International Journal of Enhanced Research in Science Technology & Engineering, ISSN: 2319-7463
Vol. 4 Issue 3, March-2015, pp: (179-184), Impact Factor: 1.252, Available online at: www.erpublications.com

A Review on Power Quality Improvement by UPQC

Sumeet Singh[1], Mukul Chanakya[2]
[1]M. Tech Student (EE), Lovely Professional University, Punjab
[2]Assistant Professor (EE), Lovely Professional University, Punjab

Abstract: The current power sector is dealing with the poor power quality issues and the reason behind this poor power quality is voltage fluctuations, harmonics, transients and reactive power demands and these problems arises due to changing trend of our demand. Nowadays in our demand the share of power from power electronic devices has increase a lot and also coupling of grids to wind farms and solar farms has raised the problem of poor power quality.[25] No doubt series and shunt compensations are effective but if they are used simultaneously as a unified unit, this enhances the effectiveness of the device and becomes more beneficiary for power sector and they are used together as UPQC. So the main task of UPQC is to improve the power quality and it proves out to be quite good at that by compensating the above mentioned problems. Hence UPQC is considered as the efficient solution of the power quality problems. As the UPQC serves purpose of both series and shunt compensators, hence to provide this it contains two inverters, which are voltage source inverters with common DC link. These are called series and shunt converters. These controllers can be controlled by various techniques such as PI controllers, FUZZY controllers, Neural Networks etc .Shunt converter compensates the distortion in load current and the series converter is responsible for smoothening of voltage.

I. INTRODUCTION

The main motive of power distribution systems is to provide uninterrupted power to the consumers with supply being purely sinusoidal and acceptable frequency but the same is not fulfilled because of non linear loads, implementation of power electronic devices as loads and clubbing of power from different sources [1].Apart from these above mention loads harmonics and transients arises due to abrupt switching of heavy appliances such as sudden shut down of generators of connection a generator to the transmission line without synchronizing its output to the grid or taking out transformers from the circuit cause such problems. The poor power quality hampers the growth as the most affected are the industries which totally rely on electricity and due to substandard power quality of power the efficiency of machines reduces hence the output decrease. The problems subjected to transmission and distribution can be bifurcated into power quality and power reliability. Impulses, swells and harmonic distortion are included in power quality and power reliability comprises of voltage sags and outages [2]. Also the harmonics in the power supply cause interaction with communication signals and cause distortions in communication signals and these high frequency harmonics cause insulation failures [3]. We can remove power quality problems by implementing FACTS devices in the system but in FACTS devices UPQC is found to be quite efficient in improving power quality as it have series and shunt converters which mitigate both current and voltage based power quality problems simultaneously.

II. POWER QUALITY

The definition of power quality varies from person to person. A layman will define power quality in a certain manner and an engineer will have its own views. According to the IEEE power quality is defined as "the concept of powering and grounding electronic equipment in such a manner that is suitable to the operation of that equipment and compatible with the premise wiring and other connected equipments". [4] The matter of concern arises as the power quality of the power system is decreasing because of implementation of various power electronic devices and circuits. With this the power quality of the system deteriorates and hence sensitive loads get affected.

Poor power quality can be detected by following signs:-

- Flickering of lamp

- Blackouts
- Sensitive load maloperation
- Interference with communication lines

A. Voltage Variations

If there is any change in the RMS value of the voltage occurring in a time span of minutes or more then the voltage is said to have variations. Voltage variations are also observed in grids, they mainly occur due to the load variations and variation in power production units. Whenever the wind power is introduced in the grid voltage variation are also generated from the wind turbine and are introduced in the grid. Voltage variations are not only generated due to the variable speed of wind turbine but also when the turbine is stopped suddenly or load is shed abruptly from the turbine. All kinds of wind turbines produce variations in voltage.

Short duration voltage variation

The main reason of short duration voltage variation is when a certain high capacity load is added or removed from the system the variation in voltage is experienced. As the name suggests they are for short interval of time i.e. few power frequency cycles.[5]

- **Voltage sag** – The situation arises when the voltage in the line is lower than the RMS value of the voltage. Figure given below describes the sag in voltage, the above axis represents the normal voltage with amplitude 1 and the lower axis shows the sag affected voltage waveform with lower amplitude.[6]
- **Voltage swell –** The voltage in this case increases from the RMS value. No doubt the increase in the voltage is not of higher magnitude but it certainly affects the quality of sine wave. Figure given below gives the view of swell , as the upper axis represents the normal voltage and lower axis gives the view of voltage with swell.[6]
- **Interruption :-** The certain conditions the voltage/current decrease to the low of 10% of the RMS value of the line.[6][24]

Long Duration Voltage Transients

- **Undervoltage:-** The voltage remains below RMS value of the line for long period of time. It is generally at 90% of rated power supply and the reasons could be taking capacitor bans or synchronous condensers out of the system. It can persist for certain minutes and even longer.[7]
- **Overvoltage:-** The voltage increase and remain above the RMS value for longer period of time and its duration is of several minutes or even longer.[7]

Due to these long variation in voltage the efficiency of the loads/devices and get reduced or harm the devices. As due to under voltage the devices will not run on their rated capacities and hence output of the devices will be less and on the other hand when overvoltage will occur the device will be subjected to the high voltage due to this the problem of insulation failure can occur in the device, hence can harm the device. So in all both the cases of over and under voltage can harm the system and its components.

B. Harmonics

In every power grid harmonics keep on flowing in the power lines regularly. There are number of sources of harmonics such as sudden loading and unloading of the transmission line, non-linear load, rectifiers, inverters, motors etc. with the injection of harmonics in the circuits the devices faces ill effects such as overheating, equipment failure, faulty operation of protective devices, nuisance in the communication systems and disturbance in pilot wire communication. Harmonics elements have higher frequency than the system frequency. For example if we are having a system of frequency 50 Hz then the harmonics which will be present in the system will be of order 2*50hz, 3*50hz etc i.e. they are integral multiples of fundamental frequency. Fixed speed turbine does not produce significant harmonics [8]

C. Transients

- **Impulsive transients:**
  The impulsive transients are generally caused by lightening, switching of long transmission lines or switching of heavy inductive loads such as induction furnaces. In impulsive transients the there is a small unidirectional variation in voltage, current or both in a power line. The reliable method of removing such transients is using Zener diode.[7][8]
- **Oscillatory transients**
  The above are caused by capacitor banks which are designated for power factor correction and due to these capacitor a bidirectional variation is caused in voltage, current or both in power line.[8]

D. Flicker

An old way to measure the voltage variations is flicker. It is based on the method of measurements of variations in the voltage amplitude. In this the duration and magnitude of variation is measured. Flicker from the wind turbines has been studied in various investigations. Flicker can be generated from wind turbine in two different operation modes given as continuous mode and switching mode. Fig depicts the variation of voltage with the variation of frequency. The figure shows the maximum permissible voltage changes with respect to number of voltage changes per second.[9]

III. UPQC

A UPFC and UPQC are quite similar in means of construction [10]. In UPQC two voltage source inverters are connected in series and shunt via DC link [11]. A transmission line needs a balanced, distortion free environment to deliver power so series or shunt compensation is provided by UPFC but if the power system contain DC components and distortion then UPQC is effective for such situations.[11]. UPQC injects series voltage to mitigate current harmonic else it is added to the voltage at the point of common coupling.[12]. Thus the task of series inverter is to remove any sort of deficiency in voltage and the shunt inverter takes care of reactive power demand and removes the current harmonics.[13]. A number of techniques are there to control the two VSIs like PI technique, Fuzzy controllers, neural networks, by using Synchronous Reference Frame theory etc.[22]
UPQC is quite effective as it provides simultaneous compensation at series and shunt levels and hence enhancing the circuit power. [26]

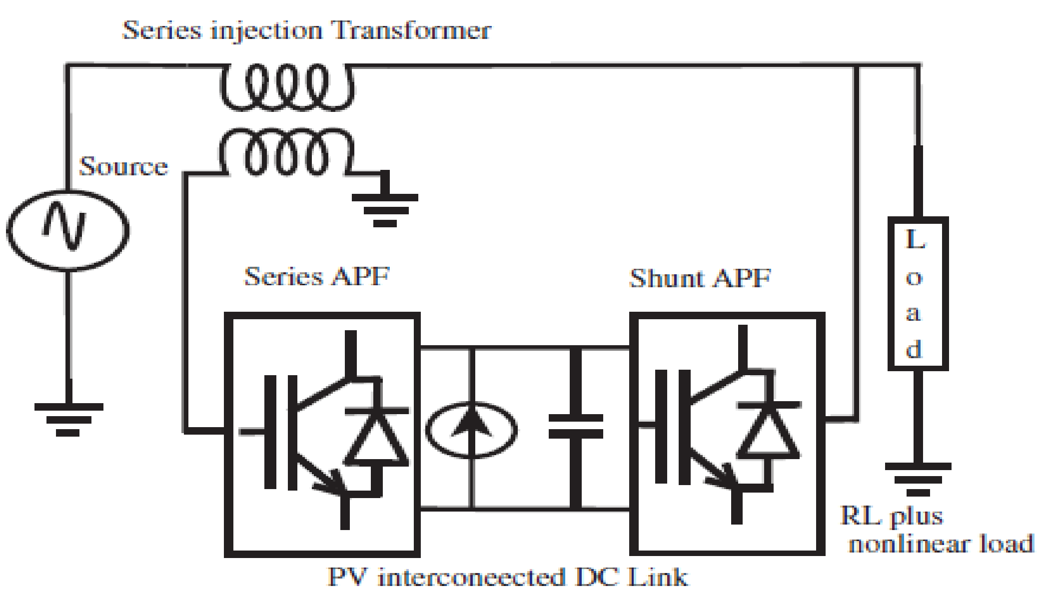

Fig-1: UPQC [14]

IV. POWER CIRCUIT TOPOLOGY

A. Right shunt UPQC

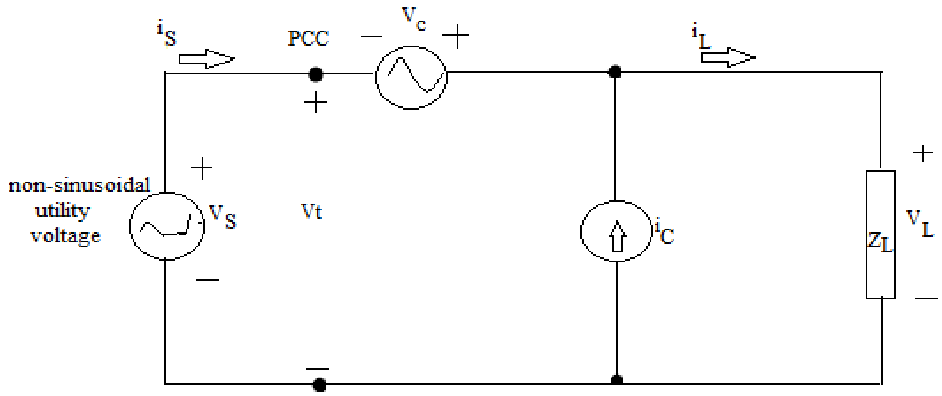

Fig-2: Right shunt UPQC

In right shunt UPQC the shunt inverter i.e. Ic is connected after the series compensator i.e. Vc

A. Left Shunt UPQC

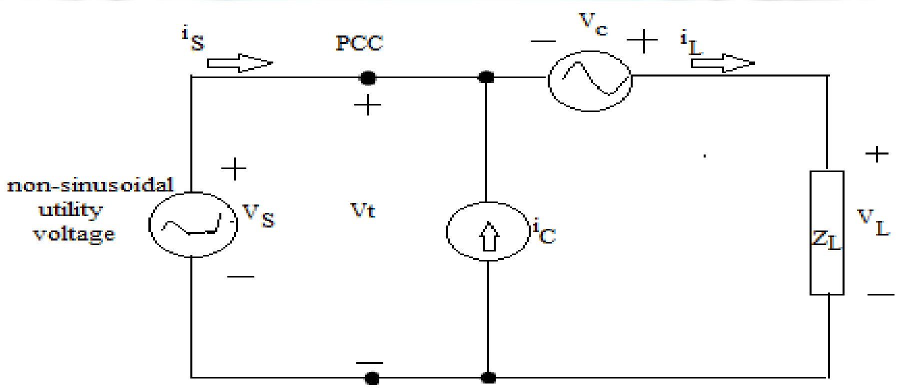

Fig-3: left shunt UPQC

In this configuration the shunt inverter is connected on left of the series inverter.

B. Equivalent circuit of UPQC

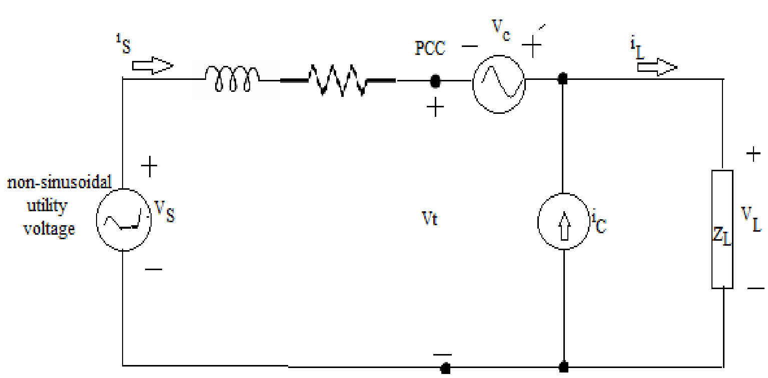

Fig-4 Equivalent circuit diagram of UPQC[23]

In the above circuits :

Vs – source voltage
Vt – terminal voltage at PCC
V_L – Load voltage
Is – source current
I_L – load current

The UPQC comprises of two voltage source inverters connected in series and shunt either in left shunt topology or right shunt topology. The main task of UPQC is to condition the power supply by mitigating the harmonics from the power supply [16]. The series inverter is provided to inject the voltage in the power line to mitigate the harmonics and the shunt inverter is desired to balance the reactive power by injecting current in the circuit. The injection of both current and voltage takes place from the injecting transformers and during balanced condition or in standby mode of UPQC the secondary of injecting transformer acts short circuited.[15] Another important component of UPQC is active power filters, these are included in UPQC in order to provide safety to the power line from undesired frequencies which get generated by harmonics and hence which cause insulation failure and malfunctioning of the devices. These filter protect harmonics being generated by inverters to penetrate into the system.[17]

V. Control of UPQC

Controller of UPQC is the most complex part of UPQC it in this where all the calculation regarding gate signals to be given to the inverters is to take place. Both series and shunt inverters have different controllers as the task of one is to provide voltage and other is to compensate the reactive power by injecting current in the circuit.[21] The controllers are developed by employing various type of controlling techniques, which include Proportional integrator controller (PI), Fuzzy logic controllers, neural networks, fast fourier transformations etc are being employed. The main task of these controllers is to provide accurate gate signals to the inverters so as to provide good compensation. Synchronous reference frame theory is used to provide reference signals.[18] According to the requirement the series inverter controller provides the required gate signal to the series VSI and hence voltage compensation takes place and the voltage sag/swell gets removed.[19] To generate the gating signal of the controllers we employ the hysteresis band which compares the line and reference currents in case of shunt controller and in series controller it compares the voltages and hence provides required gating signals.
The power balance in UPQC is provided by the DC link , in some place a PV array is introduced in order to balance the power.[20]

Conclusion

The problems of voltage fluctuation and current harmonics in power system can be reduced with the controlling UPQC. At the point of common coupling the UPQC is connected in order to improve the power quality. As the series and shunt inverters are working simultaneously the reactive power and voltage compensation takes place. The series inverter provides voltage compensation and shunt provides reactive power compensation. The UPQC is capable of providing a hassle free power supply. We can apply number of controlling techniques as given in paper

References

[1]. Mr.Subhro Paul, Pradip Kumar Saha, Gautam Kumar Panda " Power Quality Improvement Using New Control Algorithm Based Dynamic Voltage Restorer" International Journal Of Advanced Research in Electrical , Electronics and Instrumentation Engineering, VOL 1, Issue 3, 2012

[2]. S. Rajesh Rajan, "Power Quality Improvement In Grid Connected Wind Energy System Using Statcom" International Journal Of Advanced Research in Electrical , Electronics and Instrumentation Engineering, vol 2, issue 3, March 2013

[3]. Yash Pal, A. Swarup, and Bhim Singh, ―A Review of Compensating Type Custom Power Devices for Power Quality Improvement‖ 2008 Joint International Conference on Power System Technology (POWERCON) and IEEE Power India Conference New Delhi, India Page(s): 1 - 8, October 2008.

[4]. Power Quality, business, www. TNB.com

[5]. María Isabel Milanés Montero, Member, IEEE, Enrique Romero Cadaval, Member, IEEE, and Fermín Barrero González Member, 'Comparison of Control Strategies for Shunt Active Power Filters in Three-Phase Four-Wire Systems' IEEE TRANSACTIONS ON POWER ELECTRONICS VOL.22, NO. 1., IEEE JANUARY 2007.

[6]. Karuppanan P and Kamala Kanta Mahapatra 'PLL with PI, PID and Fuzzy Logic Controllers based Shunt Active Power Line Conditioners' IEEE PEDES- International Conference on Power Electronics, Drives and Energy Systems-, at IIT Delhi 2010.

[7]. R. Belaidia, A. Haddouchea, H. Guendouza 'Fuzzy Logic Controller Based Three-Phase Shunt Active Power Filter for Compensating Harmonics and Reactive Power under Unbalanced Mains Voltages' Elsevier Energy Procedia 18 560-70., 2012.

[8]. Dr. K.Ravichandrudu, P.Suman Pramod Kumar, V.E.Sowjanya "Mitigation of Harmonics And Power Quality Improvemnet For Grid Connected Wind Energy System using UPFC " Internation Journal Of Application Or Innovation in Engineering or Management, Volume 2, Issue 10, October 2013

[9]. The power quality of wind turbines AKE LARSSON ISBN 91-7197-970-0 © ÅKE LARSSON, 2000

[10]. L. Gyugyi, Unified power flow control concept for flexible ac transmission systems, Proc. IEE 139(C) (1992) 323–331.

[11]. Arindam Ghosh, Gerard Ledwich, "A unified power quality conditioner (UPQC) for simultaneous voltage and current compensation" Electric Power Systems Research 59 (2001) 55–63

[12]. H. Fujita, H. Akagi, The unified power quality conditioner: the integration of series- and shunt-active filters, IEEE Trans. Power Elect. 13 (2) (1998) 315–322.

[13]. Malabika Basu , Shyama P. Das, Gopal K. Dubey, "Comparative evaluation of two models of UPQC for suitable interface to enhance power quality" Elsevier, Electric Power Systems Research 77 (2007) 821–830

[14]. K. Palanisamy, D.P. Kothari b, Mahesh K. Mishra , S. Meikandashivam , I. Jacob Raglend, "Effective utilization of unified power quality conditioner for interconnecting PV modules with grid using power angle control method" Elsevier, Electrical Power and Energy Systems 48 (2013) 131–138

[15]. J.M.Esp ´ı Huerta, J. Castell´ o-Moreno, J.R.Fischer, and R.Garc´ ıa-Gil, "A synchronous reference frame robust predictive current control for three-phase grid-connected inverters, "IEEE Transactions on Industrial Electronics,vol.57,no.3,pp.954–962,2010.

[16]. S. K. Jain, P. Agarwal, H. O. Gupta, and G. Agnihotri, "Modeling of frequency domain control of shunt active power filter using MATLAB simulink and power system block set," in Proc. ICEMS, Vol. 2, pp.1124-1129, 2005.

[17]. N. Kasa, T. Lida and G. Majumdar, "Robust control for maximum power point tracking in photovoltaic power system," PCC-Osaka, 2002, pp. 827-832.

[18]. J. R. Vazquez and P. R. Salmern, (2000) ―Three phase active power filter control using neural networks‖, Proceedings of 10th Mediterranean Electro Technical Conference, MEleCon , vol. 3, pp.924–927.

[19]. B. Lindgren, "A PV-module oriented inverter, feeding a low voltage AC bus," European Photovoltaic Solar Energy Conference and Exhibition, 2000.

[20]. M. J. Newman and D. G. Holmes, "A universal custom power conditioner with selective harmonic voltage compensation," in Proc .IECON, Vol. 2, pp. 1261-1266, 2002.

[21]. Ewald Fuchs, Mohammad A. S. Masoum, "Power Quality in Power Systems and Electrical Machines," Academic Press, 29-Aug-2011 - Technology & Engineering.

[22]. B. Singh, P. Jayaprakash, D. P. Kothari, A. Chandra and Kamal-Al-Haddad **,** " New Control Algorithm for Capacitor Supported Dynamic Voltage Restorer" Journal of Electromagnetic Analysis and Applications, 2011, 3, 277-286 .

[23]. A. Mokhtatpour and H.A. Shayanfar "Power Quality Compensation as Well as Power FlowControl Using of Unified Power Quality Conditioner", Asia- Pacific Power and Energy Engineering Conference (APPEEC), Page(s): 1 - 4, 2011.

[24]. Roger C. Dugan, Mark F. McGranaghan, Surya Santoso and H.Wayne Beaty, "Electrical Power Systems Quality," The McGraw-Hill, Second Edition, 2004.

[25]. IEEE standard 519-1992, IEEE recommended practices and requirement for harmonic control in electrical power systems, IEEE, Inc. 1993.

[26]. Metin Kesler and Engin Ozdemir, "A Novel Control Method for Unified Power Quality

[27]. Conditioner(UPQC) Under Non-Ideal Mains Voltage and Unbalanced Load Conditions," IEEE Conference on Applied Power Electronics, Feb. 2010, pp.374-379.