Review of Dual UPQC Control Techniques for Power Quality Improvement

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Abstract- This paper presents a review of Different control technique for a dual three-phase topology of a unified power quality conditioner—iUPQC. The iUPQC is integration of two active filters, a series active filter and a shunt active filter (parallel active filter), used to minimize harmonics and unbalances. In iUPQC there is no need of coordinate transformation this reduces the complex calculation. The iUPQC system can able to compensate the nonlinear load condition and also protect the sinusoidal voltage for the load in all three phases. Different from a conventional UPQC, the iUPQC has the shunt filter controlled as a sinusoidal voltage source and the series filter controlled as a sinusoidal current source.

Out of the number of facts controller the Dual Unified Power Quality conditioner has best custom device to improving the power quality problems. In this paper different control technique for a dual UPQC is discussed.

Index Terms— Dual Unified Power Quality Conditioner (iUPQC), Active power filter (APF), active and reactive power control, unified power quality conditioner (UPQC), control strategies.

1.INTRODUCTION

The usage of power quality conditioners in the distribution system network has increased during the few years due to the steady increase of nonlinear loads connected to the electrical power system grid. The current drawn by nonlinear loads has a high harmonic content, distorting the voltage at the utility grid and therefore affecting the operation of critical loads. The main issues of a poor power quality are poor power factor, supply voltage variation harmonic currents. The UPQC has the capability of improving power quality at the point of fitting on power distribution system. By using a unified power quality conditioner (UPQC), it is possible to protect a regulated voltage for the loads, balanced and with low harmonic distortion and at the same time draining precise currents from the utility grid, even if the grid voltage and the load current have harmonic contents. The UPQC is a custom devise consists of two active filters, the series active filter (SAF) and the shunt active filter (PAF) [1], [2]. The PAF is generally controlled as a non-sinusoidal current source, which is responsible for balancing the harmonic current of the load, while the SAF is controlled as a non-sinusoidal voltage source, which is responsible for balancing the grid voltage. Both of them have a control reference with harmonic contents, and usually, these references might be produce through complex methods.

The conventional UPQC has the following drawbacks: complicated harmonic extraction of the grid voltage and the load involving complex calculations, voltage and current references with harmonic contents necessitate a high bandwidth control, and the leakage inductance of the series connection transformer affecting the voltage overcome generated by the series filter.

In order to minimize these drawbacks, the iUPQC is investigated. The scheme of the iUPQC is very similar to the conventional UPQC, using an association of the SAF and PAF, deviate only from the way the series and shunt filters are controlled. In the iUPQC, The PAF works as a voltage source imposing sinusoidal load voltage synchronized with the grid voltage, the SAF works as a current source, which imposes a sinusoidal input current synchronized with the grid voltage. In this way, the iUPQC control uses sinusoidal references for both active filters. This is a major point to observe related to the simple topology since the only request of sinusoidal reference generation is that it must be synchronized with the grid voltage. The SAF serve as high impedance for the current harmonics and indirectly compensates the harmonics, unbalances, and disturbances of the power system grid voltage since the connection transformer voltages are equal to the difference between the power system grid voltage and the load voltage. In the same way, the PAF indirectly compensates the unbalances, displacement, and harmonics of the power system grid current, providing a low impedance path for the harmonic load current.

Due to increasing complexity in the power system, power quality problems are most valuable problems. Such as harmonics, sag, swell, poor voltage regulations, load unbalancing and poor power factor, supply voltage variations, etc. To minimize power quality problems we use various equipment’s such as active filter and passive filter,
unified power flow controller and unified power quality conditioner. The UPQC is one of the major custom power solutions capable of overcoming the effect supply voltage sags at the point of common coupling (PCC) or load. A UPQC use a control method in which the series compensator injects a voltage that leads the supply current by 90°. So that the series compensator at steady state consumes no active power. However, the UPQC has some disadvantages. First, there is restriction in rating when using upqc for series compensation.

Control strategy plays an important role in the total performance of the power conditioner. Rapid detection of disturbance signal with high accuracy, fast treatment of the reference signal and high dynamic response of the controller are the prime requirements for desired composition. Generation of appropriate switching.

II. DUAL UPQC

The conventional UPQC structure is composed of a SAF and a PAF, as shown in Fig. 1. In this composition, the SAF works as a voltage source in order to compensate the unbalances, and disturbances, grid distortion like sags, swells, and flicker. Therefore, the voltage compensated by the SAF is combination of a fundamental content and the harmonics. The PAF works as a current source and it is responsible for compensating the displacement, and harmonics, unbalances of the load current, ensuring a sinusoidal grid current. The series filter connection to the utility power grid is made through a transformer, while the shunt filter is usually connected in series directly to the load, mainly in low-voltage grid applications. The conventional UPQC has the following drawbacks: complex harmonic separation of the grid voltage and the load involving complex calculations, voltage and current references with harmonic contents necessity a high bandwidth control, and the leakage inductance of the series connection transformer affecting the voltage mitigation generated by the series filter. In order to minimize these drawbacks, the iUPQC is inspected in this paper, and its scheme is shown in Fig. 2.

The scheme of the iUPQC is very similar to the conventional UPQC, using an association of the SAF and PAF, diverging only from the way the shunt and series filters are controlled. In the iUPQC, the SAF works as a current source, which introduce a sinusoidal input current synchronized with the grid voltage. The PAF works as a voltage source striking sinusoidal load Voltage synchronized with the grid voltage. In this way, the iUPQC control uses sinusoidal references for the two active filters. This is a primary point to observe related to the classic topology since the only required sinusoidal reference generation is that it must be synchronized with the grid voltage. The SAF acts as high impedance for the current harmonics and indirectly minimize the harmonics, unbalances, and disturbances of the grid voltage since the connection transformer voltages are equal to the difference between the grid voltage and the load voltage. In the same way, the PAF indirectly compensates the unbalances, displacement, and harmonics of the grid current, providing a low-impedance direction for the harmonic load current.

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**Fig. 1. Conventional UPQC.**

**Fig. 2. Dual UPQC (iUPQC).**

**Fig. 3. Complete structure of an IUPQC.**
Let us assume that the VSC-1 is connected in shunt to Feeder-1 while the VSC-2 is connected in series with Feeder-2. Each of the two VSCs is accomplishing by three H-bridge inverters [10], [11]. The schematic structure of a VSC is shown in Fig. 4. In this, each switch represents a power semiconductor device (e.g., IGBT) and an anti-parallel diode as shown in Fig. 5. All the inverters are supplied from a common single dc capacitor and both inverters has a transformer connected at its output. The complete structure of a three-phase IUPQC with two such VSCs is shown in Fig. 3. The secondary sides of the shunt-connected transformers (VSC-1) are connected in star with the neutral point being connected to the load neutral. The secondary winding of the series-connected transformers (VSC-2) are connected in series with the bus B-2 and load L-2. The ac filter capacitors and are also connected in each phase (Fig. 3) to avoid the flow of the harmonic currents generated due to switching. The six inverters of the IUPQC are controlled individually. The switching action is obtained using output feedback control.

An IUPQC connected to a distribution system is shown in Fig. 6. In this figure, the feeder impedances are denoted by the pairs. It can be seen that the two feeders supply the loads L-1 and L-2. The load L-1 is simulated to have two separate components—an unbalanced part (L-11) and a non-linear part (L-12). The currents peaked by these two loads are denoted by \( i_{L1} \) and \( i_{L2} \) respectively. We further consider that the load L-2 is a sensitive load that requires uninterrupted and regulated voltage. The shunt VSC (VSC-1) is connected to bus B-1 at the end of Feeder-1, and the series VSC (VSC-2) is connected at bus B-2 at the end of Feeder-2.

**IV. CONTROL STRATEGY**

Control strategy plays the most significant role in any power Electronics based system. It is the control strategy which decides the performance and desired operation of a particular system. The effectiveness of a iUPQC system solely depends upon its control algorithm. Which decides the switching instant of inverter switches.

1) **FUSSY CONTROL**

In this PI, ANN, FUSSY controllers used for shunt filter for generating reference current signals. PI controller is closed loop system. In view of this controller the Vdc is sensed at the regular intervals and compared with the Vdc. The error signal is proceeds to PI controller and the output of controller is denoted by \( I_{sp}(n) \). FUSSY controller is adaptive nature and vigorous performance in cases of parameters variation controller is present. In FUSSY the PI controller is mixed with the intelligent and adaptive of fussy based controller. In ANN controller the units are skilled to perform particular function by adjusting values of elements and uses LMVB (Levenberg Marquardt Back Propagation) algorithm. For series control direct
and indirect methods are used for generating reference signals [2].

2) VERSATILE CONTROL STRATEGY

These proposed control schemes gives better response under dynamic and steady state. The control system for shunt active filters uses hysteresis control for shunt filter applications. These hysteresis controls is simple to model and boost the speed and response of system. The control scheme for series active filter uses Two UPQC items are defined in depending on the angle of the injected voltage. Those are UPQC-P and UPQC-Q. In UPQC-Q the injected voltage is maintained 90 degrees with respect to the supply current. This is the reason that the series compensator absorbs no active power in steady state. In UPQC-P the injected voltage is in phase with both the supply current and voltage so that the series compensator consumes only the active power, which is delivered by the shunt compensator through the dc link. The UPQC-P algorithm is easy to implement and with this algorithm the voltage rating of series filter is reduced. UPQC-Q is not work in case of load is purely resistive nature. The enhanced steady state and dynamic performance of UPQC is due to this versatile control strategy using average dc voltage regulation, hysteresis controller based current tracking for shunt active filter and PWM controlled series active filter. The performance of the UPQC is compared with DVR and DSTATCOM [8].

3) P-Q-R INSTANTANEOUS POWER THEORY

This method provides an analysis and control algorithm for a three phase four-wire Unified Power Quality Conditioner (UPQC) based on p-q-r instantaneous power theory. The p-q-r theory transforms a three phase four-wire voltage space vector into a single de voltage and the corresponding currents into a de based active power p-axis component and two imaginary power components, q-axis and r-axis.

If there are harmonics and negative sequence exists in the voltage, the calculated reference current is not sinusoidal. In this method an extra q-axis component is used to add to the original current compensation strategy based on p-q-r theory to maintain a sinusoidal current waveform under distorted voltage. With p-q-r theory, a control block model of an integration feedback of de power is used to maintain the average de power to be zero. The analysis of the effect of sampling and quantization error on detection of de storage voltage, minimization of looping active power and loss power in the UPQC system and the consideration of power flow at the source side can be completed in the future work.

4) SWITCHING CONTROL METHOD

In this method six single phase H-bridge inverters are used in the structure of UPQC connected to a common dc storage capacitor. Of these six inverters three of them are used for series voltage insertion and the other three are used for shunt current injection. The UPQC current and voltage references are generated based on Fourier series extraction of fundamental sequence components using half cycle running (moving) averaging. They also propose a Linear Quadratic Regulator based switching controller scheme that tracks a reference using the proposed compensator. This method is suitable for both utilities and customers having sensitive loads. From the utility standpoint, it can make the current drawn balanced sinusoidal. To accomplish this, the voltage at the point of common coupling must be of similar nature and also must contain the same amount of harmonics as the source. From the customer point of view, the UPQC can provide balanced voltages to their equipment that are sensitive to Voltage dips. At the same time, the UPQC also filters out the current harmonics of the load. Therefore, the operation of UPQC is ideal from both viewpoints.

5) SYNCHRONOUS ‘D-Q’ REFERENCE BASE THEORY

This algorithm relies on the Parks transformation where three-phase voltage and current signals are transformed to a synchronously rotating frame. The active and reactive components of the system are represented by the direct and quadrate component, respectively. In this approach, fundamental quantities become d-q quantities which can be separated easily through filtering. To implement the synchronous reference frame some kind of synchronizing system PLL should be used.

The system is very stable since the controller deals mainly with the d-q quantities. The computation is instantaneous but incurs time delays in filtering the d-q quantities. This method is applicable only for three-phase systems. The modified synchronous reference frame, named as ‘instantaneous id-iq method’ is also proposed. This method is similar to synchronous reference frame method Except that the transformation angle is obtained from the voltage X- components. The speed referential is no longer constant but it varies instantaneously depending on the waveform of the three-phase voltage system. In this method, no synchronizing circuit is needed.
6) **SPWM BASED CONTROL**

SPWM controller is used to operate the voltage source inverter in such a way that the difference between the inverter voltage and the line voltage is widely adjusted so that the shunt APF generates or absorbs reactive power. The measured three phase voltages are fed to PLL to detect the phase angle of voltages. The measured voltage is passed through a first order low pass filter to attenuate voltage transients. This signal is then compared with a reference voltage and the voltage error is fed to the lag lead function block, the output of which is fed to a PI controller. The output of PI controller is the angle representing the shift between the system voltage and the shunt inverter voltage required to adjust the voltage of the dc link capacitor. This angle combined with the signal from PLL becomes the voltage modulating signal. The phase angle from the PLL is multiplied by a carrier, whose frequency is 33 times the operating frequency to generate the triangular signal whose amplitude is fixed between the extremities of unity. The triangular carrier is compared with the voltage modulating signal so as to obtain the firing pulses for the shunt APF.

V. CONCLUSION

After this review we realized that different control technique are promising solution for reference current and voltage signal generation for series active filter and shunt active power filter. The Dual UPQC is one of custom power device to compensate supply voltage power quality problems such as sags, swells, unbalance, flicker, and harmonics and for load current power quality problems such as harmonics, unbalance, reactive current etc.

REFERENCES