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A Novel Control Approach of UPQC for Power Quality Improvement

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Abstract: The new control approach is based on enhanced phase-locked loop and a vector algorithm for reference signal generation is derived for shunt and series converters and analyzed. A shunt converter can compensate for distortion and unbalance in a load so that a balanced sinusoidal current flows through the feeder. A series converter can compensate for voltage sag/swell and distortion in the supply side voltage so that the voltage across a sensitive load is perfectly regulated. A fuzzy logic controller (FLC) is used to control dc-link voltage. A fast algorithm for sag/swell detection is also presented.

Key words-Active filter, custom power, fuzzy-logic controller, reference signal generation, unified power-quality conditioner(UPQC)

I. Introduction

With increasing applications of nonlinear and electronically switched devices in distribution systems and industries, power-quality (PQ) problems, such as harmonics, flicker, and imbalance have become serious concerns. In addition, lightning strikes on transmission lines, switching of capacitor banks, and various network faults can also cause PQ Problems, such as transients, voltage sag/swell, and interruption. Power electronic controllers also called as custom power devices, have been established to pick up the quality of power distribution in industrial plants, in retort to growing demand from industries reporting production stops due to voltage disturbances, like short interruptions and voltage dips. These power quality phenomena are generally caused by clearing short-circuit faults in the power system and in spite of their very short duration, can impact the operation of low-power electronic devices, motor contactors and drive systems, where the sensitivity of electronic equipment to voltage disturbances can cause the stoppage of the whole facility. To solve this problem, different custom power devices have been proposed, many of which have at their heart a Voltage Source Converter(VSC) connected to the grid.

The Unified Power Quality Conditioner is a custom power device that integrates the series and shunt active filters, connected back-to-back on the dc side and sharing a common DC capacitor. It employs two VSI that are connected to a common DC energy storage capacitor. One of these two VSI that are connected in series with the feeder and the other is connected in parallel to the same feeder.

UPQC mostly dependent on shunt inverter to compensate the load reactive power. All voltage related problems are handled by series inverter and it is looking for controlled voltage source. Load reactive power demand from both series and shunt filters.

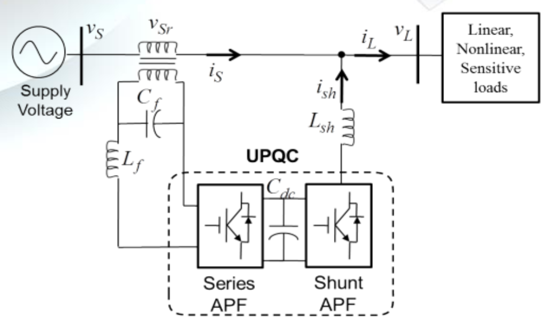

Fig 1 Schematic diagram of UPQC

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Control techniques play a vital role in the overall performance of the power conditioner. The rapid detection of the disturbance signal with high accuracy, fast processing of the reference. Instantaneous power theory is generally preferred to generate reference signals for the shunt converter. An extended method based on instantaneous reactive power theory in a rotating reference frame is used to suppress the harmonics and to correct the power factor in . The adaptive detection technique is used to minimize the effects of noise or parameter variations in . Fuzzy logic is utilized to control the compensation currents of the shunt converter in. Besides, the sinusoidal template vector algorithm, dc-link voltage, and proportional-integral (PI) controller methods are used. To generate reference signals for the series converter, transform, short-time window sampling technique, and positive-sequence calculation methods are used. To generate reference signals simultaneously for the series and shunt converter, transform, wavelet transform, artificial intelligence, neural network, and pole-shift control methods are employed. DC voltage control can be fulfilled by proportional control and PI control. The hysteresis method in , space vector pulse width modulation (PWM) in and sinusoidal PWM strategy in are preferred for series and shunt-side converter signal generation. The monitoring of or in a vector controller is the simplest type of sag/swell detection, which will return the state of supply at any instant in time and, hence, detect whether sag has occurred. The other sag/swell detection methods for the series converter side are the half-cycle average detector, root mean square method, and supply-voltage peak calculator.

II. POWER CIRCUIT CONFIGURATION OF UPQC

The extensive use of power electronic based equipments/loads almost in all areas, the point of common coupling (PCC) could be highly distorted. Also, the switching ON/OFF of high rated load connected to PCC may result into voltage sags or swells on the PCC. There are several sensitive loads, such as computer or microprocessor based AC/DC drive controller, with good voltage profile requirement; can function improperly or sometime can lose valuable data or in certain cases get damaged due to these voltage sag and swell conditions.

One of the effective approaches is to use a unified power quality conditioner (UPQC) at PCC to protect the sensitive loads. A UPQC is a combination of shunt and series APFs, sharing a common dc link. It is a versatile device that can compensate almost all power quality problems such as voltage harmonics, voltage unbalance, voltage flickers, voltage sags & swells, current harmonics, current unbalance, reactive current.

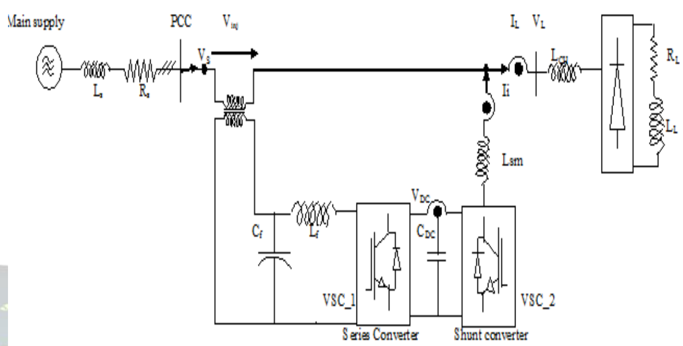

Fig 2 Circuit diagram of UPQC

The UPQC shown in Fig.2 consists of two VSCs (VSC_1 and VSC_2) that are connected back to back through a common energy storage dc capacitor (C_{DC}). Series converter (VSC_1) is connected through transformers between the supply and point of common coupling (PCC). Shunt converter (VSC_2) is connected in parallel with PCC through the transformers. VSC_1 operates as a voltage source while VSC_2 operates as a current source.

The power circuit of VSC_1 consists of three single-phase H-bridge voltage-source PWM inverters. H-bridge inverters are controlled independently. The main objective of VSC_1 is to mitigate voltage sags/swells originating from supply side. The ac filter inductor L_f and capacitor C_f are connected in each phase to prevent the flow of harmonic currents generated due to switching. The transformers connected at the output of each H-bridge inverter provide isolation, modify voltage/current levels, and prevent the dc capacitor from being shorted due to the operation of various switches.

The power circuit of VSC_2 consisting of a three-phase voltage-source PWM inverter is supplied from C_{DC} . VSC_2 is directly connected through a boost inductor L_{sm} which can boost up the common dc link voltage to the desired value .

The objectives of VSC_2 are to regulate the dc link voltage between both converters and to suppress the load current harmonics. The switching devices in VSC_1 and VSC_2 are insulated-gate bipolar transistors (IGBTs) with antiparallel diodes. C_{DC} provides the common dc-link voltage to VSC_1 and VSC_2. Ideally once charged, the dc-link voltage V_{DC} should not fall off its charge, but due to finite switching losses of the inverters—inductor and capacitor—some power is consumed and the charge of the

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dc-link voltage needs to be maintained in a closed-loop control, through the VSC_2 . A three-phase uncontrolled diode-bridge rectifier with resistive (R_L) and inductive load (L_L) is used to produce harmonic current. The ac reactor L_{ch} is placed before the rectifier to enhance the load impedance.

The proposed UPQC system offers two operation modes as follows:

MODE I:

VSC_1 off and VSC_2 on: When the PCC voltage is within its operation limits, VSC_1 is closed and VSC_2 works as the current source. During this operation of UPQC, two lower IGBTs of each phase H-bridge inverter of VSC_1 remain turned on while the two upper IGBTs remain turned off, forming a short circuit across the secondary (inverter side) windings of the series transformer through L_f . Thus, there is no need to use bypass switches across the transformers. VSC_2 suppresses the load current harmonics and regulates dc-link voltage during this mode of operation.

MODE II:

VSC_1 on and VSC_2 on: When the PCC voltage is outside its operating range; both VSC_1 and VSC_2 are open. VSC_1 starts to mitigate sag/swell using the energy stored in V_{DC} and VSC_2 continue to suppress the load current harmonics and to regulate dc-link voltage.

III. SERIES CONVERTER CONTROL

The series converter control includes the reference voltage and sag/swell detection computations. Fig.3 shows the control algorithm of a series converter for *Phase A*. This control algorithm is identical for other phases.

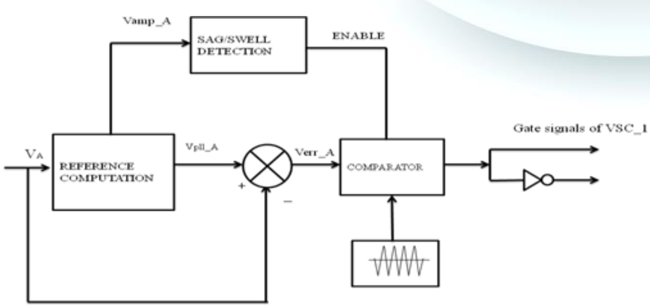

Fig 3 Control Block Diagram of the Series Converter

A. Reference Voltage Generation

The proposed controller algorithm is derived from the findings of both enhanced PLL and nonlinear adaptive filter. The proposed controller minimizes the mathematical operands in the system and reduces complex parameter tuning. The measurements of supply voltages are required for the control strategy of VSC_1.

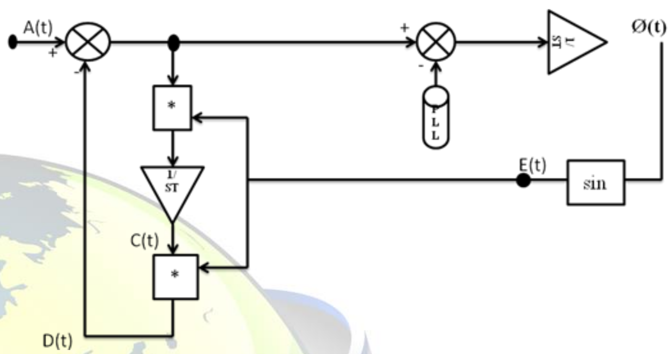

Fig 4.Reference voltage generation block

B. Sag/Swell detection method

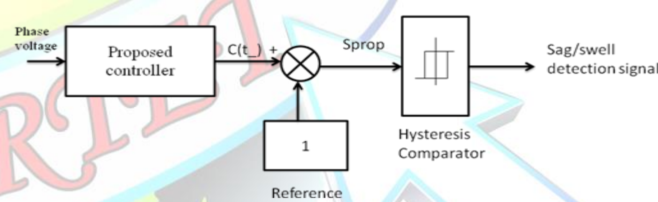

Fig 5 Sag/swell detection block

IV. SHUNT CONVERTER CONTROL

The shunt converter control includes the reference current computation and capacitor voltage control.

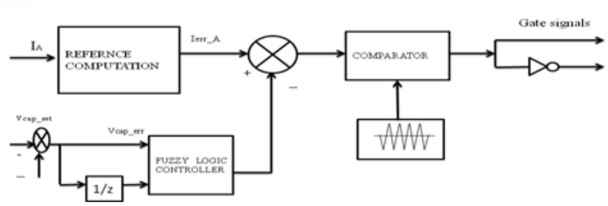

Fig 6 Control Block Diagram of the shunt converter

A. Capacitor Voltage Control

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In the proposed method, $V_{cap\text{-}err}$ is obtained from the difference of capacitor set voltage and measured capacitor voltage. $V_{cap\text{-}err}$ and its rate of change are the inputs for the FLC. The output of the FLC is subtracted from the compensating current signal $V_{cap\text{-}err}$ and its rate of change is defined as

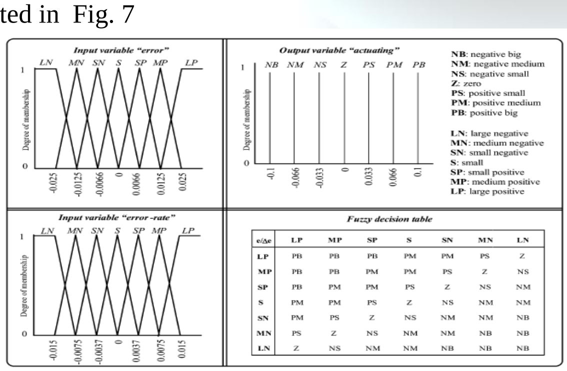
$$V_{cap\text{-}err} = V_{cap\_ref} - V_{cap\_mea}$$

The input signals are fuzzified and represented in fuzzy set notations by membership functions. The defined "IF … THEN …" rules produce the linguistic variables, and these variables are defuzzified into control signals.

V. FUZZY LOGIC IN PROPOSED CIRCUIT

In the proposed method, the FLC obtains the input from the capacitor voltage. Membership functions are preliminarily selected as symmetrical, and the approach can be successfully applied to symmetrical membership functions. The error and error-rate memberships are divided into 5 triangular and 2 trapezoidal fuzzy sets in width, and this allows the operation to change gradually from one state to the next. With this scheme, the input state of variable no longer jumps abruptly from one state to the next. A certain amount of overlap is desirable; otherwise, the controller may run into poorly defined states, where it does not return a well-defined output.

Membership functions and rules are obtained from an understanding of system behavior and the application of systematic procedure and are modified and tuned by simulation performance. The rules table and the stability of the fine-tuned controller with simulation performance are justified by using the approach evaluated and deeply discussed. By following the systematic assignment procedure, a stable and optimized rule table is obtained as presented in Fig. 7



e/Δe	LP	MP	SP	S	SN	MN	LN
LP	PB	PB	PB	PM	PM	PS	Z
MP	PB	PB	PM	PM	PS	Z	NS
SP	PB	PM	PM	PS	Z	NS	NM
S	PM	PM	PS	Z	NS	NM	NM
SN	PM	PS	Z	NS	NM	NM	NB
MN	PS	Z	NS	NM	NM	NB	NB
LN	Z	NS	NM	NM	NB	NB	NB

Fig 7. Member ship of I/O fuzzy sets and assignment of the control rules.

VI.RESULT

The output of FLC is added to the current compensating signal. FLC is developed in MATLAB/SIMULINK codes and is applied to control the dc-link voltage for the first time without any interfacing with other simulation programs.

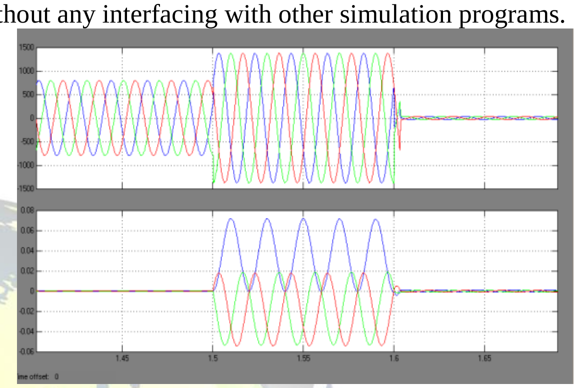


Fig 8.Transmission side details

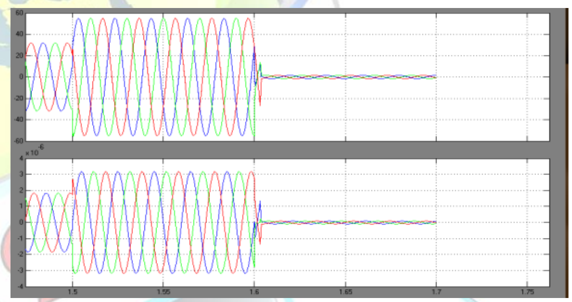


Fig 9.Load side details

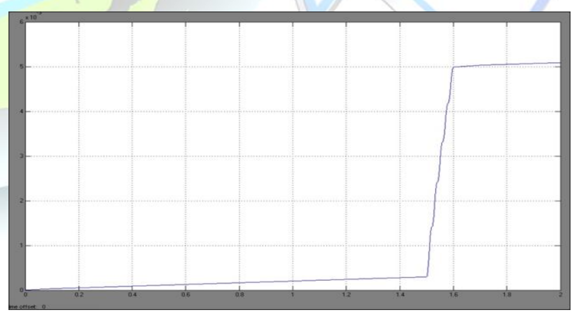


Fig 10.Capacitor Voltage

VII. CONCLUSION

A novel controller for the unified power-quality conditioner is introduced and analyzed by controlling voltage–source converters (VSC_1 and VSC_2) based on enhanced PLL and nonlinear adaptive filter

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algorithms and dc-link voltage with a fuzzy-logic controller. New functionality is added to the UPQC system to quickly extract the reference signals directly for load current and supply voltage with a minimal amount of mathematical operands. The computation method is simpler than for other control algorithms of reference extraction. The number of parameters to be tuned has also been reduced by the use of the proposed controller. This paper presents an effective and fast voltage sag/swell detection method for unbalanced faults. Through this thesis analysis of control approach of UPQC was done by simulations .In this design, replacing the UPQC by IPFC will improve the efficiency of transmission line .As a further step, the hardware can be designed and the simulation results can be compared with the results obtained in practical set of conditions. This experiment verification will be done in future.

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