—Convers. Del. Elect. Energy 21st Century, 2008, pp. 1–7.
[12] C. A Sepulveda, J. A Munoz, J. R. Espinoza, M. E. Figueroa, and P. E. Melin, ―All-on-chip dq-frame based DSTATCOM control implementation in a low-cost FPGA,‖ IEEE Trans. Ind. Electron., vol. 60, no. 2, pp. 659–669, Feb. 2013.
[13] B. Singh and S. R. Arya, ―Back-propagation control algorithm for power quality improvement using DSTATCOM,‖ IEEE Trans. Ind. Electron., vol. 61, no. 3, pp. 1204–1212, Mar. 2014.
[14] M. Aredes and R. M. Fernandes, ―A dual topology of unified power quality conditioner: The iUPQC,‖ in Proc. EPE Conf. Appl., 2009, pp. 1–10.
[15] M. Aredes and R. M. Fernandes, ―A unified power quality conditioner with voltage sag/swell compensation capability,‖ in Proc. COBEP, 2009, pp. 218–224.
[16] B. W. Franca and M. Aredes, ―Comparisons between the UPQC and its dual topology (iUPQC) in dynamic response and steady-state,‖ in Proc. 37th IEEE IECON, 2011, pp. 1232–1237.
[17] B. W. Franca, L. G. B. Rolim, and M. Aredes,―Frequency switching analysis of an iUPQC with hardwarein- the-loop development tool,‖ in Proc. 14th EPE Conf. Appl., 2011, pp. 1–6.
[18] B.W. Franca, L. F. da Silva, and M. Aredes,―Comparison between alphabeta and DQ-PI controller applied to IUPQC operation,‖ in Proc. COBEP, 2011, pp. 306–311.
[19] R. J. Millnitz dos Santos, M. Mezaroba, and J. C. da Cunha, ―A dual unified power quality conditioner using a simplified control technique,‖ in Proc. COBEP, 2011, pp. 486–493.

[20] Y. Tang et al., ―Generalized design of high performance shunt active power filter with output LCL filter,‖ IEEE Trans. Ind. Electron., vol. 59,no. 3, pp. 1443–1452, Mar. 2012.
[21] H. Akagi, E. Watanabe, and M. Aredes, Instantaneous Power Theory and Applications to Power Conditioning. New York, NY, USA:Wiley-IEEE Press, 2007.
[22] J. M. Guerrero, P. C. Loh, T.-L. Lee, and M. Chandorkar, ―Advanced control architectures for intelligent microgrids—Part II: Power quality, energy storage, and AC/DC microgrids,‖ IEEE Trans. Ind. Electron., vol. 60, no. 4, pp. 1263–1270, Apr. 2013.
[23] S. R. Bowes and S. Grewal, ―Novel harmonic elimination PWM control strategies for three-phase PWM inverters using space vector techniques,‖ Proc. Inst. Elect. Eng.—Elect. Power Appl., vol. 146, no. 5, pp. 495–514, Sep. 1999.
[24] M. Liserre, R. Teodorescu, and F. Blaabjerg, ―Multiple harmonics control for three-phase grid converter systems with the use of PI-RES current controller in a rotating frame,‖ IEEE Trans. Power Electron., vol. 21, no. 3, pp. 836–841, May 2006.
[25] R. Teodorescu, F. Blaabjerg, U. Borup, and M. Liserre,
―A new control structure for grid-connected LCL PV inverters with zero steady-state error and selective harmonic compensation,‖ in Proc. 19th Annu. APEC Expo., 2004, vol. 1, pp. 580–586.
[26] X. Yuan, W. Merk, H. Stemmler, and J. Allmeling,―Stationary-frame generalized integrators for current control of active power filters with zero steady-state error for current harmonics of concern under unbalanced and distorted operating conditions,‖ IEEE Trans. Ind. Appl., vol. 38, no. 2, pp. 523–532, Mar./Apr. 2002.
[27] D. N. Zmood and D. G. Holmes, ―Stationary frame current regulation of PWM inverters with zero steady-state error,‖ IEEE Trans. Power Electron., vol. 18, no. 3, pp. 814–822, May 2003.
[28] D. N. Zmood, D. G. Holmes, and G. H. Bode,―Frequency-domain analysis of three-phase linear current regulators,‖ IEEE Trans. Ind. Appl., vol. 37, no. 2, pp. 601–610, Mar./Apr. 2001.
[29] M. Ciobotaru, R. Teodorescu, and F. Blaabjerg, ―A new-single PLL structure based on second order generalized integrator,‖ in Proc. 37th IEEE PESC, Jeju, Island, Korea, 2006, pp. 1–6.
[30] D. R. Costa, Jr., L. G. B. Rolim, and M. Aredes, ―Analysis and software implementation of a robust synchronizing circuit based on pq theory,‖ IEEE Trans. Ind. Electron., vol. 53, no. 6, pp. 1919–1926, Dec. 2006.
[31] M.K. Ghartemani, ―A novel three-phase magnitudephase- locked loop system,‖ IEEE Trans. Circuits Syst. I, Reg. Papers, vol. 53, no. 8, pp. 1798–1802, Aug. 2006.
[32] M. S. Padua, S. M. Deckmann, G. S. Sperandio, F. P. Marafao, and D. Colon, ―Comparative analysis of synchronization algorithms based on PLL, RDFT and Kalman filter,‖ in Proc. IEEE ISIE, Jun. 2007, pp. 964–970.
[33] J. A. Moor Neto, L. Lovisolo, B. W. França, and M.\ Aredes, ―Robust positive-

sequence detector algorithm,‖ in Proc. 35th IEEE IECON, Nov. 2009, pp. 788–793.
[34] V. Khadkikar, A. Chandra, A. O. Barry, and T. D. Nguyen, ―Steady state power flow analysis of unified power quality conditioner (UPQC),‖ in Proc.ICIECA, 2005,pp.1–6.
[35] V. Khadkikar, A. Chandra, A. O. Barry, and T. D. Nguyen, ―Conceptual study of unified power quality conditioner (UPQC),‖ in Proc. IEEE Int. Symp. Ind. Electron., 2006, vol. 2, pp. 1088–1093.