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An Efficient Design of Pi, Fuzzy Logic Based Improvement of Power Quality Using Unified Power Quality Conditioner

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ABSTRACT

The unified power quality conditioner (UPQC) is a custom power device, which mitigates voltage and current related power quality issues in the power distribution systems. This paper presents a modified UPQC topology with the ANFIS controller on series device (DVR) and PSO tuned PI controller on shunt device (DSTATCOM). The proposed topology also helps to match the DC link voltage requirement of shunt and series device of UPQC. This topology uses a capacitor in series with interfacing inductor of the shunt active filter. The series capacitor enables the reduction in dc-link voltage requirement of shunt device and simultaneously compensating the reactive power required by the load, so as to maintain unity power factor, without compromising its performance. This allows us to match the dc-link voltage requirement of series and shunt device with a common dc-link capacitor. Further in this topology, the system neutral is connected to the negative terminal of the DC-link voltage to avoid the requirement of fourth leg in the voltage source inverter of shunt active filter. The average switching frequency of the switches in the VSI also reduces, consequently the switching losses in the inverter reduces. A simulation study of the proposed topology has been carried out using MATLAB. Detailed comparative studies are made for the modified topology with various controllers.

INTRODUCTION

In recent years, Power engineers are increasingly concerned over the quality of the electrical power. Most of the modern load equipment uses electronic switching devices which can contribute to poor network voltage quality. The competition in electrical energy supply has created greater commercial awareness of the issues of power quality while equipment is readily available to measure the quality of the voltage waveform and so quantify the problem. The increased sensitivity of the vast majority of processes like (industrial, services and even residential) to PQ problems. The continuous process industry and the information technology services are most critical area. Due to disturbance, a huge amount of financial losses may happen, with the consequent loss of productivity and competitiveness.

Many efforts have been taken by utilities to fulfil consumer requirement, some consumers require a higher level of power quality than the level provided by modern electric networks. This implies that some measures must be taken so that higher levels of Power Quality can be obtained.

The FACTS devices and Custom power devices are introduced to electrical system to improve the power quality of the electrical power. DVR, DSTATCOM, ACTIVE FILTERs, UPQC etc are some of the devices used to improve the power quality of the voltage and current. With the help of these devices we are capable to reduce the problems related to power quality.

Although all devices can improve the power quality but in this the focus is on UPQC.UPQC is a power electronic device consisting of both DVR and D-STATCOM, former is connected in series and latter is connected in parallel to protect the sensitive load from all disturbance.

Power Quality

Various sources give different and sometimes conflicting definitions of power quality. The Institute of Electrical and Electronics Engineers (IEEE) dictionary [159, page 807] states that "power quality is the concept of powering and grounding sensitive equipment in a matter that is suitable to the operation of that equipment."

The International Electro technical Commission (IEC) definition of power quality, as in IEC 61000-4-30 [158, page 15], is as follows: "Characteristics of the electricity at a given point on an electrical system, evaluated against a set of reference technical parameters." This definition of power quality is related not to the performance of equipment but to the possibility of measuring and quantifying the performance of the power system.

Power quality is the combination of voltage quality and current quality. Voltage quality is concerned with deviations of the actual voltage from the ideal voltage. Current quality is the equivalent definition for the current. A discussion on what is ideal voltage could take many pages, a similar discussion on the current even more. A simple and straightforward solution is to define the ideal voltage as a sinusoidal voltage waveform with constant amplitude and constant frequency, where both amplitude and frequency are equal to their nominal value. The ideal current is also of constant amplitude and frequency, but additionally the current frequency and phase are the same as the frequency and phase of the voltage. Any deviation of voltage or current from the ideal is a power quality disturbance.

Power Quality Problems

1. Harmonic Distortion
2. Voltage Dips / Sags, and Surges / Swells
3. Unbalance
4. Flicker
5. Transients

UNIFIED POWER QUALITY CONDITIONER

The Unified Power Quality Conditioner is a custom power device that is employed in the distribution system to mitigate the disturbances that affect the performance of sensitive and/or critical load [1]. It is a type of hybrid APF and is the only versatile device which can mitigate several power quality problems related with voltage and current simultaneously therefore is multi functioning devices that compensate various voltage disturbances of the power supply, to correct voltage fluctuations and to prevent harmonic load current from entering the power system. Fig. 1 shows the system configuration of a single-phase UPQC. Unified Power Quality Conditioner (UPQC) consists of two IGBT based Voltage source converters (VSC), one shunt and one series cascaded by a common DC bus. The shunt converter is connected in parallel to the load. It provides VAR support to the load and supply harmonic currents. Whenever the supply voltage undergoes sag then series converter injects suitable voltage with supply [2]. Thus UPQC improves the power quality by preventing load current harmonics and by correcting the input power factor.

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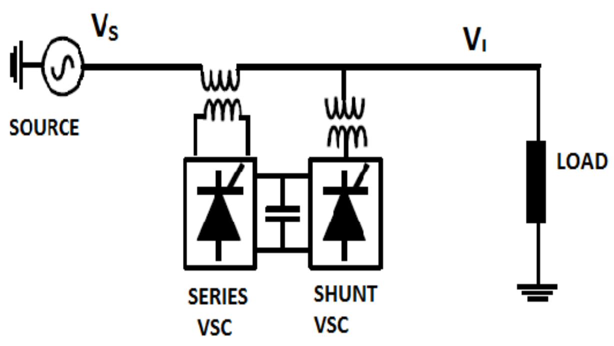

Block diagram of UPQC

Basic configuration of UPQC

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:

Series converter

It is a voltage-source converter connected in series with the AC line and acts as a voltage source to mitigate voltage distortions. It is used to eliminate supply voltage flickers or imbalance from the load terminal voltage and forces the shunt branch to absorb current harmonics generated by the nonlinear load. Control of the series converter output voltage is usually performed using sinusoidal pulse-width modulation (SPWM). The gate pulses required for converter are generated by the comparison of a fundamental voltage reference signal with a high-frequency triangular waveform.

Shunt converter

It is a voltage-source converter connected in shunt with the same AC line and acts as a current source to cancel current distortions, compensate reactive current of the load, and improve the power factor. It also performs the DC-link voltage regulation, resulting in a significant reduction of the DC capacitor rating. The output current of the shunt converter is adjusted using a dynamic hysteresis band by controlling the status of semiconductor switches so that output current follows the reference signal and remains in a predetermined hysteresis band.

Midpoint-to-ground DC capacitor bank

It is divided into two groups, which are connected in series. The neutrals of the secondary transformers are directly connected to the DC link midpoint. As the connection of both three-phase transformers is Y/Yo, the zero-sequence voltage appears in the primary winding of the series-connected transformer in order to compensate for the zero-sequence voltage of the supply system. No zero-sequence current flows in the primary side of both transformers. It ensures the system current to be balanced even when the voltage disturbance occurs.

Low-pass filter It is used to attenuate high frequency components at the output of the series converter that are generated by high-frequency switching.

High-pass filter It is installed at the output of shunt converter to absorb current switching ripples.

Modified UPQC Topology

A modified UPQC topology with reduced dc-link voltage is reported as shown in Fig.4.6. The topology consists of capacitor in series with the interfacing inductor of the shunt active filter. The series capacitor enables reduction in dc-link voltage requirement of the shunt active filter and simultaneously compensating the reactive power required by the load, so as to maintain unity power factor, without compromising its performance. This allows us to match the dc-link voltage requirements of the series and shunt

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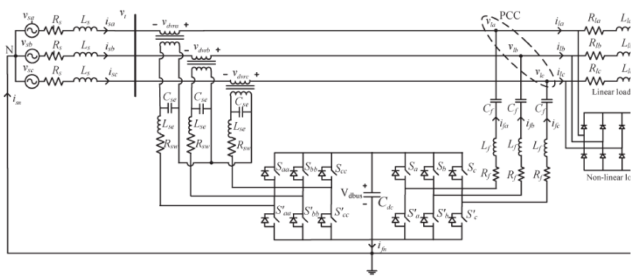
active filters with a common dc-link capacitor. Further, in this topology, the system neutral is connected to the negative terminal of the dc bus. This will avoid the requirement of the fourth leg in VSI of the shunt active filter and enables independent control of each leg of the shunt VSI with single dc capacitor.

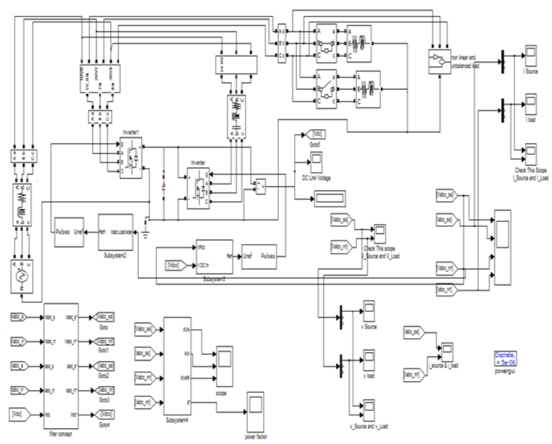


Equivalent circuit of modified UPQC topology

Control of UPQC

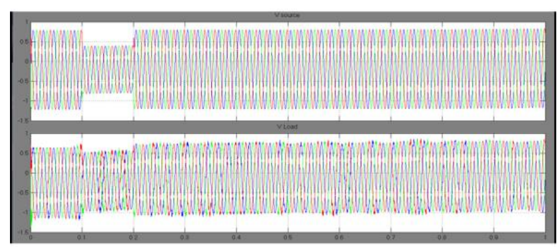
Different topologies and control strategies have been proposed and practiced in the past. The common goal of all the strategies is to improve dynamic response of the controller in order to obtain better compensation. Due to advancement of microelectronics and signal processing (DSP) systems, implementation of new control techniques are becoming feasible which are not possible in the past. Generation of appropriate switching pattern or gating signal with reference to command compensating signal determine the control strategy of the UPQC. Since derivation of reference signal from the measured distorted signal plays, the main role, many theories and techniques were proposed or practiced over the years. These are either in frequency domain or in time domain. Different modifications of the power theories have been made for calculating the reference variables. Thus effectiveness of the control strategies in estimating the reference voltage/current has been enhanced considerably in terms of performance and implementation.

Simulink model of modified UPQC –PI

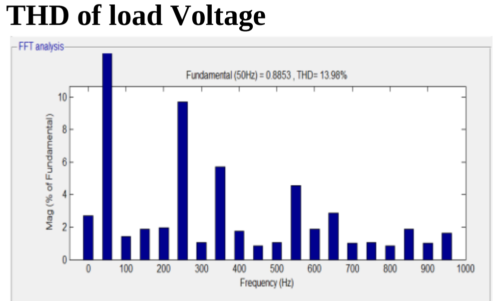


Controller

VOLTAGE WAVEFORM



THD of load Voltage



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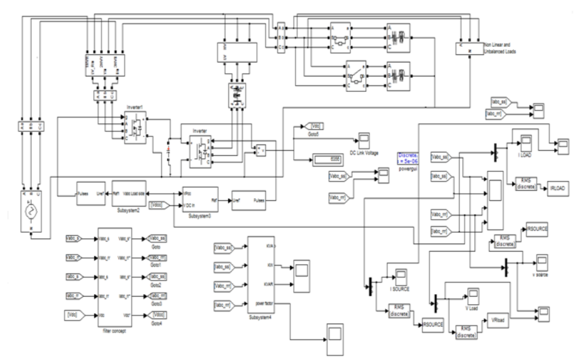
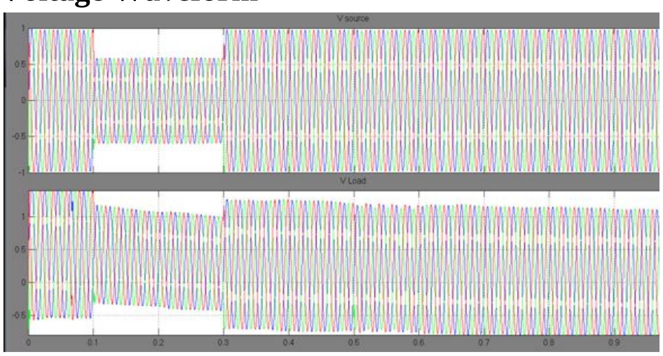
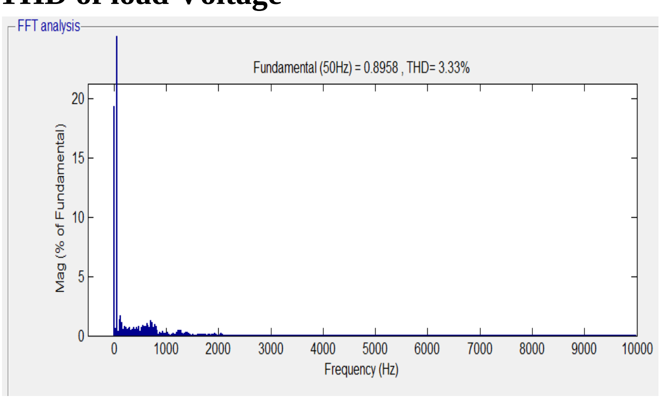
Simulink model of modified UPQC using FLC



Voltage Waveform



THD of load Voltage



COMPARISON OF PI CONTROLLER AND FUZZY CONTROLLER

S.no	FACTORS	PI Controller	Fuzzy Controller
1	Source current THD	8.74%	1.40%
2	Dynamic Response	Slow (0.2s)	Fast (0.10s)
3	Capacitor Charging	Slower	Faster
4	Capacitor Voltage balance under unbalanced load condition	Less stable	More stable
5	Source voltage THD	1.15%	0.27%

CONCLUSION

UPQC which combines the series and shunt devices has been selected and control strategy (SRF method) has been studied in detail. The relevant simulations studies of UPQC have been carried out using MATLAB under various conditions. One of the disadvantages of the SRF theory is that it requires a PI controller minimizing the error between the sensed quantity and reference quantity. However, the tuning of the PI controller is cumbersome and time consuming job.

In the present work fuzzy logic controller has been proposed in place of conventional PI controller. Fuzzy logic controller is non-linear and adaptive in nature which gives the best performance under varying condition. Further no frequent tuning required so it is less time consuming and it is more accurate method then PI controller.

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Results obtained from the simulation shows better performance of modified UPQC when fuzzy logic controller used then that of PI controller in terms of harmonic compensation and dc capacitor voltage balancing at load terminals in switching as well as unbalanced conditions. Under this condition the dynamic response of fuzzy logic controller proved to be faster than PI controller. Hence it is proved that fuzzy logic controller is superior then PI controller.

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