A Comprehensive Review on Control Strategies of Series and Shunt Active Filter Based Custom Power Device: UPQC to Improve Power Quality

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ABSTRACT-In the view of increasing demand for electrical energy and rapid depletion of conventional sources, the need for dependence on renewable energy sources has increased along with the different characterized loads in the power systems. Integration and utilization of different energy resources is one of the challenging tasks for electrical engineers to meet the differently characterized load demands, continuousness of power supply and maintain the quality of power under various operating conditions of power system. The most traditionally passive filters using LC components have many problems like large in size, effect of source impedance on the performance and resonance effect along with its high cost. One of the solutions to tackle these issues by using series and shunt active filter based custom power device called unified power quality conditioner than of existing other custom power device like statcom and dynamic voltage restorer. In this paper a comprehensive reviewon unified power quality conditioner operation, topologies, performance, control and implementations are discussed.

Keywords- *power quality, custom power device, unified power quality conditioner, active power filter, voltage sag, voltage swell, harmonics.*

INTRODUCTION

Day-by-day a wide variety of technological developments in all the sectors increasing to live and lead a better life on the globe. These developments are the indications of the financial growth of any country. For these developments one of the key factors is a good quality of electrical power because, the output of the any manufacturing process depends on the better operating points of the devices or machines put into operationwhich intern the quality of power being supplied by the supplies to the consumer. Unbalanced and nonlinear electrical loads of any power rating irrespective of voltage rating can cause power quality problems. The major industrial loads likely to cause disturbances to the customers are: resistance welding machines, arc welding machines, rolling mills, mine welders, wood chipping machines, rock/ mineral crushing equipment, large motors with varying loads, arc furnaces, induction welding machines, induction furnaces etc. The most affected ones due to power quality issues are customers like: designers of plants- defects in designs, electrical distributers – more loses, system manufactures – unexpected outcomes, public authorities and general public and end users. The quality of power is characterised with the electrical quantities in terms uninterruptable power supply with expected voltage magnitude, phase angle, balance, harmonic distortion, frequency, surges, blackouts, transients, noise, spikes etc. The critical power quality issues are like changes in voltage, frequency and waveform distortions. The members of the IEEE society discuss, develop and recommend the electrical standards [1]. The details of classified of power system disturbances, definitions, standards and guidelines are available in[2].

N. G. Hingorani introduced the concept of custom power devices[3] uses the power electronic based controllers for electrical power distribution systems like flexible AC transmission systems for transmission systems. Different methods to improve the power quality using active power filters are presented in [4] the development of many methods to improve power quality by using active power filters [5]. The classification of power line conditioners, control techniques for active filters, various signal transformations and time domain, frequency domain, instantaneous power and impedance synthesis methods and hybrid filters are discussed [6 - 11]. The classification of custom power devices are shown in Fig. 1.

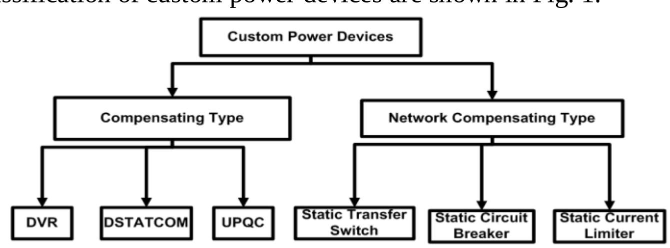


Fig 1: Classification of Custom Power Devices

Fig. 2 demonstrates the block diagram representation of generalised representation of UPQC. As it clearly shows it is the combination of a series active power filter connected at the common coupling point through a low pass filter and a shunt active power filter through a inductive link. Both the filters operatewith classical PI controllers.For both the filers a common DC link capacitor provides the DC supply. To control shunt active filer is a pulse width modulated is employed and to control the series active filter a hysteresis current control method is employed [12, 13, 14]. The main controlling objective of shunt active power filer : to regulate the DC link voltage between active power filters and maintain the DC link voltage remaining constant during abnormal conditions or disturbances on the system. Even during normal operating conditions it is observed that there is change in DC link voltage due to power consumed by the inverter switching operations[15, 16].

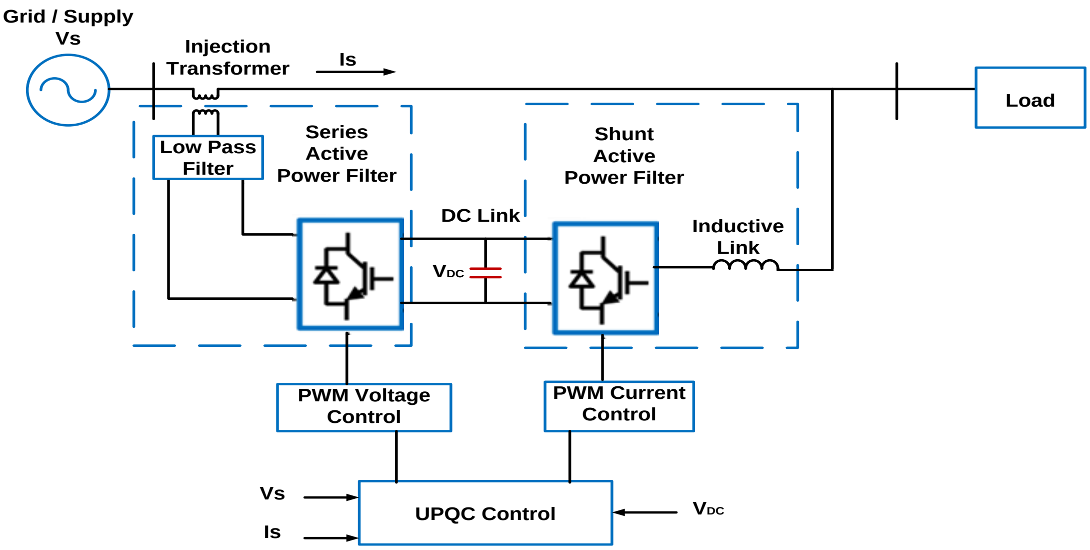


Fig 2: Block Diagram Representation of Generalized UPQC

The following equation determines the reference voltage:

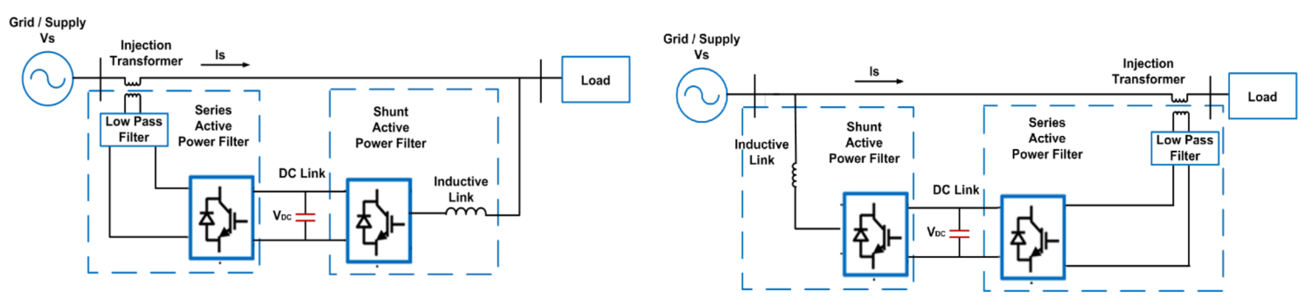
$$V_{Sh}^{Re} = K_p \Delta I_{Sh}^{Re} + K_I \int \Delta I_{Sh} dt \quad (1)$$

$$\Delta I_{Sh} = I_{Sh}^{Re} - I_{Sh} \quad (2)$$

where, I_{Sh}^{Re} - shunt active power filter reference current, K_P - proportional gain proportional gain, K_I- integral gain of the PI controller. ΔI_{Sh} estimated using the PI controller. The following equation used for a general PI controller.

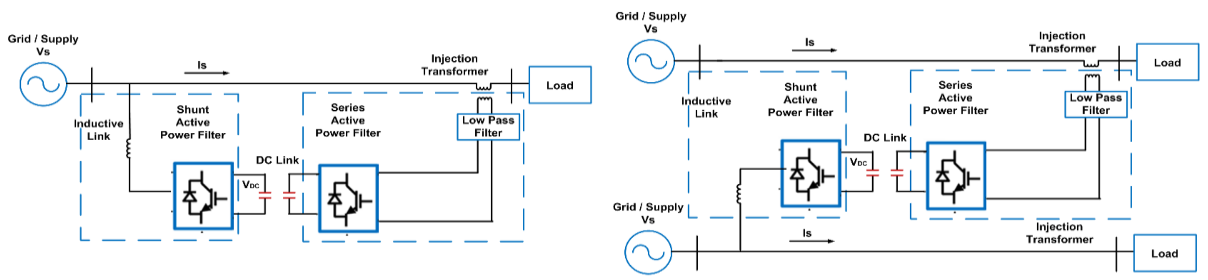
$$G(s) = K_p + \frac{K_i}{s} \quad (3)$$

The complete MATLAB software based modelling of UPQC is described interns of : control strategy, detection of compensation component, detection of current to be compensated, detection of voltage to be compensated, detection of reactive power to be compensated and carried [17 - 19].



(a) (b)

Fig. 3. (a) Right shunt UPQC block diagram (b) Left shunt UPQC block diagram



(a) (b)

Fig. 4. (a) Open UPQC block diagram (b) Interline UPQC block diagram

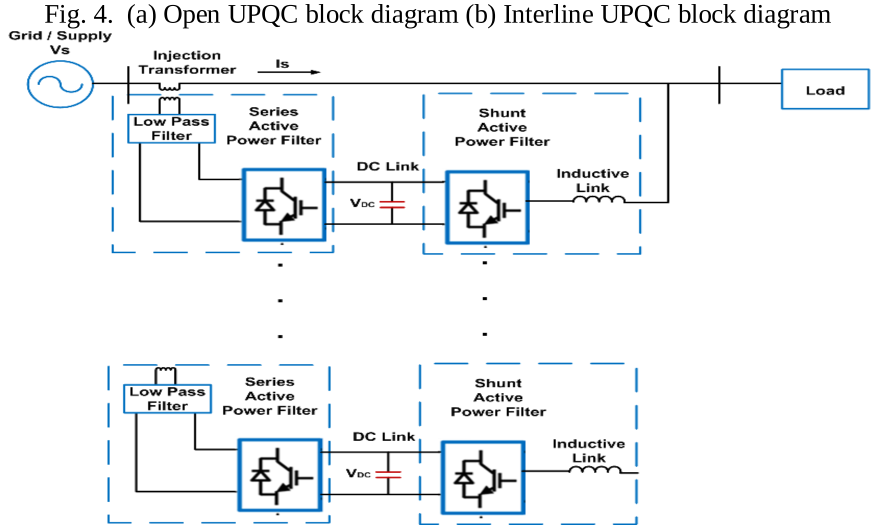


Fig. 5. Multilevel UPQC block diagram

Experimentally validated a new synchronous-reference-frame (SRF)-based three-phase four-wire unified PQ conditioner (UPQC) and its performance analysis carried for unbalanced and distorted load conditions[20].UPQC with model predictive control (MPC) is presented by K. H. Kwan, etal. by taking the systems dynamics into consideration and takes into account the system dynamics and simulation is carried for a 2kVA single phase power distribution system to compensate: power factor, harmonics in supply voltage and currents. The different control strategies of control of UPQC are proposed and discussed in [21 – 34].In [35] proposed a H-∞ bridge module based UPQC without series injection transformer with simulation validations using PSCAD/EMTDC and carried experimental works with a scaled hardware model, assuming that the UPQC is connected with on 22.9-kV distribution line.Different fuzzy, combination of Nero-Fuzzy and adaptive Nero-Fuzzy control strategies for UPQC are proposed in [36 – 50]. In [51] control algorithm to regulate DC link voltage with the implementation of enhanced PLL based resistiveoptimization technique. In [52] proposed a Harmonic signal detection algorithm based on PSO-FUZZY system which has the special features like it abandons the original vector transformation which leads to more accuracy of control.

The application of artificial Intelligence techniques increasing: an artificial intelligent control based shunt active power filter in implemented by choudhary.J et al.[53], soft computing method by Arulkumar et al. [55], an ant colony based fuzzy control technique [55]. A modified double hysteresis controlled UPQC is propose to overcome the problems of location of current error, compensation accuracy of a conventional double hysteresis controlled UPQC with the help of active disturbance rejections controller [56]. In [57] a Cuckoo Search Algorithm (CSA) based Neuro Fuzzy Controller UPQC presented to compensate the voltage for a wind farm based squirrel cage induction generator and compared the performance with PI based UPQC, NFC-UPQC, GA-NFC-UPQC, and adaptive GA-NFC-UPQC and [58] for nonlinear loads.A five-level converter[59], cascade asymmetric multilevel converters[60],ANN based controlscheme for a three-level converter[61], Hybrid fuzzy back-propagation control [62], Reductionof dc voltage sources and switches[63], Variable Phase Angle Control [64], exponentialcomposition algorithm[64], second order generalized integrator [65], for weak distribution networks[66], exponential composition algorithm based UPQC's are proposed[67].Jayanti, N. G., et al compared the performance of right and left shunts to enhance the fault right through capabilities. Fig. 3(a) represents the block diagram representation of right shunt UPQC and Fig. 3(b) represents the left shunt UPQC[68]. Fig. 4(a) represents the open UPQC block diagram. Modelling, controlling with enhanced PLL and applications to distributed generation are discussed [69 – 72]. Interline UPQC implementation using probabilistic approach, Fuzzy Control TechniqueBY. STRUCTURE [73 – 76]. Multi-converter UPQC modelling and control strategies are discussed in [77 – 85].

CONCLUSION

Power quality is one of the major concerns in power systems. Among all the custom power devices unified power quality conditioner has better features to control the power system when the power system is subjected to internal or external disturbances. In this paper reviewed the operation, different configurations, control strategies like: conventional, fuzzy logic, artificial neural network, adaptive controlled, biologically inspired methods like: genetic algorithm, particle swarm optimization, ant colony algorithm, cuckoos search methods of UPQC to compensate the power quality issues like sags, swells, under voltages, over voltages, frequency deviations in the power system.

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