PERFORMANCE ANALYSIS OF THREE-PHASE THREE-WIRE VOLTAGE SOURCE INVERTER BASED UNIFIED POWER QUALITY CONDITIONER

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Abstract- The performance analysis of three phase three wire voltage source inverter based unified power quality conditioner (UPQC) with a control configuration is implemented in this paper. UPQC is utilized for power quality improvement at distribution level. The operation of UPQC combines the operations of series component Dynamic Voltage Restorer (DVR) and shunt component Distribution Static Compensator (DSTATCOM) together. The series component of the UPQC inserts voltage so as to maintain the voltage at the point of common coupling balanced and free of distortion. Simultaneously, the shunt component of the UPQC injects current into the system such that the currents entering the bus to which the UPQC is connected are balanced sinusoids. Both these objectives must be met irrespective of unbalance or distortion in either source or load sides. When UPQC is used in a power distribution system, the series and shunt active filters of the UPQC are made to operate in an effective and efficient unified manner. The control strategy should be able to reduce the negative effects of the variations in distorted supply voltage and the nonlinear load current. The control signals, generated by the various functional modules of the control design circuit Discrete Proportional IntegralController. Phase Locked Loop and Discrete Pulse Width Modulation Generator, will be the switching schemes for the series and shunt active filters of the UPQC to provide simultaneous shunt and series compensation in a power distribution system. The validation of performance analysis of three phase three wire voltage source inverter based unified power quality conditioner is verified through simulation inMatlab.

Keywords- Compensation, Distribution Static Compensator, Dynamic Voltage Restorer and Unified Power quality Conditioner.

I. INTRODUCTION

With increasing applications of nonlinear power electronics loads and electronically switched devices in distribution systems and industries, power quality problems which include harmonics, flickering and imbalance have become a serious concern. These adverse effects pose a major problem to both the utilities and consumers. For proper operation of sensitive loads, a pure sinusoidal supply voltage is required. In order to meet power quality standard limits, it may be necessary to include some sort of compensation. Power quality is the set of limits of electrical properties that allows electricalsystems to function in their intended manner without significant loss of performance. It describes the electric power that drives an electrical load and the ability of load to function properly with that electric power. Without proper power, an electrical device (or load) may malfunction, fail prematurely or not operate at all. The application of FACTS concepts in distribution systems has resulted in a compensating device as a unified power-quality conditioner (UPQC), which is the extension of the unified power-flow controller (UPFC) concept at the distribution level. UPQC consists of combined series and shunt converters for simultaneous compensation of voltage and current imperfections in a supply feeder. The main purpose of a unified power quality conditioner (UPQC) is to provide compensation for supply voltage and load current power quality issues like sags, swells, unbalance, flicker, harmonics, reactive current and neutral current. The general block diagram representation of UPQC with main components is shown in Fig.1. The single line representation is of a Voltage Source Inverter (VSI) based UPQC system configuration. The advantages of Voltage Source Inverter (VSI) topology over Current Source Inverter (CSI) topology are light weight, no necessity of blocking diodes, reduced cost, multi-level operation capability and overall control flexibility. Shunt inverter is operated as Controlled Current Source and the series inverter as Controlled Voltage Source.

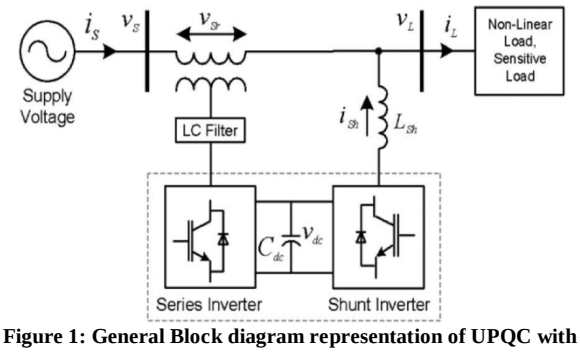


Figure 1: General Block diagram representation of UPQC with its main components.

II. PRINCIPLE OF UPQC

In principle, UPQC is an integration of shunt and series active power filters with a common self-supporting dc bus. The main parameters that contribute for classification of UPQC are type of energy storage device used, number of phases and

physical location of shunt and series inverters. Control strategy decides the behavior and desired operation of a particular system. The effectiveness of a UPQC system solely depends upon its control algorithm as it governs the shunt inverter in current control mode such that it delivers a current which is equal to the set value of the reference current. 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. 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, distortion less desired magnitude of voltage at the load terminal. The UPQC control strategy determines the reference signals (current and voltage), decides the switching instants of inverter switches and achievement of desired performance. Unified power quality conditioner is one of the devices that are able to resolve the power quality problems of supply voltage and load current, sags/swells in the supply voltage, variations in the load demands and poor power factor at the supply side. UPQC has to be capable of harmonics compensation in the supply voltage and load current, compensation of sags and swells in the supply voltage, power factor correction at the supply side and adaptive to the supply and load demand variations. The important task to be performed by the UPQC is to produce ideal source current and load voltage sine waves at a fundamental frequency of 50 Hz without any harmonic distortions, even though harmonics may exist in source voltage and load current. A coordinated control is applied to operate the series and shunt active filters of the UPQC in a unified manner more effectively and efficiently. Any control strategy chosen for UPQC must be able to minimize the negative effects of the variations in distorted supply voltage and nonlinear load current. The sizing for the kVA capacity of the UPQC will depend on the functionalities of the UPQC. The kVA capacities of the series and shunt active filters of the UPQC with similar functionalities are 7.5% and 2.5%, respectively, of the load capacity.

III. CONFIGURATION OF UPQC BY SIMULTANEOUS CONTROL OF DVR AND DSTATCOM

UPQC is a custom power device that consists of shunt and series converters connected back to back on the dc side and deals with load current and supply-voltage imperfections. The custom power concept incorporates power electronics controllers and switching equipment, one or more of which can be used to provide a value-added service to the customers. Custom Power pertains to the use of power electronics controllers in a distribution system to deal with various power quality problems. It makes sure that customers get pre-specified quality and reliability of power supply. The series part of the UPQC is known as dynamic voltage restorer (DVR) used to maintain balanced, distortion free nominal voltage at the load. The shunt part of the UPQC is known as distribution static compensator (DSTATCOM), and it is used to compensate load reactive power, harmonics and balance the load currents thereby making the source current balanced and distortion free with unity power factor.

The main purpose of a UPQC is to compensate for supply voltage flicker/imbalance, reactive power, negative-sequence current, and harmonics. In case of sag and swell in the power system, Dynamic Voltage Restorer (DVR) provides series compensation by voltage injection. The Distribution Static Compensator (D-STATCOM) provides continuously variable shunt compensation by current injection. This eliminates fluctuations in voltage. Unified Power Quality Conditioner (UPQC) eliminates the harmonics in the supply current 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 eliminating the necessity of additional power factor correction equipment. UPQC maintains load end voltage at the rated value even in the presence of supply voltage variations. The UPQC consists of two three phase inverters which are series and shunt inverters connected in cascade. The series inverter is connected in series with the supply voltage through a transformer. The shunt inverter is connected in parallel with the load. The main purpose of the shunt compensator is to compensate for the reactive power demanded by the load, to eliminate the harmonics and for regulation of common dc link voltage. The series compensator is operated in PWM voltage controlled mode. It injects voltage in quadrature advance to the supply voltage (current) such that the load end voltage is always maintained at the desired value. The two inverters operate in a coordinated manner. The operation of a UPQC that combines the operations of a Distribution Static Compensator (D-STATCOM) and Dynamic Voltage Restorer (DVR) together.

A. Choice of variables related to UPQC

The choice of the various variable quantities related to the UPQC are listed in Table 1. The outputs of UPQC are to be maintained as pure sine waves of 50Hz, as well as help in achieving a unity power factor at the supply side.

Table 1: Choice of variables related to the UPQC

Quantity	Description relevant to the UPQC
Supply voltage and Load current	Inputs developed based on external factors which act like disturbances to the UPQC
Load voltage and Supply current	Outputs of the UPQC

Control inputs which are modulated to become switching signals for the VSIs of series and shunt active filters of the UPQC	Compensation is provided for supply voltage and load current

The control design to be formulated, with the signals as listed in Table 2, aims to make the output of UPQC track a reference, under a periodic disturbance. Generally, the reference signals assigned for load voltage and supply current are pure sine waves of 50 Hz without any harmonic distortions.

Table 2: Various signals with their description

Signals	Description
Periodic disturbance signal	Supply voltage and Load current
Reference signal to be tracked	Pure sine waves of 50 Hz without any harmonic distortions assigned for load voltage and supply current
Output signal of the UPQC	Load voltage and Supply current

B. Control Design Configuration

Any control configuration can be designed for UPQC by utilizing a model of the reference and disturbance signals which can result in zero steady-state error. UPQC is treated as a two-input-two-output system to deal with the coupling effect between the series and shunt active power filters of the UPQC. As the UPQC includes the series and shunt active filters a single-phase injecting transformer is needed for interfacing the output of the series active filter with the distribution system.

IV. PERFORMANCE ANALYSIS OF UPQC

The rapid detection of the disturbance signal with high accuracy, fast processing of the reference signal, and high dynamic response of the controller are the prime requirements for desired compensation. Fig. 3 shows three-phase three-wire(3P3W) VSI-based UPQC system configuration to compensate the power quality problems in three-phase three-wire (3P 3W) supply system fed to three-phase loads consisting of series and shunt inverters (total of nine semiconductor switches). The representation of the VSI-based 3P 3W UPQC topology is assigned from the classification based on the physical structure used to tackle the power quality problems in a system under consideration and the number of phases of the supply.

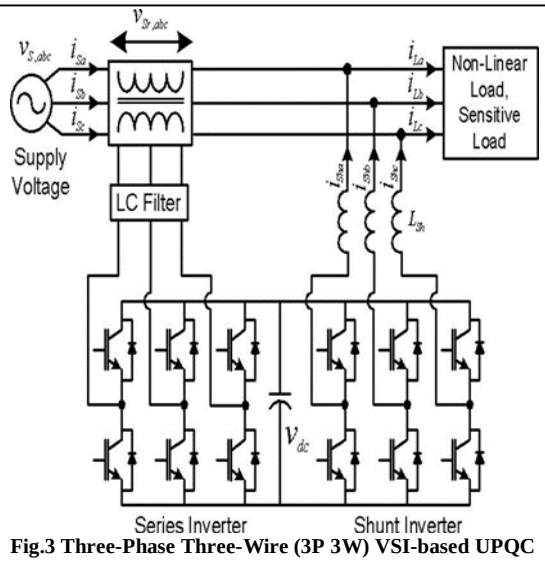


Fig.3 Three-Phase Three-Wire (3P 3W) VSI-based UPQC system configuration

In the simulation process, the Phase Locked Loop (PLL) system can be used to synchronize on a set of variable frequency, three-phase sinusoidal signals. Discrete Pulse Width Modulation (PWM) Generator generates pulses for Carrier based Pulse Width Modulation. The carrier frequency of the switching devices is 12000 Hz. The generator mode is taken as a 3-arm bridge (6 pulses). The common DC-link capacitor has a capacitance of 5000μF with an initial voltage of 600V across it. The Discrete ProportionalIntegral (PI) Controller is in series with the active filter. The proportional gain K_P is taken as 2 and integral gain K_i is taken as 20. Control of series part of UPQC is based on discrete PI Controller and control of shunt part of UPQC is based on discrete PLL and discrete PWM Generator.In order to validate the performance of 3P 3W VSI based UPQC, the block diagram configuration shown in Fig.4 is simulated in Matlab/ Simulink environment. The primary condition for reactive power compensation is that the magnitude of reference dc-bus capacitor voltage should be higher than the peak voltage at the point of common coupling (PCC). Voltage rating of dc-link capacitor largely influences the compensation performance of an active filter. The various quantities that are used in modeling of 3P 3W VSI-based UPQC system configuration depicted in Fig.3 are listed in Table 3.

Table 3: List of quantities

Symbol	Quantity that is modeled
v_{sabc}	Supply Voltage
i_{sabc}	Supply Current
v_{srabc}	Injected Voltage of the Series Active Filter
i_{shabc}	Injected Current of the Shunt Active Filter
i_{Labc}	Load current
V_{dc}	Common DC Link Voltage across Capacitor

For the simulation to be carried out the system rms voltagein the system parameters is taken as 380V (phase to phase) at a frequency of 50Hz. The simulation results for the UPQC configuration based on VSI topology with the combination of linear and non-linear loads are shown in Figures 5 to 10.

V. SIMULATION RESULTS

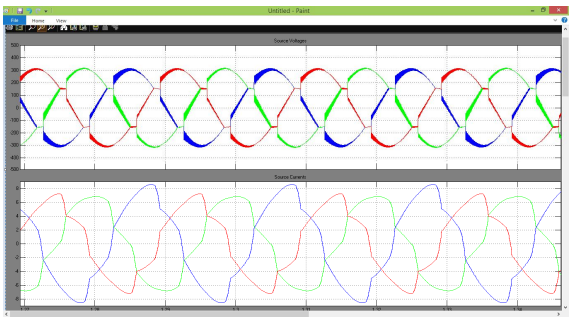


Fig.5. Source voltage and Source current withoutproviding any compensation

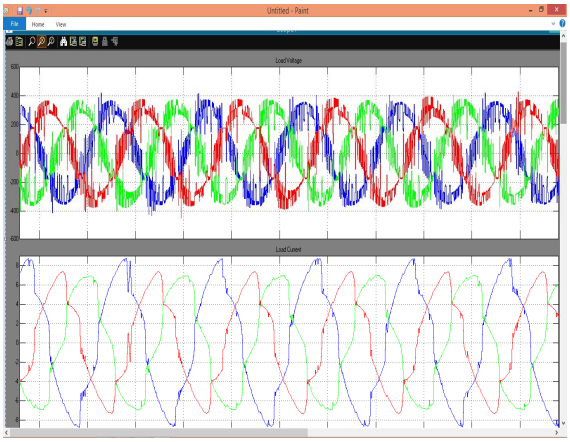


Fig.6 Load voltage and Load current withoutproviding any compensation

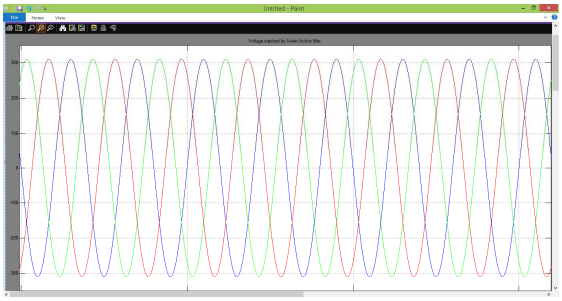


Fig.7. Voltage injected by series active filter

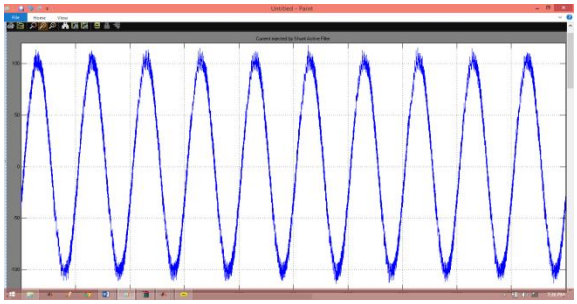


Fig.8 Current injected by shunt active filter

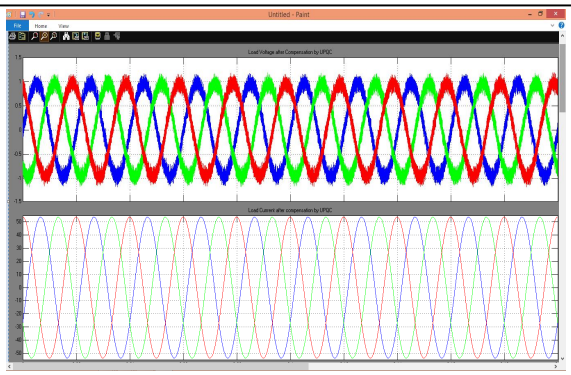


Fig.9 Source voltage and Source current after compensation by UPQC

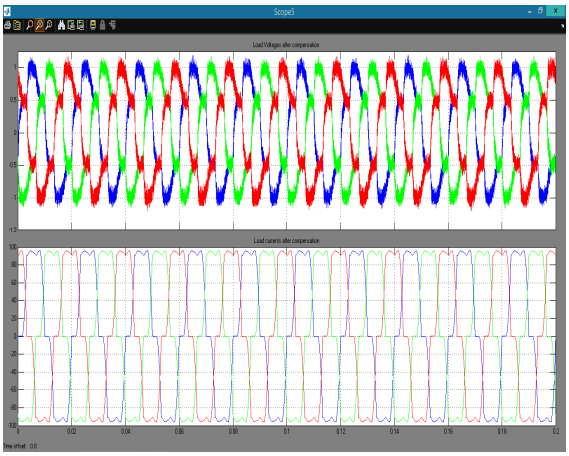


Fig.10 Load voltage and Loadcurrent after compensation by UPQC

CONCLUSION

The control techniques play an important role in the overall performance of the UPQC. The control signals are pulse width modulated to become the switching signals for the VSIs of series and shunt active filters of the UPQCto provide simultaneous shunt and series compensation in a power distribution system. The control design circuit also includes discrete proportional integral controller,phase locked looptaking into account the actual dc voltage level of the common dc link capacitor. By utilizing this control strategy, the load voltage and the supply current will be regulated to become a pure sine wave at the desired fundamental frequency of 50 Hz without any harmonic distortions.

The source currents after compensation are balanced and sinusoidal. The unbalanced and distorted load voltages are maintained to the desired voltage using series active filter. The shunt filter currents which are injected into the point of common coupling to make the source currents balanced and sinusoidal. The simultaneous performance of the shunt and series active filter of the UPQC is studied by compensating the load current and maintaining the load voltage to the desired value during any changes in voltage. The load voltages after compensation are balanced and sinusoidal. With proper shunt and series control by

using any of the various advanced control techniques the power quality problems like harmonics, reactive power, and voltage sags can be compensated with no appreciable degradation in performance. In this paper, simulation is carried out to evaluate the performance analysis of three phase (3P) three wire (3W) voltagesource inverter based unified power quality conditioner by simultaneous control of series and shunt active filters.

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