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Research Paper

A HIGH EFFICIENT UPQC USING ADAPTIVE FUZZY CONTROL FOR POWER QUALITY IMPROVEMENT

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Power quality is major concern in industries today because of enormous losses in energy and money. Voltage sags are considered to be one of the most severe disturbances to the industrial equipments. A control technique for a dual three-phase topology of a UPQC has the series filter controlled as a sinusoidal current source. The shunt filter controlled as a sinusoidal voltage source. The pulse width modulation controls of the UPQC. The conventional UPQC is controlled using non sinusoidal references. Transient stability time of sag rectification is less than 1ms. Compensation voltage source is used separate dc source or we can implement any renewable energy sources. Voltage Sag and swell is compensated, also sag reduction response time is low. The simulation result shows the effective mitigation of voltage sags in less time using MATLAB/simulink.

Keywords: Voltage Source Inverter(VSI), Fuzzy control, Voltage sag & swell, control design, power line conditioning, unified power quality conditioner (UPQC)

INTRODUCTION

Modern electric power systems are complex networks with hundreds of generating stations and thousands of load centers are interconnected through long power transmission and distribution networks. Power quality problems are associated with an extensive number of electromagnetic phenomena in power systems with broad ranges of time frames such as long duration variations, short duration variations and other disturbances. A momentary disturbance for sensitive electronic devices causes voltage reduction at load end leading to frequency deviations which results in interrupted power flow, scrambled data, unexpected plant shutdowns and equipment failure. In existing method DC-link source is from the grid supply when the fault occurs the DC-link voltage also varies so sag injection voltage is not stable. If DC-link voltage not stable means response time for voltage sags reduction is high. Due to instability of DC-link voltage harmonics level is high in ac-grid system the PWM controls of the iUPQC deal with a well-known frequency spectrum, since it is controlled using voltage and current sinusoidal references, different

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from the conventional UPQC that is controlled using non-sinusoidal references (Aredes M and Fernandes G, 2009).

Also the system was analyzed through simulations with PSCAD/EMTDC and experimental works with a scaled hardware model, assuming that the UPQC is connected with the 22.9-kV distribution line. It has flexibility in expanding the operation voltage by increasing the number of H-bridge modules (Han B *et al*., 2006). The optimized unified power-quality conditioner (UPQC), which aims at the integration of series active and shunt active power filters with minimum volt-ampere (VA) loading of the UPQC. The series active filter is a dynamic voltage restorer (DVR), which regulates the voltage at the load end with minimum VA loading of the overall UPQC by injecting the voltage at an optimum angle (Kolhatkar Y and Das S, 2007). The control of series compensator (SERC) of the UPQC is such that it injects voltage in quadrature advance to the supply current. Thus, the SERC consumes no active power at steady state. The other advantage of the proposed control scheme is that the SERC can share the lagging VAR demand of the load with the shunt compensator (SHUC) and can ease its loading. The phasor diagram, control block diagram, simulations and experimental results are presented to confirm the validity of the theory (Basu M *et al*., 2008).

This feature not only helps to share the load-reactive power demand, but also helps to reduce the shunt APF rating, and hence, the overall cost of UPQC. This results in better utilization of the existing series inverter. The iUPQC has voltage sag/swell compensation capability, with fast response, comparable to that of a dynamic voltage restorer (DVR) (Khadkikar V and Chandra A, 2008; Aredes M and Fernandes G, 2009). A phase-locked loop-less software grid synchronization method has been implemented for the effective operation of the UPQC under conditions of grid frequency variation. A sequence-based compensation strategy has been developed to compensate for balanced and unbalanced sags while accommodating the fact that the voltage injection capability of the UPQC is limited (Axente I *et al*., 2010). Another power electronic solution to the voltage regulation is the use of a dynamic voltage restorer UPQC. UPQC's are a class of custom power devices for providing reliable distribution power quality. They employ a series of voltage boost technology using solid state switches for compensating voltage sags/swells. The UPQC applications are mainly for sensitive loads that may be drastically affected by fluctuations in system voltage.

POWER QUALITY PROBLEMS

In practice, power systems, the nonlinear load at distribution end predominantly affects the quality of power supplies. While power disturbances occur on all electrical systems, the sensitivity of today's sophisticated electronic devices makes them more susceptible to the quality of power supply. Power Quality problems encompass a wide range of disturbances such as voltage sags/swells, flicker, harmonics distortion, impulse transient, and interruptions.

Voltage dip: A voltage dip is used to refer to short-term reduction in voltage of less than half a second.

Voltage sag: Voltage sags can occur at any instant of time, with amplitudes ranging from 10 – 90% and a duration lasting for half a cycle to one minute.

Voltage swell: Voltage swell is defined as an increase in rms voltage or current at the power frequency for durations from 0.5 cycles to 1 min.

Voltage 'spikes', 'impulses' or 'surges': These are terms used to describe abrupt, very brief increases in voltage value.

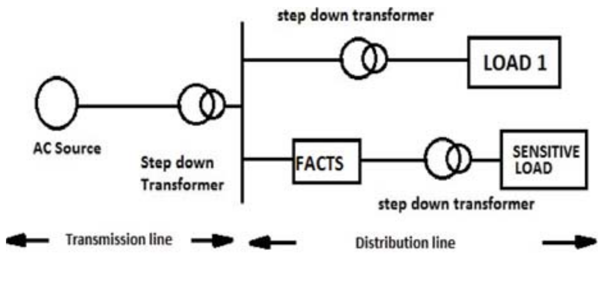
Voltage transients: They are temporary, undesirable voltages that appear on the power supply line. Transients are high over-voltage disturbances (up to 20KV) that last for a very short time.

Harmonics: The fundamental frequency of the AC electric power distribution system is 50 Hz. A harmonic frequency is any sinusoidal frequency, which is a multiple of the fundamental frequency. Harmonic frequencies can be even or odd multiples of the sinusoidal fundamental frequency.

Flickers: Visual irritation and introduction of many harmonic components in the supply power and their associated ill effects.

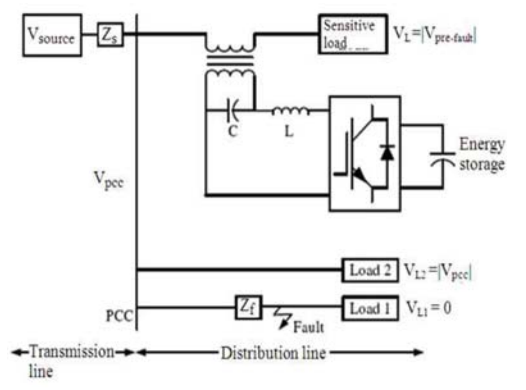
Among the power quality problems (sags, swells, harmonics…) voltage sags are the most severe disturbances. In order to overcome these problems the concept of custom power devices is introduced recently. One of those devices is the Dynamic Voltage Restorer (UPQC), which is the most efficient and effective modern custom power device used in power distribution networks. UPQC is a recently proposed series connected solid state device and is normally installed in a distribution system between the supply and the critical load feeder at the point of common coupling (PCC). It employs a series of voltage boost technology using solid (static) state switches of 3-PHASE VSC that injects voltage into the system; to restore the load side voltage for compensating voltage sags/swells. Other than voltage sags and swells compensation, UPQC can also added other features like: line voltage harmonics compensation, reduction of transients in voltage and fault current limitations.

Figure 1: Location of UPQC



When a fault occurs on the line feeding Load 1, its voltage collapses to zero. Load 2 experiences sag equals to the voltage at the PCC and the voltage of sensitive load protected by the UPQC is restored to its pre-fault value.

Figure 2: Basic structure of UPQC



Using the voltage divider model, where the voltage magnitude at the PCC is given by:

$U_{sag} = E\,[Z_f\ /(Z_s + Z_f\ )\ ]$

Zs = the source impedance including the transformer impedance

Zf = the impedance between the PCC and the fault including fault and line impedances.

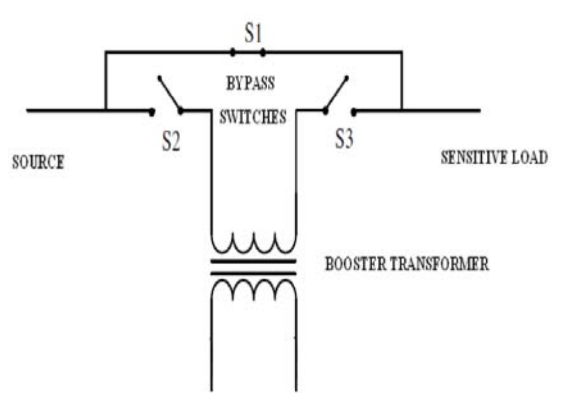
OPERATING MODES OF UPQC

The basic function of the UPQC is to inject a dynamically controlled voltage VUPQC generated by a forced commutated converter in series to the bus voltage by means of a booster transformer. The momentary amplitudes of the three injected phase voltages are controlled such as to eliminate any detrimental effects of a bus fault to the load voltage VL. This means that any differential voltages caused by transient disturbances in the ac feeder will be compensated by an equivalent voltage generated by the converter and injected on the medium voltage level through the booster transformer. The UPQC has three modes of operation which are: protection mode, standby mode, injection/boost mode.

Protection Mode: If the over current on the load side exceeds a permissible limit due to short circuit on the load or large inrush current, the UPQC will be isolated from the systems by using the bypass switches (S2 and S3 will open) and supplying another path for current (S1 will be closed).

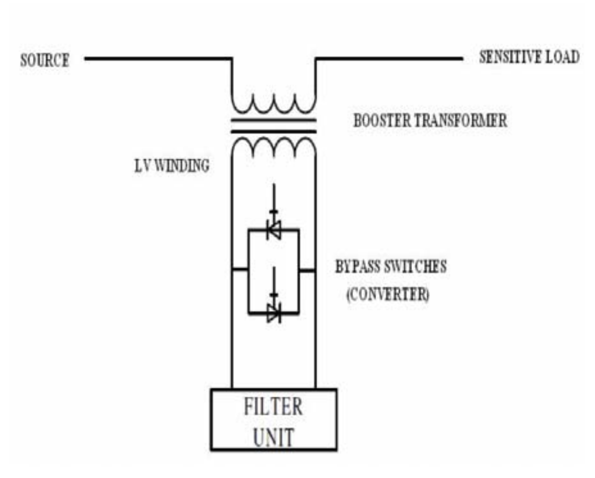
Injection/Boost Mode (V_{UPQC}*>0:* In the Injection/ Boost mode the UPQC is injecting a compensating voltage through the booster transformer due to the detection of a disturbance in the supply voltage.

Figure 3: Protection mode



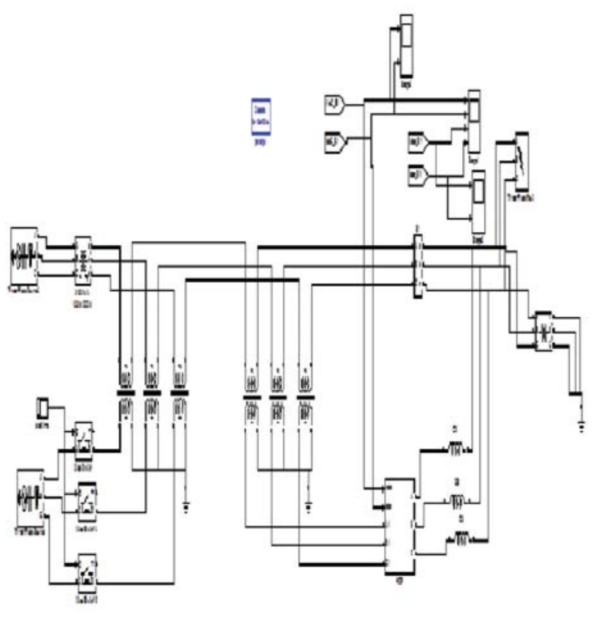
Standby Mode (V_{UPQC}*= 0):* In the standby mode the booster transformer's low voltage winding is shorted through the converter. No switching of semiconductors occurs in this mode of operation and the full load current will pass through primary.

Figure 4: Standby mode



MODEL OF UPQC CONTROLLER

Figure 5: Simulink model of UPQC controller



SIMULATION AND RESULT

Table 1: System Parameters

Sl no.	System quantities	Standards
1.	Three phase source	13KV, 50Hz.
2.	Step-up transformer	Y-Δ , 13/115KV
3.	Transmission line parameter	R=0.001 ohms,L=0.005 H
4.	Step-down transformer	Δ-Y, 115/11KV
5.	Load 1 &2	10KW, 400VAR
6.	Inverter	IGBT based,3 arms , 6 Pulse, Carrier Frequency =1080 Hz, Sample Time= 5 μs
7.	PI controller	K_p=0.5 K_i=50 Sample time=50 μs
8.	DC battery	6.5 KV
9.	C_2	750 Mf
10.	Linear/Isolation transformer	1:1 turns ratio, 11/11KV

After the MATLAB Simulation of faults in transmission line, it was observed that the voltage and current waveforms are transient. During the initial part of the short circuit, the short-circuit current was limited by sub- transient reactance of synchronous machine & impedance of the transmission line between the machine and the point of fault. After that it was limited by transient reactance of synchronous machine and impedance of line.

Finally, the short-circuit current settled down to steady state limited by synchronous reactance of the machine and line impedance. The negative and zero sequence components were present initially only and disappeared after the circuit breaker cleared the fault.

There are six modes of operation in a cycle and the duration of each mode is 60 degree. The gating signals are shifted from each other by 60 degree to obtain three-phase balanced (fundamental) voltages. Figure 5.4.1 is simulated in MATLAB and sinusoidal phase-ground voltages are obtained.

Figure 6: Phase -phase, three-phase and p.u. voltages at load point

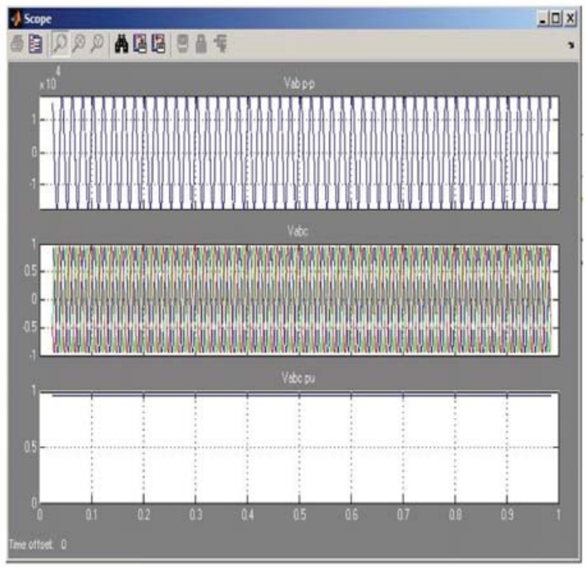


Figure 7: Phase -phase, three-phase and p.u. voltages at load point for a-g fault

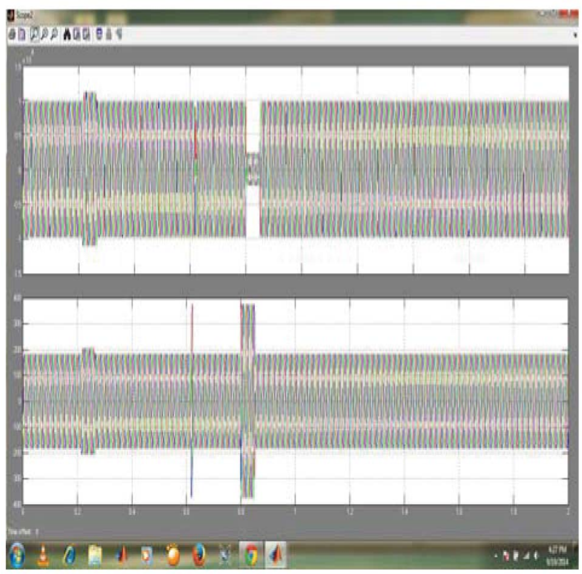
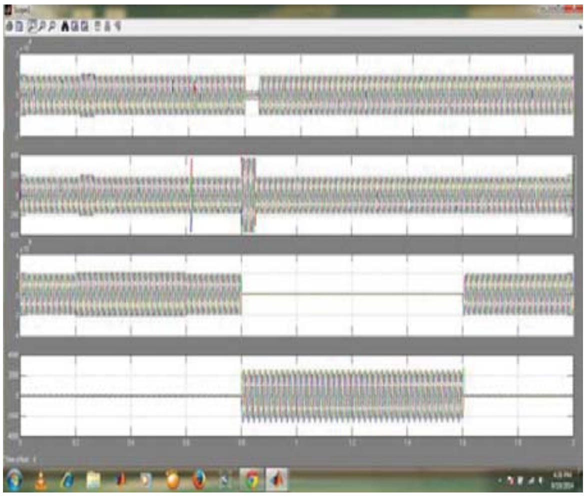
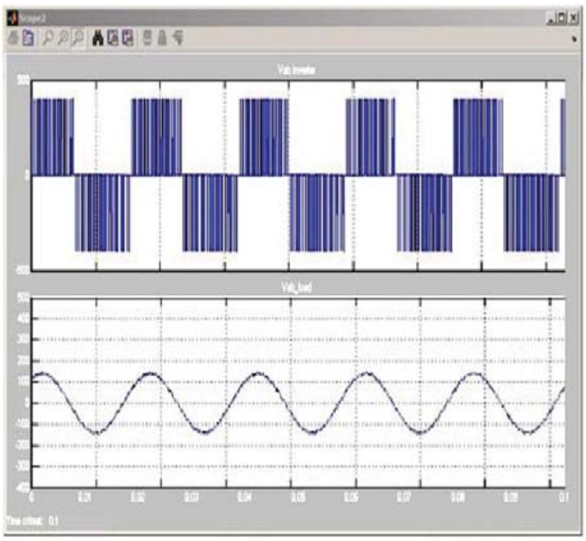


Figure 8: Phase-ground sine wave voltages at load point



Next simulation is carried out at the same scenario as above but a UPQC is now introduced at the load side to compensate the voltage sag occurred due to the three phase fault applied.

Figure 9: Phase-phase voltage across inveter and load



When the UPQC is in operation the voltage interruption is compensated almost completely and the RMS voltage at the sensitive load point is maintained at normal condition.

CONCLUSION

In order to show the performance of UPQC in mitigation of voltage sags, s simple distribution network is simulated using MATLAB. A UPQC is connected to a system through a series transformer with a capability to insert a maximum voltage of 50% of phase to ground system voltage. In-phase compensation method is used. UPQC handles both balanced and unbalanced situations without any difficulties and injects the appropriate voltage component to correct rapidly any deviation in the supply voltage to keep the load voltage constant at the nominal value. The main advantages of the proposed UPQC are simple control, fast response and low cost. The proposed PWM control scheme using PI controller is efficient in providing the voltage sag compensation. As opposed to fundamental frequency switching schemes already available in the MATLAB/SIMULINK, this PWM control scheme only requires voltage measurements. This characteristic makes it ideally suitable for low-voltage custom power applications. UPQC works independently of the type of fault as tested for the system as based on the analysis of test system UPQC mitigates voltage sags due to three phase, single L-G and double line faults. The main shortcoming of the UPQC, being a series device, is its inability to mitigate complete interruptions.

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