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Unit Vector Sample Technique for UPQC

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ABSTRACT: This paper represent a MATLAB-based model to reduce supply voltage and current waveform deformation. The Unit Vector technique is used for generating control signals from UPQC is a device used to control voltage and current waveform at the same instant in a power system. Generally, UPQC consists of a shunt and series inverter. In a power system, there is the various reason of unbalance distortion and DC component. Power quality has become a crucial factor today due to the wide application of power electronics-based equipment. Day by day in industries and distribution areas, power electronics-based devices are widely used and create more power quality problems. The quality of the power is defective for certain reasons.

INTRODUCTION

The wide application of power electronic-based equipment has resulted in a serious impact on the nature of the electric power supply. The smooth, uninterrupted sinusoidal voltage at desired magnitude and frequency should always be provided to the consumers. On the other hand, consumers should draw sinusoidal current [1]. Many researchers are making efforts to the improvement of power quality. UPQC is considered the most powerful solution to the problems arising due to power quality. It is adequate to manage supply voltage disturbances like voltage sag/swells, voltage flickers, load reactive power, and voltage and current harmonics. The UPQC can also be named the universal active power line conditioner, universal power quality conditioning system, and universal active filter. It is a cascade series and shunts active power filter (APF) connected through a common DC link capacitor [2]. Poor power quality affects electricity consumers in many ways. The poor power quality may result in loss of production, damage of equipment or appliances, increased power losses, interference with communication lines. The declining quality of electric power is mainly because of current and voltage harmonics due to wide range application of static power electronics converters, zero and negative sequence components originated by the use of single-phase and unbalanced load, reactive power, voltage sag, voltage swell, flicker, voltage interruption. Therefore, it is very crucial to maintain standard power quality.

UPQC

In the context of up-gradation of quality of power, UPQC plays a very vital role. It provides blessings of parallel and series active power filter both. Being a multitasking power conditioner, UPQC can be utilized for compensation of numerous voltage disturbances, voltage flickers, and it also provides prevention to the harmonics in the load current. It doesn't allow them to enter into the power system and contaminate the quality of power. This custom power equipment can mitigate the problems affecting the working of sensitive equipment or loads. UPQC provides compensation to harmonics in the current (shunt part) and the voltage (series part), controls the flow of power, and overcomes the disturbances in voltage like voltage swell, sag. The essential parts of a unified power quality conditioner are shunt inverter, series inverter, Dc link capacitor, Shunt coupling inductor, and series transformer.

UPQC CONFIGURATION

UPQC mainly consists of the following parts-

Shunt inverter: A shunt-connected voltage source inverter acts as a shunt inverter. It is helpful in the cancellation of current distortions, i.e., compensates for the harmonic current of the load. It also assists in keeping up a steady value for the DC link capacitor voltage and helps improve the system power factor. Furthermore, it is also helpful in the compensation of reactive load current. Usually, a hysteresis band controller is employed for controlling the shunt inverter output current. Adjusting the semiconductor switches reference current can be made to follow the output current and stay within the particular hysteresis band.

Series inverter: It is a series-connected VSI (voltage-source inverter) acting as a source of voltage. Its connection is in series with the line by using a series transformer. It helps in overcoming voltage-based distortions. It helps maintain a sinusoidal load voltage by eliminating the load voltage imbalances and the flickers in the terminal voltage. PWM techniques are used for controlling the series inverter. Mostly hysteresis band technique of pulse width modulation is used. There are many advantages of using this PWM technique. It provides a better and faster response speed is easy to implement, and can work properly even without knowing the system's parameters.

DC link capacitor: It is used for back-to-back connection of the series and shunts VSIs. The DC voltage developed across the capacitor acts as a constant voltage and helps operate both shunt and series inverters properly. If regulated properly to the voltage provided by this capacitor can be used as a source for both active and reactive power, and any external DC source, e.g., the battery, can be eliminated.

Shunt coupling inductor: It is helpful in the interfacing of the shunt inverter to the network. The main benefit is to smoothen the current wave shape by eliminating the ripples producing the current.

LC filter: It is present near the series inverter output of UPQC. Acting as a low-pass filter (LPF), it is helpful in the attenuation of high-frequency voltage components of the output voltage of the series inverter.

Series transformer: The series inverter generates a voltage to maintain load voltage sinusoidal at a particular required value. Series inverter helps in the injection of this voltage through the series transformer. It is required to maintain a particular turn ratio to maintain a low current flow through the series inverter.

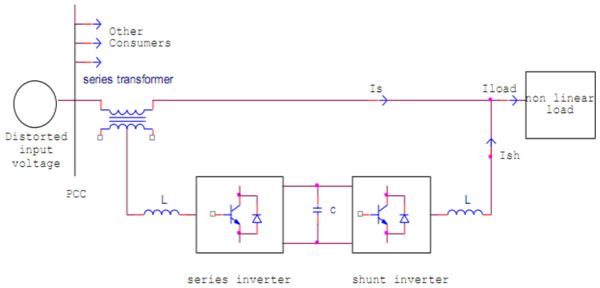

Figure 1 Basic block diagram of UPQC

UPQC-CLASSIFICATION

There are many criteria for classifying the UPQC. The main criteria of classification can be divided broadly into two groups. Firstly, classifying them based on their structure which is seen physically, and the other is based on the method in which they compensate for the sag in the load voltage. These two methods can further be subdivided into various groups. The one that depends on the physical structure can be again divided based on the type of converter used, type of supply, whether three-phase or single-phase, and the last one is in the basis of UPQC configuration. The various classes of UPQC have been described below.

BASED ON PHYSICAL STRUCTURE

Based on physical structure, it can be further subdivided into three groups as given below

BASED TOPOLOGY OF THE CONVERTER

Converter used can be either-

- VSI-Shares, a common DC link capacitor commonly used for losses, are low losses and low price, and it can also be utilized in the case of the multilevel inverter.

- CSI-Uses an inductor to form the DC link not commonly used as it results in high losses, high price, and it's not possible to incorporate them as we go for the multilevel inverter.

BASED ON THE SUPPLY SYSTEM

It can either use a single-phase supply or a three-phase supply.

(i) SINGLE PHASE-

- 2H bridge- It has a total of eight switches, and it's the most familiar configuration.

- 3leg topology- It has 6 switches in total. It can be used for operations demanding less cost and power.

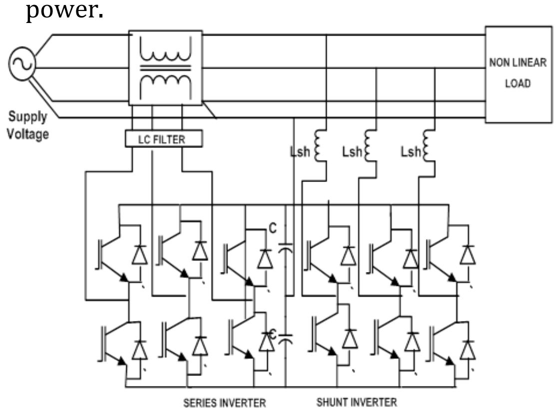

Figure3: Three-phase four-wire UPQC

BASED ON UPQC CONFIGURATION

Based on UPQC configuration mainly there are five types of UPQC as described below-

- **Right and Left Shunt UPQC** is based on the parallel converter's position compared to the series converter. If the shunt converter is laced on the right-hand side of the series converter, it is termed UPQC-R, and if it is laced on the left-hand side, it is termed UPQC-L. UPQC-R is the one that is most commonly used. It shows improved performance in comparison to that of the UPQC-L. UPQC-L can be utilized for some particular cases.

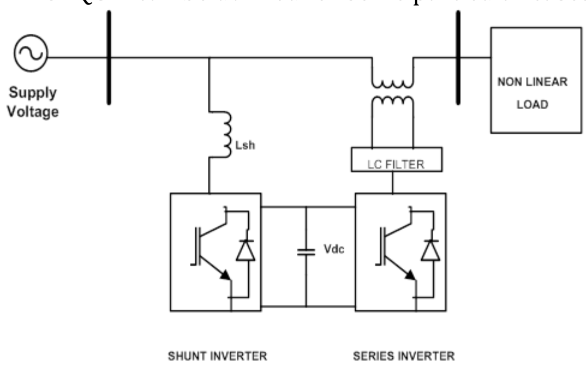

Figure4: UPQC-L

Interline UPQC: Here, the inverters of UPQC, i.e., series and shunt inverters, are used between two distribution feeders. The connection of one UPQC is in series with the first feeder, and the second is in parallel with the second feeder. In this way, both the feeders get the advantage of effective control of the voltage. But it also shows some problems and is hence used only for certain particular cases.

Modular UPQC: It is the connection of several H-bridge inverter modules. The shunt part has series-connected H-bridge inverter modules with that of the transformer, and the series part connection is indirectly in series and doesn't need a series transformer for connection with the distribution transformer.

Multilevel UPQC is Used for getting higher power levels. It can be of various levels as per the requirement.

Various levels of MLI that are usually realized are three, five, seven. As the number of levels increases, the power level increases, but it has a disadvantage too. With the increase in the number of levels, the harmonic content also increases.

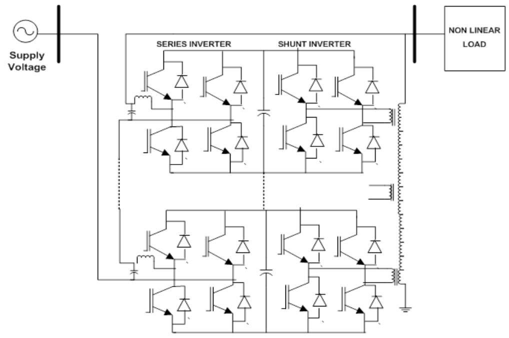

Figure 5: Modular UPQC

Multi-converter UPQC: Here, three inverters are used. The third inverter is used to assist the dc capacitor voltage. There are various ways for the connection of the third inverter.

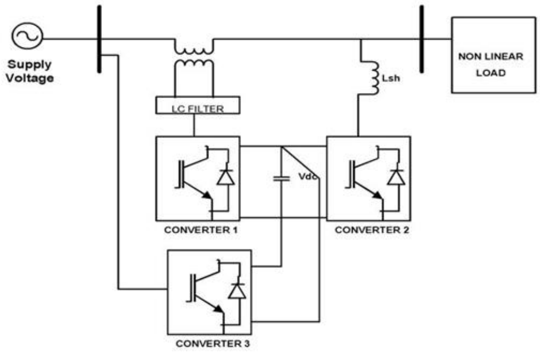

Figure 6: Multi-converter UPQC

BASED ON VOLTAGE SAG COMPENSATION

- UPQC-P: It is an active power control UPQC where active power is used to mitigate voltage sag. Here injection of a voltage component is done in series with the ac line. The voltage component injected into the system equals the difference between the load and the existing voltage.
- UPQC-Q is a reactive power control UPQC, where reactive power is used to mitigate voltage sag. The main principle here is the injection of a quadrature voltage. But the disadvantage of UPQC-Q is that it increases the rating of the series inverter.
- UPQC-VA min: It is a minimum volt-ampere loading UPQC. It is used to minimize the volt-ampere loading during the compensation. In this case, the injection of voltage is done at a certain angle regarding the current.
- UPQC-S: It gives simultaneous active and reactive power control. In this system, the series inverter can be effectively utilized. Its control is a little difficult, and hence it is used widely if the control is digital[10].

CONTROL TECHNIQUE FOR UPQC

Various control techniques have been used for the control of harmonics in voltage and current by using UPQC. Here, two methods have been described: the unit-vector template generation method and the Synchronous reference frame and PQ theory.

UNIT VECTOR TEMPLATE GENERATION

The control technique used here is the Unit-vector template generation technique to supply voltage is made distorted, and Unit Vector Templates are extracted from it. The distorted input source voltage contains harmonic components in addition to the fundamental component. For extraction of these unit vectors, the supply voltage is first measured, and the product of this and gain (1/ Vm) is done, Vm being the peak fundamental supply voltage. After this unit, vector templates are generated using a phase-locked loop. The supply voltage is then multiplied with the unit vector templates, and reference load voltage is generated. The reference load voltage generated is given by V*abc.

- Va = Sinωt
- Vb = Sin (ωt-120)
- Vc= Sin (ωt+120)

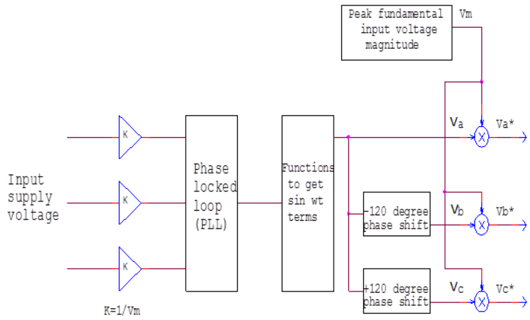

Figure.7: Generation of Unit Vector Templates and reference Load Voltages

V*abc= Vm*Uabc

Then the comparison of actual load voltage and reference load voltage is made. Error is calculated and sent into a hysteresis band for generating the gate pulse for the series inverter. Shunt Active Power Filter is used for current harmonics compensation. Generation of pulses for the shunt inverter DC link voltage is then measured, and its comparison is made with the reference dc-link voltage. After that error is processed using a PI controller, these results are multiplied by unit vector templates to produce the reference current. A comparison of reference and actual source current is done, a hysteresis band controller is used to process the error, and the production of gate pulses for parallel inverter circuits is completed.

SYNCHRONOUS REFERENCE FRAME AND P-Q CONTROL OF UPQC-

Control Method for Series Active Filter

For controlling the source side voltage aggravation, SAF is utilized. In this method, the reference voltage that needs to be infused by the series transformers is

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ascertained by comparing the positive–sequence component of the source voltage with that of the source voltage. The reference generation calculation for SAF is demonstrated as follows- Equation depicting the transformation of supply voltage and load current into d-q-o coordinate are given below.

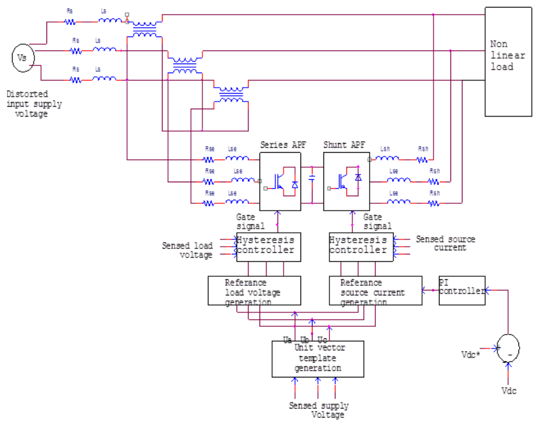

Figure 8: Overall Control Circuit

$$\begin{bmatrix} V\alpha \\ V\beta \end{bmatrix} = \frac{\sqrt{2}}{\sqrt{3}} \begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} Va \\ Vb \\ Vc \end{bmatrix} \quad \text{...... (1)}$$

$$\begin{bmatrix} Vd \\ Vq \end{bmatrix} = \begin{bmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{bmatrix} \begin{bmatrix} V\alpha \\ V\beta \end{bmatrix} \quad \text{....... (2)}$$

Along with the fundamental component, harmonics are also present in the d-axes voltage. A second-order LPF is used for filtering out the harmonic components. Then the reference voltage Vref is then estimated by utilizing d-q-o to a-b-c transformation. The reference voltage Vref is then estimated by utilizing d-q-o to a-b-c transformation. Then the output of the series active filter and the reference voltage generated is fed to a hysteresis band controller to generate the gate pulses.

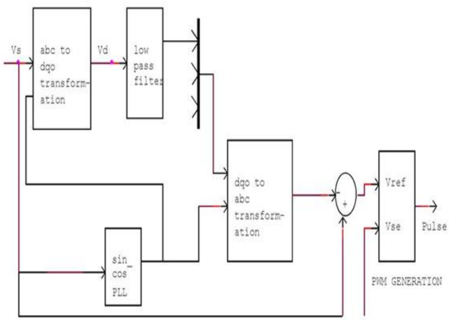

Figure 8: Control algorithm of SAF

Control Method Employed for Shunt Active Filter

For calculating the reference current in this method, the P-Q methodology has been utilized. Clarke's transformation given in equation (1),(2),(3), and (4) are used for transformation of reference voltages generated at SAF and load current into α-β-0 coordinates[8-10] –

$$\begin{bmatrix} I\alpha \\ I\beta \end{bmatrix} = \frac{\sqrt{2}}{\sqrt{3}} \begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} Ia \\ Ib \\ Ic \end{bmatrix} \quad \text{....... (3)}$$

$$\begin{bmatrix} Id \\ Iq \end{bmatrix} = \begin{bmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{bmatrix} \begin{bmatrix} I\alpha \\ I\beta \end{bmatrix} \quad \text{....... (4)}$$

Equation (5) is used to calculate real power and imaginary power on the Source side. These are instantaneous power-

$$\begin{bmatrix} P \\ Q \end{bmatrix} = \begin{bmatrix} V\alpha & V\beta \\ -V\beta & V\alpha \end{bmatrix} \begin{bmatrix} I\alpha \\ I\beta \end{bmatrix} \quad \text{....... (5)}$$

Real power is taken as the reference for compensating reactive power and the harmonic component, and the current source reference can be calculated by Eq.(6).

$$\begin{bmatrix} Is\alpha * \\ Is\beta * \end{bmatrix} = \frac{1}{V\alpha^2 + V\beta^2} \begin{bmatrix} V\alpha & -V\beta \\ V\beta & V\alpha \end{bmatrix} \begin{bmatrix} P + \Delta P \\ 0 \end{bmatrix} \quad \text{....... (6)}$$

Where $\Delta P = Po + Ploss$

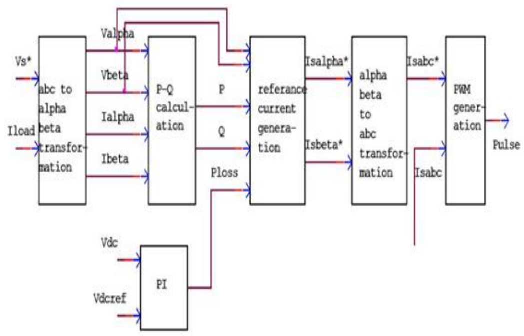

Figure 9: Control algorithm of PAF

Due to the absence of unbalancing, the power Po is zero. Comparison of measured and reference DC-link voltage is made, and a Proportional integral controller is used for processing the error produced. The main reason behind using this controller is that it helps in reducing the steady-state error to a zero value. PI controller's yield is termed as Ploss. Then the reference source current is converted to the a-b-c frame of reference using the Eq.(7)-

$$\begin{bmatrix} Isa * \\ Isb * \\ Isc * \end{bmatrix} = \frac{\sqrt{2}}{\sqrt{3}} \begin{bmatrix} 1 & 0 \\ -\frac{1}{2} & \frac{\sqrt{3}}{2} \\ -\frac{1}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} Is\alpha * \\ Is\beta * \end{bmatrix} \quad \text{...... (7)}$$

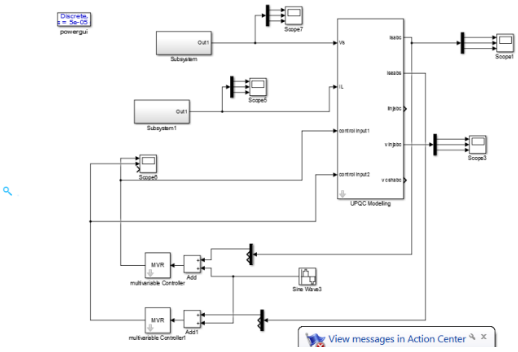

Figure 9: Simulink model of UPQC

Finally, the comparison of these current and actual source currents is made with the help of a hysteresis band controller, and gate pulses for the shunt Active power filter are generated.

Simulink Model:
SIMULINK RESULT

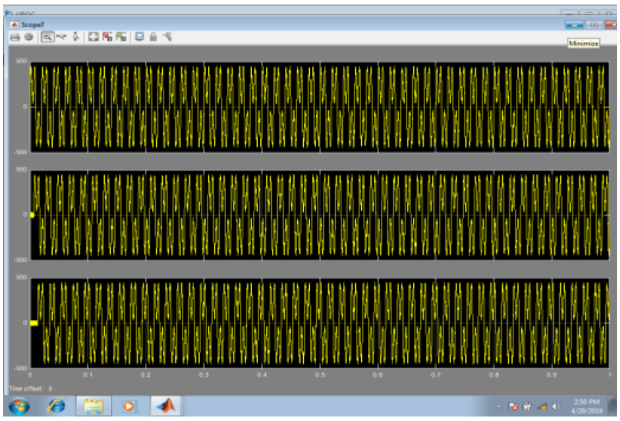

Figure 10: 3 phase input waveforms

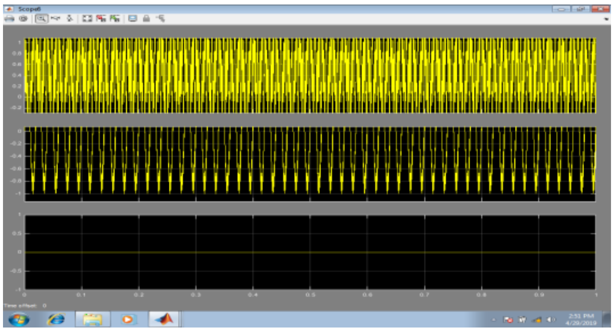

Figure 11: Multilevel Converter Output

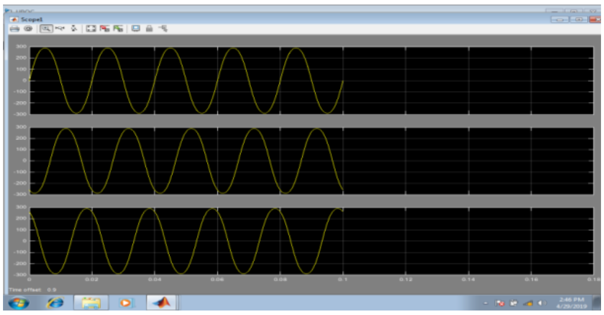

Figure 12: Output Voltage

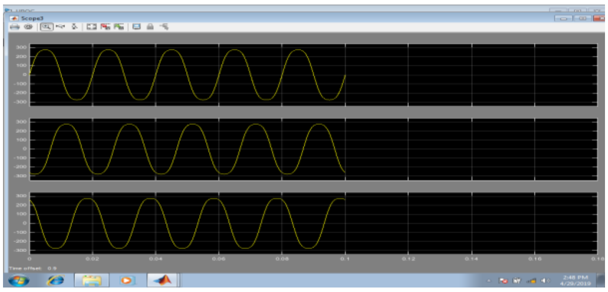

Figure 13: Output Current

CONCLUSION

Simplified control of UPQC relies on the generation of unit vector templates, and another method based on the synchronous reference frame, the P-Q control technique, has been given for UPQC. Both of these methodologies provide an effective solution for improving power quality, solving the problems related to power quality, and helping mitigate voltage and current harmonics. Simulation of a Simulink-based model has been done. From the simulation results, it can be inferred that the current harmonics caused by the non-linear load can be compensated very effectively by using the proposed Unit Vector sample control method for UPQC.

REFERENCES

[1]. Wanda J. Orlikowski and Jack J. Baroudi, Studying information technology in organizations: Research approaches and assumptions, Information systems research, 2(1), pp. 1–28, 1991.

[2]. M.S. Dresselhaus and I.L. Thomas, Alternative energy technologies, Nature, 414, (6861) pp. 332–337, 2001.

[3]. Mark Z. Jacobson and Mark A. Delucchi, Providing all global energy with wind, water, and solar power, Part I: Technologies, energy resources, quantities and areas of infrastructure, and materials, Energy Policy, 39(3), pp. 1154-1169, 2011.

[4]. Bert JM De Vries, Detlef P. van Vuuren, and Monique M. Hoogwijk, Renewable energy sources: Their global potential for the first-half of the 21st century at a global level: An integrated approach, Energy Policy, 35(4), pp. 2590–2610, 2007.

[5]. Joanna I. Lewis, Technology acquisition and innovation in the developing world: wind turbine development in China and India, Studies in comparative international development, 42(3–4) pp. 208–232, 2007.

[6]. Larsson, A, "Flicker and Slow Voltage Variations from Wind Turbines," Proceedings of the 7th International Conference on Harmonics and Quality of Power (ICHQP '96), Las Vegas, USA. October 1996, p. 270 - 275.

[7]. R Blaabjerg, Z. Chen, SB Kjaer, "Power Electronics as efficient interface in the dispersed power generation system." IEEE Trans. On Power Electron. Vol. 19, No. 5, pp. 1184¬1194., Sept. 2004

[8]. Sung-Hun, Seong R. Lee, HoomanDehbonei, Chemmangot V. Nayar," Application of Voltage-and current-controlled Voltage Source Inverters for

Distributed Generation System.," IEEE Transaction On Energy Conversion, Vol.21, No.3, pp. 782¬788, Sept. 2006.

[9]. Juan Manel Carrasco, 'Power Electronic System for Grid Integration of Renewable Energy Source: A Survey, IEEE Trans on Industrial Electronics, Vol. 53, No. 4, pp. 1002¬1014, August 2006

[10]. X. Zhang, W. Zhang, Y. Lv, W. Liu, and Q. Wang, "Unified power quality conditioner with model predictive control," Proc. 5th Int. Conf. Comput. Sci. Educ., Aug. 24–27, 2010, pp. 1239–1244.

[11]. Yash Pal, A. Swarup, Bhim Singh, "A control strategy based on UTT and Icosф theory of three-phase, four-wire UPQC for power quality improvement" International Journal of Engineering, Science and Technology Vol. 3, No. 1, 2011, pp. 30-40.

[12]. S.Shankar, A.Kumar, and W.Gao "Operation of Unified Power Quality Conditioner under Different Situation," IEEE Proc. Power and Energy Society General Meeting, July 2011, pp.1-10.

[13]. H. Fujita, H. Akagi, "The unified power quality conditioner: The integration of series and shunt active filters," IEEE Trans. Power Electron., vol. 13, no. 2, pp. 315–322, Mar. 1998.

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