

# Power Quality Improvement Using Compensating Type Custom Power Devices: A Review

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**Abstract:**-The present deregulation market has to face many power quality problems like voltage sag, voltage swell, flickers, voltage imbalances. This paper describes an inclusive review of different compensating devices used for mitigation of different power quality problems. Custom power devices(CPD) like DVR(dynamic voltage restorer), DSTATCOM (distribution static compensator), UPQC(unified power quality conditioner) are the highlighting topics of the review. Organised references proposed in this paper would be beneficial for future work of engineers and researchers.

**Keywords:** Voltage sag, voltage swell, Flicker, Dynamic Voltage Restorer(DVR), Distribution Static Compensator(DSTATCOM), Unified Power Quality Conditioner(UPQC), Custom Power Devices(CPD)

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## 1. Introduction

Due to rapid advancement in the sector of power electronics and drives, the power distribution systems have to face many power quality issues[1-3]. The power quality problems such as voltage sag, voltage swell, flicker, notching, harmonics and imbalances have become a matter of concern. Also, lightning strike which occurs on the transmission line gives rise to power quality problems. Earlier, the problems affecting the supply of electricity were considered acceptable by power sector and user, but these days, it is considered as a power quality problem by power sector and user. The above mentioned are the consequences of extensive advancement in the usage of non- linear loads, power electronic switches, electronic ballast, in industries and power distribution system. For the sake of proper loading operation, supply voltage, which is purely sinusoidal in nature is required, wherein, sensitive loads such as digital electronics are deployed. In an industrial network, Electric Arc Furnace(EAF) is an irritating source of harmonics which also gives rise to inter-harmonics and voltage fluctuations. Due to its harm causing results, special note has to be taken of voltage flicker caused due to EAF[4-6]. To overcome with this problem, various compensating devices from FACTS family such as Distribution Static Compensator (DSTATCOM), Static Var Compensator (SVC), passive filters and series capacitors are used. However, each one have some constraints. The problem such as variable frequency harmonics and flicker cannot be compensated by passive filter. The usage of series inductor might cause reduction of short circuit power which will eventually led in decreased productivity. Capacitor is susceptible for resonance. Though SVC are extensively used for the compensation of EAF, they have some limitation as they have some default delays which limits their capability for the suppression of voltage flicker. Also by using SVC, they inject large amount of current harmonics, which at the end is needed to be filtered. Reactive power compensation is done by DSTATCOM but only at the fundamental frequency. In order to make this problem less severe, active filters have been introduced to improve the power quality. Current harmonics compensation is done by shunt active filters. Power quality problem can be completely mitigated by the shunt active filter as the voltages are distorted at EAF

installation point. Hence, a newly emerged device in recent past namely Unified Power Quality Conditioner (UPQC) can mitigate this problem as it consists of series and shunt active filters fed by a common dc link capacitor, which as a whole will eventually help in elimination of voltage flicker and imbalances in system. The dual of shunt and series active filter is known as Universal Power Quality Manager (UPQM)[7]. UPQC is a custom power device used at the distribution level to enhance the power quality. A UPQC can be connected to electrical distribution network both in series and parallel manner by connecting two diode clamped multilevel inverter to a common dc link. In order to avoid the transformer, one uses multilevel inverter for interfacing with the distribution system. Dynamic Voltage Restorer (DVR) is another custom power device from FACTS family used at the distribution level. The functions of both DVR and DSTATCOM are fulfilled by UPQC. Reactive power is one of the important issue regarding power system and distribution engineering. The type of load determines the load reactive power. Reactive power is compensated by capacitor bank. UPQC is similar in construction to that of the UPFC, but has different objective. UPQC is deployed in power distribution system while UPFC is used in power transmission system. The basic objective of UPFC is to control the flow of power at fundamental frequency. While distribution system is more prone to dc problems such as unbalance and distortions. Hence UPQC shouldn't be reluctant to perform under these operation. As mentioned earlier, UPQC is a combination of two active power filters (APF). During normal steady state operation, the utilization factor of shunt APF is much more higher than that of series APF. However there are some drawbacks of UPQC [2-3]. Supply frequency variation are not compensated by UPQC. There is no any other device to regulate the supply frequency. UPQC will not compensate the supply frequency as there is change in frequency.

### 1.1 State Of Art

For the mitigation purpose of the harmonics, lossless passive filters have been used since a long. However this passive filter have some demerits. To overcome this, active filters have been used but they too have some demerits as in some instances, their rating is almost equal to the load, i.e (80% of

load). As a consequence of which it becomes a costly affair. In reciprocation to this factor, hybrid filters are the excellent option[4-6]. They can be used on account of their simple design, reduced cost. Considering custom power devices, one can use power electronic static controller for the purpose of power quality enhancement. For isolated power distribution system as well as grid connected system, their implementation has been manifested. There are two types of power electronic controller and they are compensating type and reconfiguration type. This paper presents review of compensating type custom power devices. Except this, Flexible Distribution Generation (FDG) is clinching admiration over other alternative for energy resources. In recent years, many power conditioners have emerged for the purpose of power quality enhancement like UPFC, IPFC, UPQC [7-9].

**2. Configuration**

Considering number of phases and different topology, the classification of compensating custom power devices can be done. Voltage Source Inverter(VSI) is generally used for power quality improvement rather than Current Source Inverter(CSI). If connected in parallel, the topology is DSTATCOM, if connected in series, the topology is DVR and the combination of both is the UPQC[10-13].

**2.1 Converter Based Classification**

Usually, VSI is used for development of custom power devices. It is due to its self- supporting bus. Active filters use CSI and the incorporating example is DSTATCOM and UPQC. VSI topology is acclamable owing to its expansion to multistep converter. Also, this topology has prominent tradeoff of real power considering the energy storage devices, for replacement of dc capacitor.

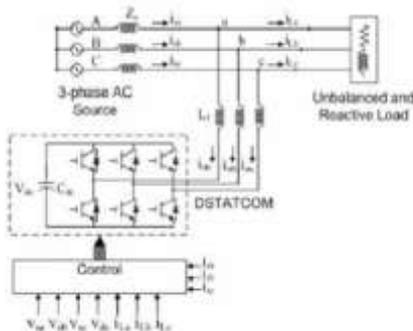


Figure 1. Three phase three wire DSTATCOM

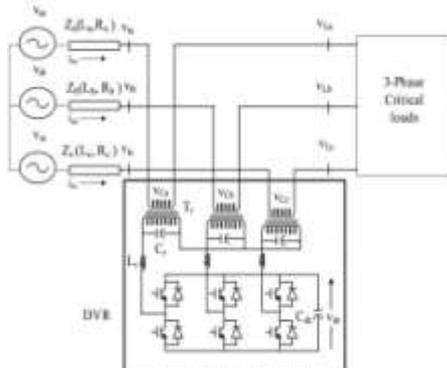


Figure 2. Three phase three wire DVR

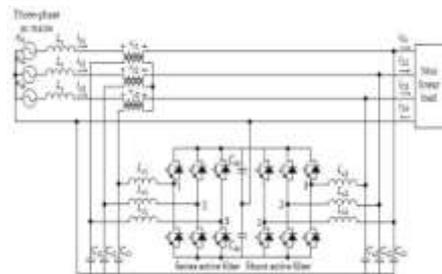


Figure 3. Three phase four wire UPQC.

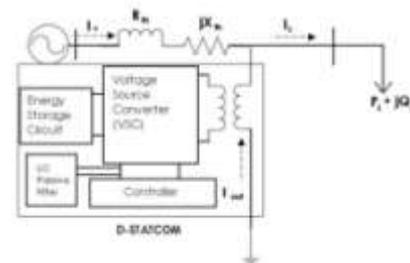


Figure 4. Single phase DSTATCOM

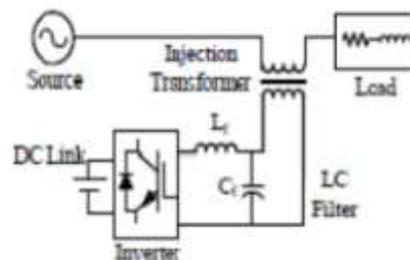


Figure 5. Single phase DVR

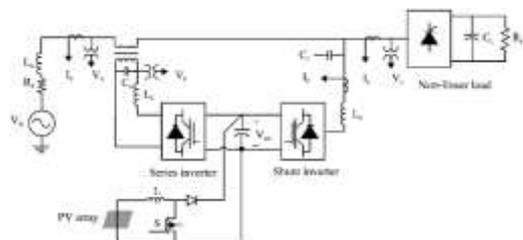


Figure 6. Single phase UPQC

**2.2 Topology Based Classification**

Topology based classification consists of DSTATCOM for shunt, DVR for series compensation and UPQC for the combination of series and shunt APF. Fig 1 shows depicts three phase three wire DSTATCOM. DSTATCOM is widely used for power factor correction in the power distribution system. It can also carry out voltage regulation when connected to distribution bus. Fig 2 shows the DVR three phase three wire, DVR is mainly used for the elimination of series transformer, for better utilisation of rectifiers, for the inverters with minimum switch count and for elimination of energy storage devices[13-15]. Fig 3 shows the UPQC which is three phase three wire and the combination of series and shunt APF. Power exchange takes place through the common dc link capacitor. It is the most versatile device, as it has the capability of injecting current in shunt and voltage in series. Its demerits are its high cost and complexity in control due to involvement of large number of solid state devices. There are two topology of

UPQC. They are right shunt UPQC(R-UPQC), Left shunt UPQC(L-UPQC). R-UPQC is superior in all aspects to L-UPQC. UPQC connected between multiple lines is known as interline UPQC. Q-UPQC is also another configuration described when there is no sharing of active power during steady state[16]. Fig 4, 5, 6, represents the single phase representation of DSTATCOM, DVR and UPQC respectively.

### 2.3 Supply System Based Classification

Supply system based classification is based on load system having different configuration like single phase two wire and three phase three wire or four wire system. Also, classification of compensating devices is based on these three configuration as two wire, three wire or four wire system[17-19].

#### 2.3.1 Two Wire Compensating Devices

These type of compensating devices work in all three modes such as shunt series and combination of both like the DVR, DSTATCOM and UPQC respectively.

#### 2.3.2 Three Wire Compensating Devices

Adjustable speed drives(ASD) are the highlighting application of solid state power converter. Recently, lot of research have been realised in DSTATCOM. They are coupled with cascaded H-bridge, multilevel VSI, multipulse VSI, cascaded H-bridge.

#### 2.3.3 Four Wire Compensating Devices

Basically, the four wire compensating devices are DSTATCOM, DVR and UPQC. For the development of these three phase four wire system, three single phase bridge VSI configurations, four pole VSI and capacitor midpoint are used.

## 3. Control Strategy

Control strategy plays a crucial role in overall execution of compensating devices. In three stages, the control of a compensating device can be perceived. Hall-effect sensors, potential transformer, current transformer, isolation amplifier senses the necessary voltage and current during the first stage. By using various control methods, compensating commands in term of voltage and current are procured, in the second step. Lastly, gate pulses are developed for the solid state devices. The control can either be open loop or closed loop. Pulse Width Modulation(PWM) and Sine Pulse Width Modulation(SPWM) are the most accepted schemes for open loop [20-23]. Whereas for closed loop, for lower order system, hysteresis control technique is used. Conventional methods like pole shift control, linear quadratic regulator(LQR), sliding mode control, dead beat control are used for second and higher order system. Recently, complex algorithm like neural network, fuzzy logic, genetic have emerged due to development in microcontroller, microprocessor and digital signal processor [24].

### 3.1 Compensation in Frequency Domain

Fourier analysis, wavelet transform and infinite impulse response are the technique involved in frequency domain. Distorted signal is separated from the harmonic component with the aid of fourier transform or wavelet transform for computing results on account of its slow response time. Hence, real time application of it is complex [25].

### 3.2 Compensation in Time Domain

It consists of p-q theory, extended 'p-q' theory, 'p-q-r' theory. Other acceptable control schemes to obtain reference signals in time domain are unit vector control, symmetrical component transformation and synchronous reference frame theory.

### 3.3 Generation of Gating Signal

Last step in control strategy is providing gating signal to compensating device. The gating signal is generated in terms of voltage and current for the compensating device.

## 4. Technical And Economic Analysis

Technical and economic analysis is of utmost importance while designing any compensator. Corresponding to the report given by IEEE P1409 custom power task force, there are 50 custom power devices in service upto May 2000. The operation of compensator can be more flexible and efficient if energy storage is attached with power conditioners [26-30]. Various factors have been considered to improve the rendition of CPD like minimum power injection, reduced switching losses, reduced parts etc. The judging factor in deciding the potential of the device is the uttermost quantity of real power that a CPD can supply to load.

### 4.1 Applications of Compensating Devices

A brief review of applications of compensating devices is given in this section.

#### 4.1.1 Current Based Compensation

DSTATCOM has a dual function as it mitigates the current harmonics and also is used for power factor correction. In addition to this, it can also compensate for reactive power, and at the load terminals, it can perform load balancing[31-33]. When connected to distribution network, can mitigate voltage sag, swell, reduce voltage flicker and voltage fluctuations.

#### 4.1.2 Voltage Based Compensation

Voltage based compensation is done by DVR. DVR also have similar functions unlike DSTATCOM. It compensates for reactive power, does voltage regulation and compensates for voltage sag and swell.

#### 4.1.3 Voltage and Current Based Compensation

In today's deregulation market, many application requires current and voltage based compensation. UPQC is such a device who caters the needs of such application. It is the combination of shunt and series APF who provides voltage and current based compensation respectively [34-38]. Expect this, it is capable of reactive power compensation, power factor correction, reduction in voltage sag, voltage swell, reducing flicker and voltage fluctuations simultaneously.

## 5. Conclusion

An exhaustive review is provided on different types of custom power devices. A comprehensive outlook is provided on various compensating devices that can be used by manufacturers, researchers and engineers. Compensating solution to a variety of power quality problems like voltage sag, swell, harmonics, flickers imbalances, is provided in this paper. The utility can analyse the problem and accordingly can choose the compensating device meeting the desired needs.

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