

POWER QUALITY ISSUE AND UPQC : REVIEW

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1. INTRODUCTION :

Most of the power quality problems are introduced by the Power Electronics devices because of its fast switching & non-linear characteristics.

Because of increase in non-linearity causes different undesirable features like low system efficiency and poor power factor. It also causes disturbance to other consumers and interference in nearby communication networks. Hence, it is very important to overcome these undesirable features.

Any Power Quality problem manifested in voltage and/or current deviations result into failure or disoperation of customer equipment. Both electric utility and end users of electric power are becoming increasingly concerned about the quality of electric power.

2. POWER QUALITY

The PQ issue is defined as “any occurrence manifested in voltage, current, or frequency deviations that results in equipment overheating, damage devices, EMI related problems etc.” Almost all PQ issues are closely related with Power Electronics in almost every aspect of commercial, domestic, and industrial application. Equipment using power electronic device are residential appliances like TVs, PCs etc. business and office equipment like copiers, printers etc. industrial equipment like programmable logic controllers (PLCs), adjustable speed drives (ASDs), rectifiers, inverters, CNC tools and so on. The Power Quality (PQ) problem can be detected from one of the following several symptoms depending on the type of issue involved.

- Lamp flicker
- Frequent blackouts
- Sensitive-equipment frequent dropouts
- Voltage to ground in unexpected
- Locations
- Communications interference
- Overheated elements and equipment.

Harmonics are produced by rectifiers, ASDs, soft starters, electronic ballast for discharge lamps, switched-mode power supplies, and HVAC using ASDs. Equipment affected by harmonics includes transformers, motors, cables, interrupters, and capacitors (resonance). Notches are produced mainly by converters and they principally affect the electronic control devices. Neutral currents are produced by equipment using switched-mode power supplies, such as PCs, printers and photocopiers. Neutral currents seriously affect the neutral conductor temperature and transformer capability.

Inter harmonics are produced by static frequency converters, cyclo-converters, induction motors & arcing devices. Equipment presents different levels of sensitivity to PQ issues, depending on the type of both the equipment and the disturbance. Furthermore, the effect on the PQ of electric power systems, due to the presence of PE and also depends on the type of PE utilized. The maximum acceptable values of harmonic contamination are specified in IEEE standard in terms of total harmonic distortion. Power electronics are alive and well in useful applications to overcome distribution system problems. Power electronics has three faces in power distribution: one that introduces valuable industrial and domestic equipment; a second one that creates problems; and, finally, a third one that helps to solve those problems. On one hand, power electronics and microelectronics have become two technologies that have considerably improved the quality of modern life, allowing the introduction of sophisticated energy-efficient controllable equipment to industry and home. On another hand, those same sensitive technologies are conflicting with each other and increasingly challenging the maintenance of quality of service in electric energy delivery, while at the same time costing billions of dollars in lost customer productivity.

3. SOLUTIONS TO POWER QUALITY PROBLEMS

There are two approaches to the mitigation of power quality problems. The first approach is called load conditioning, which ensures that the equipment is made less sensitive to power disturbances, allowing the operation even under significant voltage distortion. The other solution is to install line-conditioning systems that suppress or counteract the power system disturbances. Passive filters have been most commonly used to limit the flow of harmonic currents in distribution systems. They are usually custom designed for the application. However, their performance is limited to a few harmonics, and they can introduce resonance in the power system. Among the different new technical options available to improve power quality, active power filters have been proven to be an important and flexible alternative to compensate for current and voltage disturbances in power distribution systems (i.e. at PCC). The idea of active filters is relatively old, but their practical development was made possible with the new improvements in power electronics and microcomputer control strategies as well as with cost reduction in electronic components. Active power filters are becoming a viable alternative to passive filters and are gaining market share speedily as their cost becomes competitive with the passive variety. Through power electronics, the active filter introduces current or voltage components, which cancel the harmonic components of the nonlinear loads or supply lines, respectively. Different active power filter topologies have been introduced and many of them are already available in the market.

4. POWER FILTER TOPOLOGIES

Depending on the particular application or electrical problem to be solved, active power filters can be implemented as shunt type, series type, or a combination of shunt and series active filters (shunt-series type like UPQC). These filters can also be combined with passive filters to create hybrid power filters. The shunt-connected active power filter, with a self-controlled dc bus, has a topology similar to that of a static compensator (STATCOM) used for reactive power compensation in power transmission systems. Shunt active power filters compensate load current harmonics by injecting equal-but opposite harmonic compensating current. In this case the shunt active power filter operates as a current source injecting the harmonic components generated by the load but phase-shifted by 180° .

Series active power filters were introduced by the end of the 1980s and operate mainly as a voltage regulator and as a harmonic isolator between the nonlinear load and the utility system. The series-connected filter protects the consumer from an inadequate supply- voltage quality. This type of approach is especially recommended for compensation of voltage unbalances and voltage sags from the ac supply and for low-power applications and represents an economically attractive alternative to UPS, since no energy storage (battery) is necessary and the overall rating of the components is smaller. The series active filter injects a voltage component in series with the supply voltage and therefore can be regarded as a controlled voltage source, compensating voltage sags and swells on the load side. In many cases, series active filters work as hybrid topologies with passive LC filters. If passive LC filters are connected in parallel to the load, the series active power filter operates as a harmonic isolator, forcing the load current harmonics to circulate mainly through the passive filter rather than the power distribution system. The main advantage of this scheme is that the rated power of the series active filter is a small fraction of the load kVA rating, typically 5%. However, the apparent power rating of the series active power filter may increase in case of voltage compensation.

The series-shunt active filter is a combination of the series active filter and the shunt active filter. The shunt active filter is located at the load side and can be used to compensate for the load harmonics. On the other hand, the series portion is at the source side and can act as a harmonic blocking filter. This topology has been called the Unified Power Quality conditioner (UPQC). The series portion compensates for supply voltage harmonics and voltage unbalances, acts as a harmonic blocking filter, and damps power system oscillations. The shunt portion compensates load current harmonics, reactive power, and load current unbalances. In addition, it regulates the dc link capacitor voltage. The power supplied or absorbed by the shunt portion is the power required by the series compensator and the power required to cover losses.

Hybrid power filters are a combination of active and passive filters. With this topology the passive filters have dynamic low impedance for current harmonics at the load side, increasing their bandwidth operation and improving their performance. This behavior is reached with only a small power rating PWM inverter, which acts as an active filter in series with the passive filter. Multilevel inverters are being investigated and recently used for active filter topologies. Three-level inverters are becoming very popular today for most inverter applications, such as machine drives and power factor compensators. The advantage of multilevel inverters is that they can reduce the harmonic content generated by the active filter because they can produce more levels of voltage than conventional inverters (more than two levels). This feature helps to reduce the harmonics generated by the filter itself. Another advantage is that they can reduce the voltage or current ratings of the semiconductors and the switching frequency requirements. The more levels the multilevel inverter has, the better the quality of voltage generated because more steps of voltage can be created.

5. VOLTAGE SOURCE INVERTERS

Most of the active power filter topologies use voltage source Inverters, which have a voltage source at the dc bus, usually a capacitor, as an energy storage device. This topology, shown in Figure 1.1, converts a dc voltage into an ac voltage by appropriately gating the power semiconductor switches (IGBT). Although a single pulse for each half cycle can be applied to synthesize an ac voltage, for most applications requiring dynamic performance, pulse width modulation (PWM) is the most commonly used today. PWM techniques applied to a voltage source inverter consist of chopping the dc bus voltage to produce an ac voltage of an arbitrary waveform. There are a large number of PWM techniques available to synthesize sinusoidal patterns or any arbitrary pattern. With PWM techniques, the ac output of the filter can be controlled as a current or voltage source device.

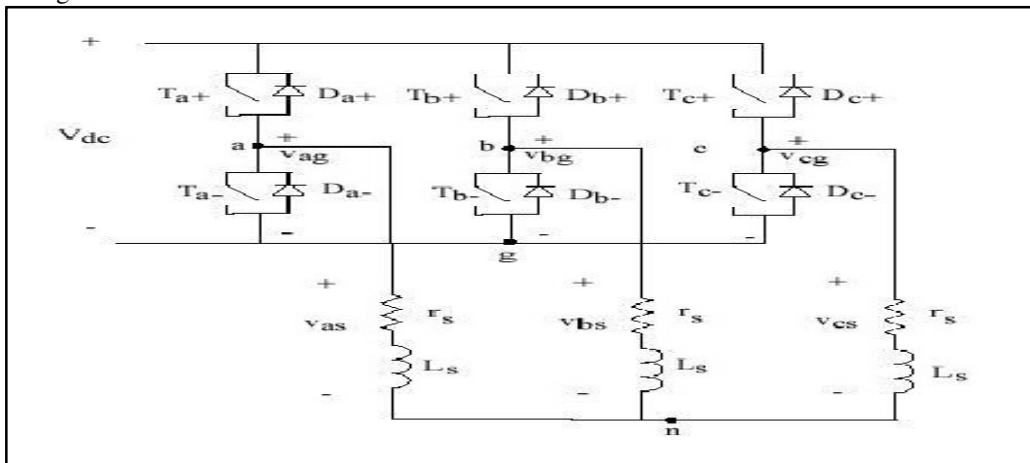


Figure.1. 1 Voltage source inverter topology for active filters.

Voltage source inverters are preferred over current source inverter because it is higher in efficiency and lower initial cost than the current source inverters. They can be readily expanded in parallel to increase their combined rating and their switching rate can be increased if they are carefully controlled so that their individual switching times do not coincide. Therefore, higher-order harmonics can be eliminated by using inverters without increasing individual inverter switching rates.

6. CONTROL STRATEGIES

Most of the active filters developed are based on sensing harmonics and reactive volt-ampere requirements of the non-linear load and require complex control. In some active filters, both phase voltages and load currents are transformed into the α - β orthogonal quantities, from which the instantaneous real and reactive power is estimated. The compensating currents are calculated from load currents and instantaneous powers. The harmonic components of power are calculated using high pass filters in the calculation circuit. The control circuit of the dc capacitor voltage regulates the average value of the voltage to the reference value. Reactive power compensation is achieved without sensing and computing the reactive current component of the load, thus simplifying the control circuit. Current control is achieved with constant switching frequency producing a better switching pattern. An active filter based on the instantaneous active and reactive current component in which current harmonics of positive and negative sequence including the fundamental current of negative sequence can be compensated. The system therefore acts as a harmonic and unbalanced current compensator. A comparison between the instantaneous active and reactive current component - method and the instantaneous active and reactive power method is realized.

DC capacitor voltage is regulated to estimate the reference current template. Conventional solutions for controller requirements were based on classical control theory or modern control theory. Widely used classical control theory based design of PID family controllers requires precise linear mathematical models. The PID family of controllers failed to perform satisfactorily under parameter variation, non-linearity, load disturbance, etc.

During the past several years, Digital Controllers has emerged as one of the most active and fruitful areas for research in the applications of FPGA, especially in the area of industrial processes, which do not lend themselves to control by conventional methods because of a lack of quantitative data regarding the input-output relations. The Digital Controller is based on FSMD Architecture (Finite State Machine with DATAPATH) that is much closer in spirit to human thinking and natural language than traditional logical systems. The FSMD Architecture is based on Finite State Machine (FSM) that is used to control the

DATAPATH. Recently, Digital controllers have generated a good deal of interest in certain applications. The advantages of Digital controllers over the conventional controllers are:

- FPGA's provide reconfigurable hardware designs.
- Low cost development (reprogrammable ability).
- FPGA's can process information faster than a general purpose DSP.
- Bit widths for data registers can be selected based on application needs.
- Designed in Hardware Description Language (VHDL or VERILOG) the controller becomes independent of process technology.

7. LITERATURE REVIEW

In the modern electrical distribution system, power quality is one of the major issues. The power quality can be analyzed as voltage unbalance, voltage sag and swell, partial or total loss of one or more phases. The voltage unbalance is mainly caused due to uneven distribution of single-phase loads which may continuously changes across a three-phase system.

The lack of quality power can cause loss of production, damage of equipment or appliances, increased power losses, interference of communication lines and so forth. The power system equipment and customer equipment's such as overhead and underground cables, transformers and rotating electric machines, protection systems also affected with poor quality voltage. Passive filter have been used traditionally for mitigating the distortion due to harmonic current in industrial power sector. But they have many drawbacks such as resonance problem, dependency of their performance on the system impedance, absorption of harmonic current of nonlinear load, which could lead to further harmonic propagation through the power system.

To overcome of such problems active power filters is introduced. It has no such drawbacks like passive filter. They inject harmonic voltage or current with appropriate magnitudes and phase angle into the system and cancel harmonics of nonlinear loads. But it has also some drawbacks like high initial cost and high power losses due to which it limits there wide application, especially with high power rating system. The widespread use of power electronics based equipment has produced a significant impact on quality of electric power supply.

S. M. Mousavi G. & Kamal Al-Haddad^[2], Presents a perspective on power quality issues through railway electrification development and investigates the necessity of power quality and system requirements for appropriate power quality. Compensation strategies are classified and compared.

A. Farzanehrafat & Neville R. Watson^[2], discuss about Power Quality State Estimator (PQSE). PQSE has been proposed as a smart algorithm for managing power quality issues in a smart grid environment where great amounts of data are available. The output from a PQSE can be used not only for detecting sources of power quality emissions but potentially also for taking remedial actions.

Bhim Singh & Ambrish Chandra^[3], discuss that Active filtering of electric power has now become a mature technology for harmonic and reactive power compensation in two-wire (single phase), three-wire (three phase without neutral), and four-wire (three phase with neutral) ac power networks with nonlinear loads. Active filter configurations, control strategies, selection of components, other related economic and technical consideration are depended on the specific applications.

K. R. Suja & I. Jacob Raglend^[4], Presents One of the artificial intelligence technique use for controlling UPQC is Fuzzy Logic Controller (FLC) yields the results which are superior to those obtained with the conventional controllers such as PI, PID etc. In the Fuzzy controller PI controller is combined with the intelligent & adaptive of the fuzzy logic based control system. The addition of FLC with UPQC reduces the voltage sag levels in the output voltage.

Nermeen Talaat, and Marijallic^[5], discuss that the classification techniques of various events causing unacceptable Power Quality (PQ) problem. Because of the overall complexity associated with the power quality analysis and diagnosis is a complex one for many reasons, a computerized system analysis is becoming vital for the realization of effective and efficient power quality diagnosis systems. A novel feature extraction method based on center clustering is obtained which is used as input to Artificial Neural Network (ANN) for classifying power quality disturbances is presented as one of the tools in support of computerized power quality diagnosis. To demonstrate the potential of this approach and provide comparison with other techniques, extensive simulations of different types of poor power quality phenomena to be made.

Swapnil Y. Kamble & Madhukar M. Waware^[6], Presents an advanced control approach for power quality compensation using Unified Power Quality Conditioner (UPQC). This approach has capability of voltage distortion mitigation as well as current harmonics compensation. In the UPQC control, Series Active Filter (SAF) is controlled by d-q-o approach for voltage harmonic compensation. Voltage signal calculated at SAF is used for calculation of required reference signals using P-Q theory for Parallel Active Filter (PAF) control

for current harmonic compensation. This control strategy requires reduced number of measurements (source voltage & load current).

G.-Myoung Lee, Dong-Choon Lee & Jul-Ki Seok^[7], discuss that the novel control scheme compensating for source voltage unbalance and current harmonics in series-type active power filter systems combined with shunt passive filters is proposed, which focuses on reducing the delay time effect required to generate the reference voltage. Using digital all-pass filters, the positive voltage sequence component out of the unbalanced source voltage is derived. The all-pass filter can give a desired phase shift and no magnitude reduction, unlike conventional low or high-pass filters. Based on this positive-sequence component, the source phase angle and the reference voltage for compensation are derived.

Raphael Jorge Millnitz dos Santos, Marcello Mezaroba and Jean Carlo da Cunha^[18], Present a dual three-phase topology of unified power quality conditioner (UPQC) composed of two filters: a series active filter and a parallel active filter to compensate the current and voltage harmonics. Different from conventional UPQC, the dual UPQC has the series filter controlled as a sinusoidal current source and the parallel filter controlled as a sinusoidal voltage source. Therefore, the PWM controls of the dual UPQC deal with a well-known frequency spectrum, since it is controlled using voltage and current sinusoidal references, differently from the conventional UPQC which is controlled using non-sinusoidal references.

K.Vijayakumar & Subhranshu Sekhar Dash^[9], discuss that Power electronics based equipment has produced a significant impact on the quality of electric power supply. Conventional power quality mitigation equipment is proving to be inadequate for an increasing number of applications and this fact has attracted the attention of power engineers to develop dynamic and adjustable solutions to power quality problems. The development of UPQC control schemes and algorithms for power quality improvement and implementation of a versatile control strategy to enhance the performance of UPQC. The proposed control scheme gives better steady-state and dynamic response.

S.P.Srivastava & Aurobinda Panda^[10], presents the device combines a UPQC, shunt active filter with an active series filters in the back to back configuration. UPQC designed for simultaneous compensation of current and voltage harmonics. A simple control strategy with voltage sag-swell/harmonic/flicker compensation, fuzzy controller benefits over PI controller.

A. Kazemi & R. Rezaei pour^[11], discuss that the time domain analysis of reference signal, we can instantaneously adjust the performance of series and parallel UPQC filters such that several problems of power quality including notch, sag, swell, flickers and existence of harmonics and load misbalancing can be solved.

Metin Kesler and Engin Ozdemir^[12], presents a new synchronous-reference frame (SRF)-based control method to compensate power-quality (PQ) problems through a three-phase four-wire unified PQ conditioner (UPQC) under unbalanced and distorted load conditions. The proposed UPQC system can improve the power quality at the point of common coupling on power distribution systems under unbalanced and distorted load conditions.

Swapnil Y. Kamble & Madhukar M. Waware^[13], presents an advanced control approach for power quality compensation using Unified Power Quality Conditioner (UPQC). This approach has capability of voltage distortion mitigation as well as current harmonics compensation. In the UPQC control, Series Active Filter (SAF) is controlled by d-q-o approach for voltage harmonic compensation. Voltage signal calculated at SAF is used for calculation of required reference signals using P-Q theory for Parallel Active Filter (PAF) control for current harmonic compensation.

Sai Shankar and Ashwani Kumar^[14], presents unified power quality conditioner (UPQC) has been modelled for both active and reactive power compensation using fuzzy control strategy. The behavior of UPQC has been analyzed with sudden switching of loads as well as occurrences of L-G fault. The control scheme has been devised using fuzzy logic controller in UPQC. The results have also been obtained with PI controller for comparison.

K.S. Ravi Kumar, V.Divya & N.S.Prasanna^[15], discuss the compensating principle and different control strategies (GA based PI) of the UPQC in detail and the results are compared with FUZZY UPQC and ANN UPQC. GA are programmed in MATLAB and the control strategies are modeled using SIMULINK. The performance of UPQC is examined by considering a thyristor rectifier feeding an RL-load (non-linear load) that acts as source of harmonics to the system of concern.

Joshita Gupta and Avadh Pati^[16], presents a new and improved converter in which the peaks can be reduced to the maximum possible extent by using a PID controller. The new improved hybrid filter is implemented reducing the peaks and modifying the signal close to sinusoid by the PID control method. Also, the quality of the load current waveform will be compared on the basis of other controlling techniques.

Karuppanan P and Kamala Kanta Mahapatra^[17], presents a novel Phase Locked Loop (PLL) circuit in conjunction with Proportional Integral (PI) or Proportional Integral Derivative (PID) or Fuzzy Logic Controller (FLC) based shunt Active Power Line Conditioners (APLC) for the power-quality improvement such as current harmonics and reactive power compensation due to the non-linear/unbalanced loads. The

shunt APLC system is implemented with three phase current controlled Voltage Source Inverter (VSI) and is connected at the point of common coupling for compensating the current harmonics by injecting equal but opposite filter currents. The compensation process is based on PLL synchronization with PI or PID or fuzzy logic controller. These controllers are capable of controlling dc-side capacitor voltage and estimating reference currents.

S.Srivastava, M. Gupta, AsthaManaktala&KamayaniSadhvani^[18], discuss the application of an optimization technique inspired by natural evolution, namely Genetic Algorithm (GA) for the design of Fractional order Proportional and Integral (FOPI) based DSTATCOM (Distributed Static Compensator) and ELC (Electronic Load Controller). The GA technique helps search efficiently the optimal parameters of the FOPI controller. Conventional controllers use integral order control which is less robust as compared to fractional order control. This paper is based on a novel application of fractional order controller optimized by genetic algorithm for power quality improvement using DSTATCOM and ELC in a power system.

Rahul Virmani, Prerna Gaur, HimanshuSantosi, &Bhim Singh^[19], presents the performance comparison of the conventional Active Power Filters (APF) namely, the Series Active Filter for voltage and Shunt Active Filter for current against a combined topology named Unified Power Quality Conditioner (UPQC) using MATLAB/SIMULINK for the non-linear loads such as variable torque DC machine. In this paper IEEE-519 standards is taken for comparison with the obtained results from simulation. The results show that Unified Power Quality Conditioner (UPQC) is more effective tool against the harmonics in comparison to the Active Power Filters.

8. CONCLUSION

01 To balance the source currents by injecting negative and zero sequence components required by the load.

02 To compensate for the harmonics in the load current by injecting the required harmonic currents.

03 To control the power factor by injecting the required reactive current (at fundamental frequency).

04 To regulate the DC bus voltage.

05 To balance the voltages at the load bus by injecting negative and zero sequence voltages to compensate for those present in the source.

06 To isolate the load bus from harmonics present in the source voltages, by injecting the harmonic voltages.

07 To regulate the magnitude of the load bus voltage by injecting the required active and reactive components (at fundamental frequency) depending on the power factor on the source side.

08 To control the power factor at the input port of the UPQC (where the source is connected). Note that the power factor at the output port of the UPQC (connected to the load) is controlled by the shunt converter.

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