

# UPQC for Power Quality Improvement – A Review

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**Abstract:** In recent years, power engineers are increasingly concerned over the quality of the electrical power. In modern power system consists of wide range of electrical, electronic and power electronic equipment in commercial and industrial applications. Since most of the electronic equipments are nonlinear in nature these will induce harmonics in the system, which affect the sensitive loads to be fed from the system. One among the many compensating devices is Unified Power Quality Conditioner (UPQC) which specifically aims at the integration of series-active and shunt-active power filters to mitigate any type of voltage and current fluctuations and power factor correction in a power distribution network, such that improved power quality can be made available at the point of common coupling. In this paper presents a comprehensive review on the unified power quality conditioner (UPQC) to enhance the electric power quality at distribution levels. This is intended to present a broad overview on the different possible UPQC system configurations.

**Keywords:** power quality (PQ), harmonics, voltage sag, voltage swell, active power filter (apf), unified power quality conditioner (UPQC).

## 1. Introduction

The quality of the power is effected by many factors like harmonic contamination, due to the increment of non-linear loads, such as large thyristor power converters, rectifiers, voltage and current flickering due to arc in arc furnaces, sag and swell due to the switching (on and off) of the loads etc. These problems are partially solved with the help of LC passive filters. However, this kind of filter cannot solve random variations in the load current waveform and voltage waveform. Active filters can resolve this problem, however the cost of active filters is high, and they are difficult to implement in large scale. Additionally, they also present lower efficiency than shunt passive filters [1]. been reported in the last five years, which indeed suggest the rapid interest in utilizing UPQC to improve the quality of power at the distribution level [2],[3]. The UPQC is a combination of series and shunt active filters connected through a common DC link capacitor. The main purpose of a UPQC is to compensate for supply voltage power quality issues such as, sags, swells, unbalance, flicker, harmonics, and for load current power quality problems such as, harmonics, unbalance, reactive current and neutral current [4].

## 2. Power Quality Problems

Power quality is very important term that embraces all aspects associated with amplitude, phase and frequency of the voltage and current waveform existing in a power circuit. Any problem manifested in voltage, current or frequency deviation that results in failure of the customer equipment is known as power quality problem. The increasing number of power electronics based equipment has produced a significant impact on the quality of electric power supply. The lack of quality power can cause loss of production, damage of equipment or appliances, increased power losses, interference with communication lines and so forth. Therefore, it is obvious to maintain high standards of power quality [3]. The major types of power quality problems are: Interruption, Voltage-sag, Voltage-swell, Distortion, and Harmonics.

### a) Interruption



Figure 1: Interruption

An interruption is defined as complete loss of supply voltage or load current as shown in Fig. 2. Interruptions can be the result of power system faults, equipment failures, and control malfunction. There are three types of interruptions which are characterized by their duration:

- 1) The momentary interruption is defined as the complete loss of supply voltage or load current having duration between 0.5 cycles & 3 sec.
- 2) The temporary interruption is the complete loss lasting between 3 seconds and 1 minute,
- 3) The long term interruption is an interruption which has duration of more than 1 minute.

### b) Voltage Sags

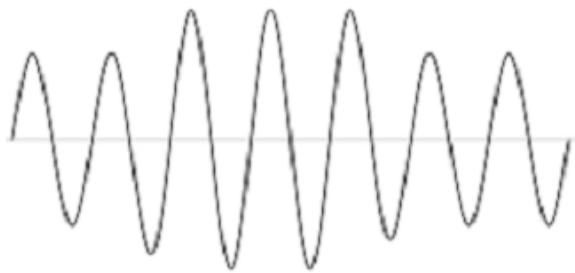


Figure 2: Voltage Sags

Voltage sags (dips) are short duration reductions in rms voltage caused by short duration increases of the current. The most common causes of the over currents leading to voltage sags are motor starting, transformer energizing and faults. A sag is decrease in voltage at the power frequency for duration from 0.5 cycle to 1min. Voltage sags are usually

associated with system faults but can also be caused by energisation of heavy loads at starting of large motors as shown in Fig. 3.

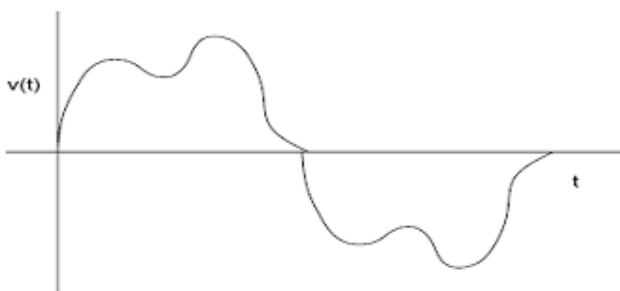
**c) Voltage Swells**



**Figure 4: Voltage Swells**

Voltage swell is an rms increase in the AC voltage, at the power frequency, for duration from a half cycle to a few seconds as shown in Fig 4. Voltage swells are normally due to lightning, switching and sudden decreasing in loads, which leads to damage to the motors, electronic loads and other equipment's. The severity of voltage swell during a fault condition is a function of fault location, system impedance and grounding

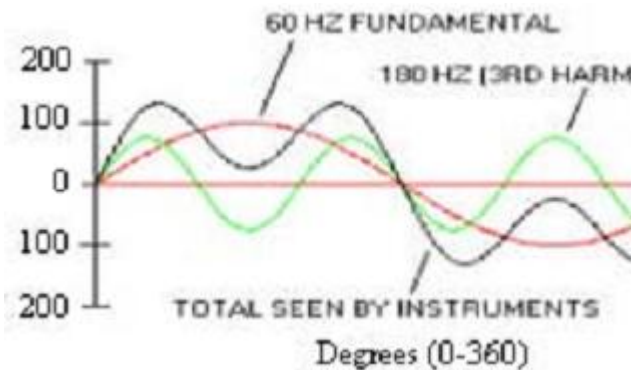
**d) Waveform Distortion**



**Figure 3: Distorted Waveform**

Voltage or current wave forms assume non-sinusoidal shape called distorted wave as shown in Fig 5. When a waveform is identical from one cycle to the next, it can be represented as a sum of pure sine waves in which the frequency of each sinusoid is an integer multiple of the fundamental frequency of the distorted wave.

**e) Harmonics**



**Figure 4: Waveform with 3<sup>rd</sup> Harmonic**

Harmonics are sinusoidal voltages or current having frequency that are integer multiples of the fundamental frequency. Here, 3<sup>rd</sup> harmonics is seen in the Fig. 6. In order

to meet PQ standard limits, it may be necessary to include some sort of compensation. Modern solutions can be found in the form of active rectification or active filtering. A shunt active power filter is suitable for the suppression of negative load influence on the supply network, but if there are supply voltage imperfections, a series active power filter may be needed to provide full compensation

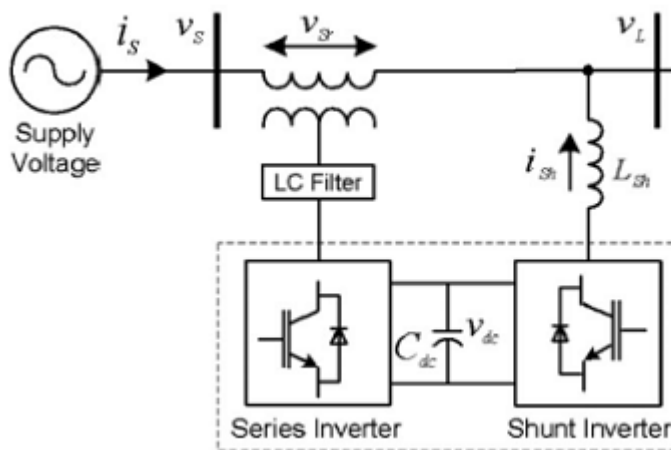
**3. Basic Configuration of UPQC**

The Unified Power Quality Conditioner is a custom power device that is employed in the distribution system to mitigate the disturbances that affect the performance of sensitive and/or critical load [19]. It is a type of hybrid APF and is the only versatile device which can mitigate several power quality problems related with voltage and current simultaneously therefore is multi functioning devices that compensate various voltage disturbances of the power supply, to correct voltage fluctuations and to prevent harmonic load current from entering the power system. The system configuration of a single-phase UPQC is shown in Fig. 5.

Unified Power Quality Conditioner (UPQC) consists of two IGBT based Voltage source converters (VSC), one shunt and one series cascaded by a common DC bus. The shunt converter is connected in parallel to the load. It provides VAR support to the load and supply harmonic currents. Whenever the supply voltage undergoes sag then series converter injects suitable voltage with supply [2]. Thus UPQC improves the power quality by preventing load current harmonics and by correcting the input power factor. The main components of a UPQC are series and shunt power converters, DC capacitors, low-pass and high-pass passive filters, and series and shunt transformers. The main purpose of a UPQC is to compensate for supply voltage power quality issues, such as, sags, swells, unbalance, flicker, harmonics, and for load current power quality problems, such as, harmonics, unbalance, reactive current, and neutral current. The key components of this system are as follows.

- 1) Two inverters —one connected across the load which acts as a shunt APF and other connected in series with the line as that of series APF.
- 2) Shunt coupling inductor  $L_{sh}$  is used to interface the shunt inverter to the network. It also helps in smoothing the current wave shape. Sometimes an isolation transformer is utilized to electrically isolate the inverter from the network.
- 3) A common dc link that can be formed by using a capacitor or an inductor. In Fig. 1, the dc link is realized using a capacitor which interconnects the two inverters and also maintains a constant self-supporting dc bus voltage across it.
- 4) An LC filter that serves as a passive low-pass filter (LPF) and helps to eliminate high-frequency switching ripples on generated inverter output voltage.
- 5) Series injection transformer that is used to connect the series inverter in the network. A suitable turn ratio is often considered to reduce the voltage and current rating of series inverter.

In principle, UPQC is an integration of shunt and series APFs with a common self-supporting dc bus. The shunt inverter in UPQC is controlled in current control mode such that it delivers a current which is equal to the set value of the reference current as governed by the UPQC control algorithm [20]. Additionally, the shunt inverter plays an important role in achieving required performance from a UPQC system by maintaining the dc bus voltage at a set reference value. In order to cancel the harmonics generated by a nonlinear load, the shunt inverter should inject a current. Similarly, the series inverter of UPQC is controlled in voltage control mode such that it generates a voltage and injects in series with line to achieve a sinusoidal, free from distortion and at the desired magnitude voltage at the load terminal. In the case of a voltage sag condition, actual source voltage will represent the difference between the reference load voltage and reduced supply voltage, i.e., the injected voltage by the series inverter to maintain voltage at the load terminal at reference value. In all the reference papers on UPQC, the shunt inverter is operated as controlled current source and the series inverter as controlled voltage source except [112] in which the operation of series and shunt inverters is interchanged.



**Figure 5:** UPQC general block diagram

#### 4. Operation Strategy

Loads, such as, diode bridge rectifier or a thyristor bridge feeding a highly inductive load, presenting themselves as current source at point of common coupling (PCC), can be effectively compensated by connecting an APF in shunt with the load[4-6]. On the other hand, there are loads, such as Diode Bridge having a high dc link capacitive filter. These types of loads are gaining more and more importance mainly in forms of AC to DC power supplies and front end AC to DC converters for AC motor drives. For these types of loads APF has to be connected in series with the load [21]. The voltage injected in series with the load by series APF is made to follow a control law such that the sum of this injected voltage and the input voltage is sinusoidal. Thus, if utility voltages are non-sinusoidal or unbalanced, due to the presence of other clients on the same grid, proper selection of magnitude and phase for the injected voltages will make the voltages at load end to be balanced and sinusoidal. The shunt APF acts as a current source and inject a compensating harmonic current in order to have sinusoidal, in phase input

current and the series APF acts as a voltage source and inject a compensating voltage in order to have sinusoidal load voltage.

The developments in the digital electronics, communications and in process control system have increased the number of sensitive loads that require ideal sinusoidal supply voltage for their proper operation. In order to meet limits proposed by standards it is necessary to include some sort of compensation. In the last few years, solutions based on combination of series active and shunt active filter have appeared [8-9]. Its main purpose is to compensate for supply voltage and load current imperfections, such as sags, swells, interruptions, imbalance, flicker, voltage imbalance, harmonics, reactive currents, and current unbalance.

#### 5. Conclusion

The UPQC performance mainly depends upon how accurately and quickly reference signals are derived. By using conventional Akagi's principle reference signals was derived. The simulated result shows that it has considerable response time for yielding effective compensation in the network. This may not be desirable in modern power system control. Using conventional compensator data, a fuzzy logic controller (FLC) is tuned with large number of data points. Then conventional compensator was replaced with fuzzy logic controller and ANN. The simulation results have shown that the UPQC perform better with ANN and FLC proposed scheme eliminates both voltage as well as current harmonics effectively. The ANN controller also performs in a similarly with slightly better voltage compensation It is also observed that the response time for derivation of compensation signals reduces significantly with improved accuracy.

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