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Control Algorithm for Three-Phase, Four-Wire Unified Power Quality Conditioner

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Abstract

A simplified control algorithm for a three-phase, four-wire unified power quality conditioner (UPQC) is presented to compensate for supply voltage distortions/unbalance, supply current harmonics, the supply neutral current, the reactive power and the load unbalance as well as to maintain zero voltage regulation (ZVR) at the point of common coupling (PCC). The UPQC is realized by the integration of series and shunt active filters (AFs) sharing a common dc bus capacitor. The shunt AF is realized using a three-phase, four leg voltage source inverter (VSI) and the series AF is realized using a three-phase, three leg VSI. A dynamic model of the UPQC is developed in the MATLAB/SIMULINK environment and the simulation results demonstrating the power quality improvement in the system are presented for different supply and load conditions.

Keywords: Active Filter, Harmonics, Reactive Power, Unbalance, UPQC, Voltage Regulation

I. INTRODUCTION

The main objective of electric utility companies is to supply their customers with uninterrupted sinusoidal voltage of constant magnitude. However this is becoming increasingly difficult to do, because the size and number of non-linear and poor power factor loads such as adjustable speed drives, computer power supplies, furnaces and traction drives are increasing rapidly. Due to their nonlinear nature, these solid state converters cause excessive neutral currents in three phase four wire systems. Moreover, in the case of the distribution system, the overall load on the system is seldom found to be balanced. In the past, the solutions to mitigate these identified power quality problems [1] were through using conventional passive filters. But their limitations such as, fixed compensation, resonance with source impedance and the difficulty in tuning time dependence of filter parameters have ignited the need for active and hybrid filters [2]–[4]. The rating of active filters is reduced through augmenting them with passive filters [5], [6] to form hybrid filters, which reduce overall cost. Also they can provide better compensation than either passive or active filters. If one can afford the cost, then a hybrid of two active filters provides the best solution and thus it is known as a unified power quality conditioner (UPQC) or universal active filter. Presents a 3-phase, 4-wire UPQC configuration suitable for power distribution systems and a simple control algorithm for its control. The series AF is controlled to maintain voltage regulation and to eliminate supply voltage sag/swell, harmonics and unbalance from the load terminal voltage. The shunt AF is controlled to alleviate the supply current from harmonics, negative sequence current, reactive power and neutral current. The dc bus voltage is held constant by the shunt active filter. The performance of the proposed system is demonstrated through simulated waveforms and the harmonic spectra of supply currents and load voltages with and without UPQC. UPQC consists of two IGBT based VSC, one shunt and one series cascaded by a common DC bus. 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 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 is used to interface the shunt inverter to the network. It also helps in smoothing the current wave shape. 3) A common dc link that can be formed by using a capacitor or an inductor. 4) An LC filter that serves as a passive low-pass filter 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. 6) The integrated controller of the series and shunt APF of the UPQC to provide the compensating voltage reference Vc and compensating current reference Ic.

II CONTROL SCHEME OF SERIES FILTER

A simple algorithm is developed to control the series and shunt filters. The series filter is controlled such that it injects voltages (vca; vcb; vcc), which cancel out the distortions and/or unbalance present in the supply voltages (vsa; vsb; vsc), thus making the voltages at the PCC (vla; vlb; vlc) perfectly balanced and sinusoidal with the desired amplitude. In other words, the sum of the supply voltage and the injected series filter voltage makes the desired voltage at the load terminals.

CONTROL SCHEME OF SHUNT FILTER

The control algorithm for a shunt AF consists of the generation of 3-phase reference supply currents and it is depicted in Fig. 3. This algorithm uses supply in-phase, 120_ displaced three unit vectors computed using eqn. (1). The amplitude of the reference supply current (I_ sp) is computed as follows. A comparison of the average and the reference values of the dc bus voltage for the shunt AF results in a voltage error, which is fed to a proportional integral (PI) controller and the output of the PI controller is taken as the reference amplitude of the supply currents. The three in-phase reference supply currents are computed by multiplying their amplitude (I_ sp) and in phase unit current vectors

SRF Control Technique

In the SRF-based APF applications in three-phase four wire (3P4W) systems, voltage and current signals are transformed into the conventional rotating frame (d−q−0). In the SRF method, the transformation angle (ωt) represents the angular position of the reference frame which is rotating at a constant speed in synchronism with the three-phase ac voltage.

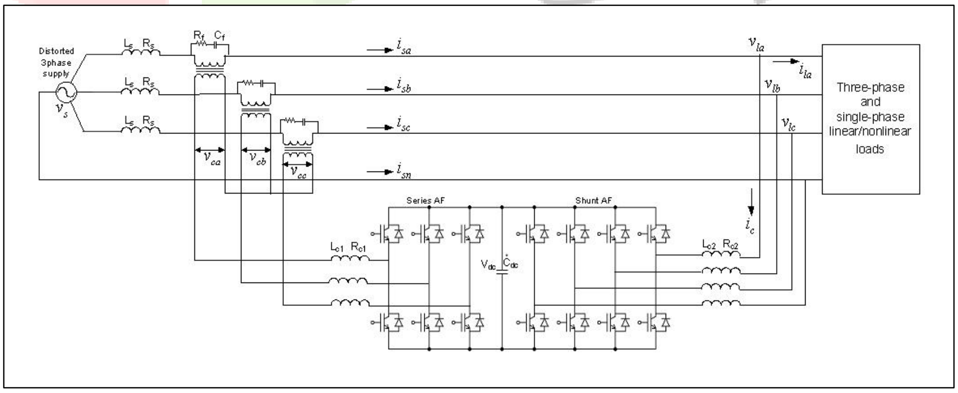
III. OBJECTIVES

1. Series inverter - The inverters connected in series to the supply known as the series active filter. This inverter behaves as a voltage source line which eliminates a voltage interruption.
2. Shunt inverter - The inverter connected in shunt to the supply line is known as shunt active filter. It eliminates the current related harmonics also minimize the reactive current in the load circuit.
3. DC link - The capacitor or inductor can be used as common DC link. the capacitor is used as DC link, which supplies the DC voltage.
4. LC filter - The output of the series active filter produces high switching ripples. The LC filter minimizes the ripples in a system. The LC filter acts as the low-pass filter.
5. Lsh Filter - The Lsh filter act as a high-pass filter. The ripples during switching mode are minimized by Lsh filter.
6. Injection transformer - The series injection transformer connected to series convertor.

IV. PROPOSED METHODOLOGY

Generally, a 3P4W distribution system is realized by providing a neutral conductor along with three power conductors from generation station or by utilizing a three-phase Δ–Y trans- former at distribution level. Fig. 1 shows a 3P4W network in which the neutral conductor is provided from the generating station itself, whereas Fig. shows a 3P4W distribution network considering a Δ–Y transformer.

Proposed System Design



Assume a plant site where three-phase three-wire UPQC is already installed to protect a sensitive load and to restrict any entry of distortion from load side toward utility, as shown in Fig. 3. If we want to upgrade the system now from 3P3W to 3P4W due to installation of some single-phase loads and if the distribution transformer is close to the plant under consideration, utility would provide the neutral conductor from this transformer without major cost involvement. In certain cases, this may be a costly solution because the distribution transformer may not be situated in close vicinity. Recently, the utility service providers are putting more and more restrictions on current total harmonic distortion (THD) limits, drawn by nonlinear loads, to control the power distribution system harmonic pollution. At the same time, the use of sophisticated equipment/load has increased significantly, and it needs clean power for its proper operation. Therefore, in future distribution systems and the plant/load centers, application of UPQC would be common the proposed novel 3P4W topology that can be realized from a 3P3W system. This proposed system has all the advantages of general UPQC, in addition to easy expansion of 3P3W system to 3P4W system. Thus, the proposed topology may play an important role in the future 3P4W distribution system for more advanced UPQC- based plant/load center installation, where utilities would be having an additional option to realize a 3P4W system just by providing a 3P3W supply. As shown in Fig. 3, the UPQC should necessarily consist of three-phase series transformer in order to connect one of the inverters in the series with the line to function as a controlled voltage source. If we could use the neutral of three-phase series transformer to connect a neutral wire to realize the 3P4W system, then 3P4W system can easily be achieved from a 3P3W system (Fig. 4). The neutral current, present if any, would flow through this fourth wire toward transformer neutral point. This neutral current can be compensated by using a split capacitor topology [2], [9], [10] or a four-leg voltage-source inverter (VSI) topology for a shunt inverter [2], [11]. The four-leg VSI topology requires one additional leg as compared to the split capacitor topology. The neutral current compensation in the four-leg VSI structure is much easier than that of the split capacitor because the split capacitor topology essentially needs two capacitors and an extra control loop to maintain a zero voltage error difference between both the capacitor voltages, resulting in a more complex control loop to maintain the dc bus voltage at constant level. In this paper, the four-leg VSI topology is considered to compensate the neutral current flowing toward the transformer neutral point. A fourth leg is added on the existing 3P3W UPQC, such that the transformer neutral point will be at virtual zero potential. Thus, the proposed structure would help to realize a 3P4W system from a 3P3W system at distribution load end. This would eventually result in easy expansion from 3P3W to 3P4W systems. A new control strategy to generate balanced reference source currents under unbalanced load condition is also proposed in this paper and is explained in the next section.

V. CONCLUSION

This paper resents a review of UPQC for improving the quality of electric power. Now after overall review of UPQC, the Distributed generation integrated with UPQC is main concern. In this UPQC is one of the devices, which eliminates the voltage and current harmonics simultaneously. Different configurations of UPQC are briefly discussed in this paper.The control algorithm for the UPQC is evaluated by using MATLAB/Simulink software under combination of linear and nonlinear load conditions. The simulation results for the proposed three phase four wire system realized from a three phase three wire system utilizing UPQC

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