Application of UPQC with Principle of Operation & Control: A Review

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Abstract— Unbalanced supply system may damage the connected equipment. It is the responsibility of the power engineer to supply fine sinusoidal voltage and current for consumer satisfaction. The non-linearity in load may distort the voltage and current waveform hence a compensator is needed to connect at PCC to rule out the harmonics. UPQC is a customized power electronic device capable of compensating both line voltage and load current to obtain sinusoidal waveforms. This paper presents a review on operation and control of UPQC. It also presents the application and performance at distribution system.

Key words: Point of Common Coupling (PCC), Unified Power Quality Conditioner (UPQC)), Series Active Filter (SAF), Parallel Active Filter (PAF), Voltage Source Converter (VSC)

I. INTRODUCTION

The electrical equipment and apparatus connected at distribution system or industrial as well as commercial load demands sinusoidal supply. The power generated by synchronous generator is almost sinusoidal but after dispatching from the generator terminal, its get distorted due to transmission line impedances, transformer impedances, some undesirable and/ or unpredictable disturbances like lighting strokes, transmission line faults non-linear loading such as induction motor switch in and switch off, power electronic converter, electric furnaces etc. With the advancement in technology customer terminal is burdened with voltage sensitive equipments like computers, programmable logic controllers, and microcontrollers. The performances of such devices demands stable sinusoidal voltages which if not checked properly the device may het damaged.

Such issues related to power quality [1,2] are being addressed by employing compensating devices to regulate supply voltage and current. At early stage of rectifying this problem passive filters were connected at load side. At early stage of rectifying this problem passive filters were connected at load side. With the advancement in technology FACTS controller [3-7] were connected at transmission as well as distribution side. But this was not sufficient to meet the specific demand of consumer. Than active filter came into picture whose updated version was hybrid filters, which improves voltage regulation, as well as steady-state and instantaneous active and reactive power control at fundamental frequency. Shunt APF is used for compensating current based distortions on the other hand series APF regulates the system voltage profile. The hybrid filters is used to mitigate higher order harmonics. More specific controller which are customized as per the specific demands are based on custom power devices (CPD) [8, 9]. CPDs are multifunctional controller having capabilities of compensating series and shunt active (P) and reactive (Q) power, voltage regulation, frequency stability at fundamental and harmonic frequencies. Numerous varieties of CPD controllers has been addressed in literature [10-13] to mitigate the power quality issues. Broadly CPD are classified as network reconfiguring and compensating types. The classification CPD is presented in figure 1.

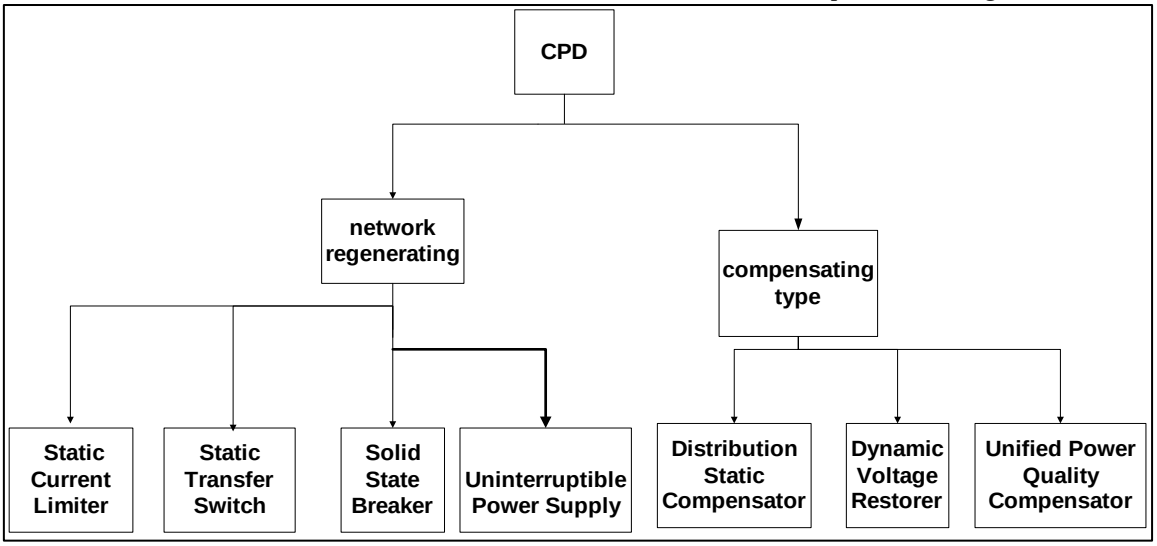

Fig. 1: Classification of CPD

CPD of network reconfiguring type are based on GTO/thyristors like static switch, static breaker, solid state current limiter, uninterruptable supply of power (UPS). CPD of compensating types are designed using active filters both series and/shut and also hybrid filters were employed to design these types of CPD. Static compensator distribution side, voltage restorer and UPQC are its three main type.

Non-linearity in voltage and current generated at distribution side due to non-linear loads can be precisely rule out a series-shunt CPD specifically customized to install at distribution system is UPQC.

II. UNIFIED POWER QUALITY CONDITIONER

The best protection for sensitive loads from sources with inadequate quality is shunt- series connection i.e. unified power quality conditioner (UPQC). Recent research efforts have been made towards utilizing unified power quality conditioner (UPQC) to solve almost all power quality problems for example voltage sag, voltage swell, voltage outage and over correction of power factor and unacceptable levels of harmonics in the current and voltage The basic configuration of UPQC is shown in figure 1

The main purpose of a UPQC is to compensate for supply voltage flicker/imbalance, reactive power, negative-sequence current, and harmonics [14]. In other words, the UPQC has the capability of improving power quality at the point of installation on power distribution systems or industrial power systems. The UPQC, therefore, is expected as one of the most powerful solutions to large capacity sensitive loads to voltage flicker/imbalance.

Unified Power Quality Conditioner (UPQC) for non-linear and a voltage sensitive load has following facilities:

It eliminates the harmonics in the supply current, thus improves utility current quality for nonlinear loads.

UPQC provides the VAR requirement of the load, so that the supply voltage and current are always in phase, therefore, no additional power factor correction equipment is necessary.

UPQC maintains load end voltage at the rated value even in the presence of supply voltage sag.

The voltage injected by UPQC to maintain the load end voltage at the desired value is taken from the same dc link, thus no additional dc link voltage support is required for the series compensator.

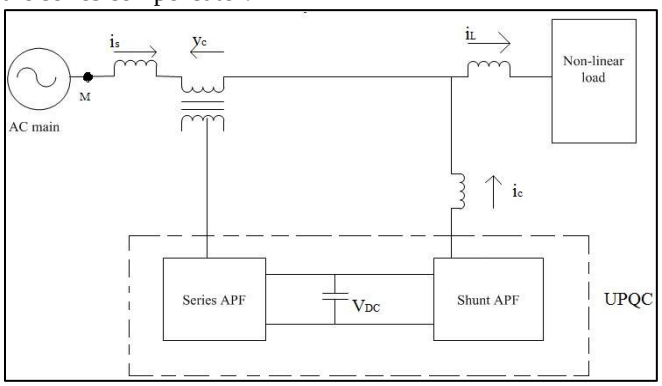

Fig. 2: Schematic of UPQC

Since last two decades there has been tremendous work is available in literature [15-20]. UPQC is emerging as one of the most popular controller could be installed distribution side resolving various power quality issues like voltage regulation, active and reactive power management transient as well as dynamic stability, current harmonic mitigation. UPQC are also different types to resolve different power system issues like; active power control approach in which an in-phase voltage is injected through series inverter [16]–[22], popularly known as UPQC-P; reactive power control approach in which a quadrature voltage is injected [23], [24], known as UPQC-Q;

And a minimum VA loading approach in which a series voltage is injected at a certain angle, [25]–[28]. The broad classification of UPQC is presented in figure 3. Whose nomenclature is given in table 1

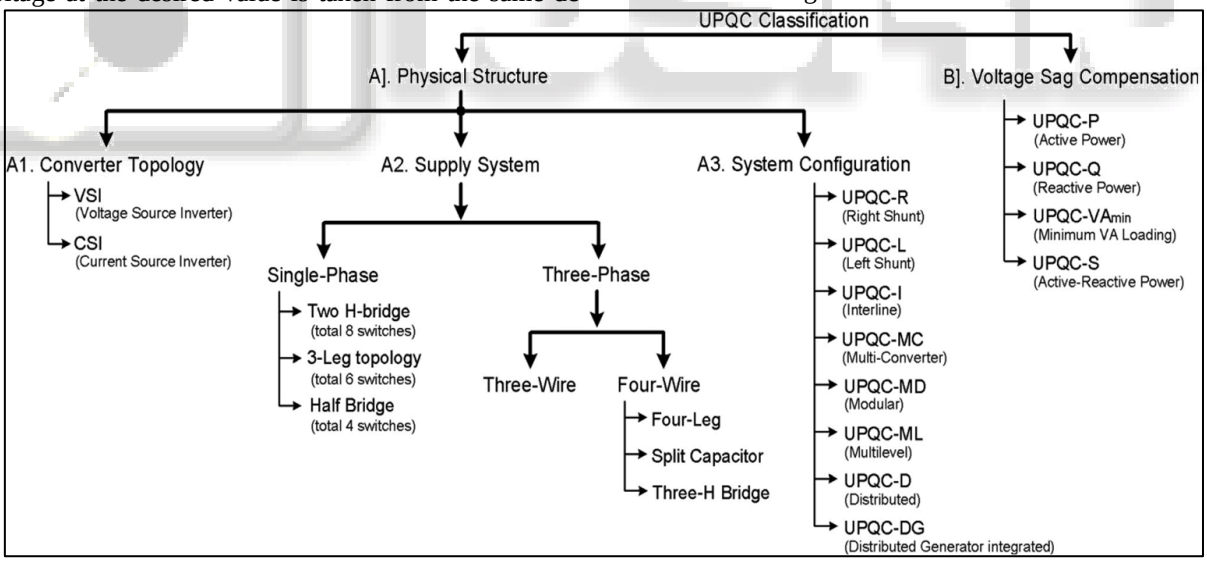

Fig. 3: Classification of UPQC

UPQC-R	Right shunt UPQC
UPQC-L	Left shunt UPQC
UPQC- I	Interline UPQC
UPQC-MC	Multi converter UPQC
UPQC-MD	Modular UPQC
UPQC-ML	Multi-level UPQC
UPQC-D	Distributed UPQC
UPQC-DG	Distributed generator integrated with UPQC
UPQC-P	Active power controlled UPQC

UPQC-R	Reactive power controlled UPQC
UPQC-VAmin	Minimum VA loading in UPQC
UPQC-S	UPQC mitigates both active power and reactive power

Table 1: Nomenclature of various Types of UPQC

III. CONTROL OF UPQC

Conventionally UPQC are controlled nonsinusoidally. It is difficult to develop control algorithm for APF which are

nonsinusoidal. Additional control is desired to improve the performance of such system. Also some paper [29,30] has reported control of UPQC sinusoidally hence less effort is required to control shunt and series APF. Such type of control is called synchronous reference frame (SRF). SRF control resembles the instantaneous control theory. The characteristics property of this strategy is that only load current is essential here for the generation of reference current and hence disturbances present in source or distortions present in voltage have will leave no negative impact on the performance of the designed UPQC system. In literature two broad control techniques of UPQC are reported. One is park's transformation [31-33] another is instantaneous power theory [34-37].

In park's transformation, the three phase voltage or current signals are sensed and to develop the control signal they are transformed from abc to rotating dq0 frame. The transformation angle (ωt) is angular position of proposed reference frame. This ωt is rotating at constant speed and is synchronized with the 3-Ø ac voltage using PLL. After this, currents having same magnitude but with reverse phase is produced and injected to the proposed system for compensating neutral current, harmonics, and reactive power.

In the stationary reference frame abc coordinates are stationary, while in the SRF, d−q−0 coordinate is rotating in synchronism with supply voltages. This is presented in Figure 2.

In instantaneous power theory, the concept of instantaneous real and imaginary power will be relied on to generation of voltage and current reference signals. The three-phase voltage and current signals are transformed to the αβ0 reference frame from three phase abc frame and the instantaneous real, imaginary, and zero-sequence powers are calculated. The decomposition of voltage and current harmonic components into symmetrical components shows that the average of real and imaginary powers consists of interacting components of voltage and current that have the same frequency and sequence order. Therefore, with the calculation of instantaneous powers and the derivation of their oscillation parts, the voltage and current reference signals can be obtained and applied to the PWM controls of power electronic converters. Before analyzing the control systems of the shunt and series converters, the circuits of the phase-lock loop (PLL) and the positive-sequence voltage detector (PSVD) will be introduced.

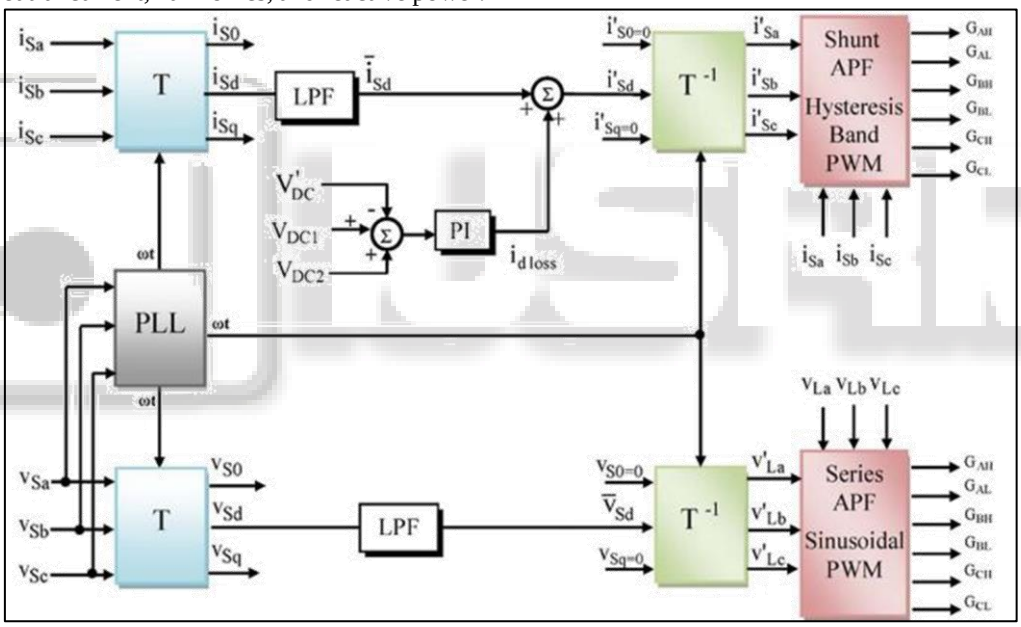

Fig. 4: SRF control for UPQC operation

From figure 2 it is clear that two controls are developed; one for series APF and another for shunt APF. The series APF acts as a controlled sinusoidal current source whose three phase current is transformed into dq0 using park's transformation as in equation (1)

$$\begin{bmatrix} Iso \\ Isd \\ Isq \end{bmatrix} = T \begin{bmatrix} Isa \\ Isb \\ Isc \end{bmatrix} \quad (1)$$

Where,

$$T = \sqrt{\frac{2}{3}} \begin{vmatrix} \frac{1}{\sqrt{2}} & \sin(\omega t) & \cos(\omega t) \\ \frac{1}{\sqrt{2}} & \sin(\omega t - 120°) & \cos(\omega t - 120°) \\ \frac{1}{\sqrt{2}} & \sin(\omega t + 120°) & \cos(\omega t + 120°) \end{vmatrix} \quad (2)$$

The reference current is again obtained from Inverse Park's transform.

The shunt APF acts as a sinusoidal voltage source. The supply voltage is sensed and then it is transformed into d-q-0 frame of reference by the following transformation matrix:-

$$\begin{bmatrix} Vso \\ Vsd \\ Vsq \end{bmatrix} = T \begin{bmatrix} Vsa \\ Vsb \\ Vsc \end{bmatrix} \quad (3)$$

Both the measured and reference source current are compared now and are synthesized using PI controller for getting the gating signals for operation of shunt and series APF in the given UPQC model and thereby eliminating all the current related problem from the system.

IV. CONCLUSION

This paper presents the review on architectural design of UPQC. A brief overview on system design classification and various control techniques available in literature is presented.

The UPQC is generally installed at distribution side in the point of common coupling of consumer and distribution system. The main advantage of UPQC is that it can simultaneously control system voltage and can mitigate load current harmonics maintaining approximately sinusoidal voltage and current waveform. UPQC is the most commonly used hybrid filter designed using series as well as shunt controller hence voltage and current can be controlled simultaneously. UPQC is capable of resolving various PQ issues by customizing its design hence it is most popular among various distribution side controller.

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