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Review on Unified Power Quality Conditioner for Power Quality Improvements

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Abstract: *In order to get the most out of our gadgets and appliances, we need to improve the quality of the electricity they're using. Power quality may be enhanced using a number of available devices. "Distribution Static Synchronous Compensator (DSTATCOM), Static VAR Compensator (SVC), Dynamic Voltage Restorer (DVR), and Unified Power Quality Compensator (UPQC)" are only some of the devices that may be used to enhance power quality in industries. The UPQC is an example of an active power filter. Together with power factor correction and the incorporation of renewable energy sources into the distribution network, it helps to reduce PQ problems associated to voltage and current. Topologies, compensation strategies, control theories, and technology advancements over the last several years are all covered in this study. It is anticipated that this study will play a pivotal role in assisting researchers in making use of the UPQC.*

Keywords: *Power quality; solar photovoltaic; unified power quality conditioner; fuzzy adaptive control; coordination control; voltage sag.*

1. Introduction

Power quality is a very important issue in distribution system. Power quality, or the purity of the transmitted energy, is simply described as a property of electricity. The purpose of an electrical grid is to provide reliable electricity for use by a wide range of electrical appliances. Recent years have been a focus on power quality as a result of the widespread use of power electronic controlled applications across many sectors of business. These applications do things like regulate or convert AC power to provide electrical loads. Issues with harmonic distortion limits have been raised because of non-linear loads. The prevalence of nonlinear loads means that power quality issues will emerge sooner or later.

A unified power quality conditioner (UPQC) installed at the Point of Common Coupling (PCC) is one efficient method for safeguarding sensitive loads. Each APF in a UPQC, whether shunt or series, is connected to a shared dc source. It is a multifunctional device that can rectify practically all power quality issues such as voltage harmonics, voltage imbalance, voltage flickers, voltage sags & swells, current harmonics, current unbalance, reactive current, etc. In order to combat non-linear harmonic generating loads and the impact of utility voltage disruption on sensitive industrial loads, the Unified Power Quality Conditioner (UPQC) has developed into one of the most complete tailored power solutions available.

Maintaining command of UPQC's power filters is essential for ensuring its optimal performance. To regulate them, there are several topologies has been introduce. Control strategy plays a key part in the overall functioning of the power conditioner. Desired compensation requires three main things: (1) rapid and accurate detection of the disturbance signal; (2) rapid processing of the reference signal; and (3) strong dynamic responsiveness from the controller. The UPQC's technique for controlling itself is determined by the method used to generate a suitable switching pattern or gating signal in response to the command compensatory signal. Many different theories and procedures have been developed or used throughout the years to derive the reference signal from the observed distorted signal. Some of these are detailed in this study.

1.1 Unified Power Quality Conditioner (UPQC)

A Unified Power Quality Conditioner (UPQC) is a device that is very much in similar in construction to a Unified Power Flow Conditioner (UPFC). The UPQC utilizes two voltage source inverters that are connected to energy storage capacitor. One of these is connected in series and the other is connected in shunt with the ac system.

The UPQC is one of the most powerful custom power devices, which can mitigate both voltage and current related problems simultaneously. The UPQC is a combination of back-to-back connected series and shunt APFs to a common dc link voltage. The series APF compensate all voltage harmonics and shunt APF cancels current-based distortions.

And improve power factor by compensating reactive component of load current. In this paper, the improved synchronous-reference-frame with SPWM based control method for the UPQC system is optimized without using transformer voltage, load, and filter current measurement, so that the numbers of the current measurements are reduced and the system performance is improved.

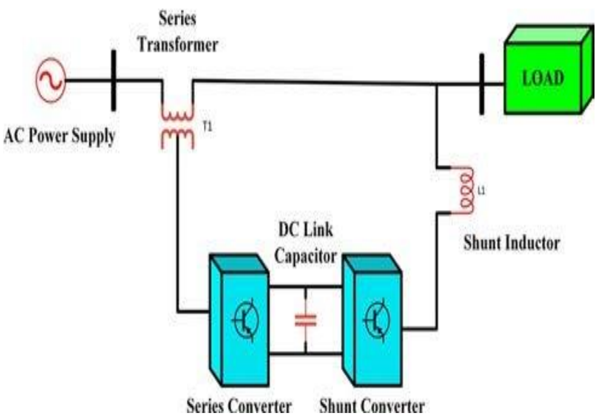

Fig. 1: Block diagram of UPQC

In the figure 1 configuration of UPQC is depicted. The main purpose of the series active filter is harmonic isolation between a sub transmission system and a distribution system. In addition, the series active filter has the capability of voltage flicker/imbalance compensation as well as voltage regulation and harmonic compensation at the utility-consumer point of common coupling (PCC).

The main purpose of the shunt active filter is to absorb current harmonics, compensate for reactive power and negative sequence current, and regulate the dc link voltage between both active Filters.

2. Literature Review

R. Pea-Alzola, D. Campos-Gaona, P. F. Ksiazek, and M. Ordonez, [1] in paper titled **"DC link control filtering options for torque ripple reduction in low-power wind turbines,"** states that small wind energy conversion systems (WECSs) are becoming an attractive option for distributed energy generation. WECSs use permanent-magnet synchronous generators (PMSGs) directly coupled to the wind turbine and connected to the grid through a single-phase grid-tie converter. The loading produced on the dc link is characterized by large ripple currents at twice the grid frequency. These ripple currents are reflected through the dc bus into the PMSG, causing increased heating and ripple torque. This paper depicts the use of PMSG inverter to control the dc-link voltage. In order to avoid reflecting the ripple currents into the PMSG, the feedback dc-link voltage is passed through a filter. The Butterworth filters, notch filters, anti-resonant filter (ARF) and moving average filter (MAF) are considered.

S. Devassy and B. Singh, [2] in their work **"Modified p-q theory-based control of solar PV integrated UPQC-S,"** proposes a modified p-q theory-based control of solar photovoltaic array integrated unified power quality conditioner (PV-UPQC-S). The system incorporates clean energy generation along with power quality improvement thereby

increasing functionality of the system. The fundamental fr equency positive sequence (FFPS) components of voltage at the point of common coupling (PCC) are extracted using generalized cascaded delay signal cancellation (GCDSC) technique which is then used in p-q theory based control to estimate reference signals for the PV-UPQC-S.

A. Javadi, L. Woodward, and K. Al-Haddad, [3] the trio in their paper titled **"Real-time implementation of a three-phase THSeAF based on VSC and p+r controller to improve power quality of weak distribution systems,"** has proposed a single-phase transformer-less hybrid series active filter (THSeAF) based on duo-neutral-point-clamped (D-NPC) converter to address distribution level power quality to investigate experimentally the efficiency of the hardware-in-the-loop (HIL) implementation for power electronics applications. This benchmark contributes to demonstrating the capability and efficiency of such real-time implementation for smart grid power quality (PQ) analysis which requires fast switching process with small sampling time. Such applications require the compensator to address major power quality issues related to a nonlinear load.

Y. Singh, I. Hussain, B. Singh, and S. Mishra, [4] in their work **"Single-phase solar grid interfaced system with active filtering using adaptive linear combiner filter-based control scheme,"** deals with a control scheme for single-stage solar photovoltaic (SPV) grid-interfaced system. The voltage-source inverter (VSI) is a power electronic interface between SPV array and the grid. The VSI provides power quality features, i.e. harmonics mitigation, power factor correction and perturb and observe maximum power point tracking for single-stage SPV grid-interfaced system. The SPV array supplies active power to the non-linear load and grid through VSI, during daytime only or when SPV generation is more than the load power.

A. Parchure, S. J. Tyler, M. A. Peskin, K. Rahimi, R. P. Broadwater, and M. Dilek,[5] in their paper titled **"Investigating PV generation induced voltage volatility for customers sharing a distribution service transformer,"** discusses that **t**he number of grid-connected rooftop solar photovoltaic systems is expected to increase significantly in the next few years. Many studies have been conducted on analyzing transmission level voltage stability with high PV penetration, and recent efforts have also analyzed voltage stability at the medium and low voltage distribution levels. However, those studies have not considered detailed distribution secondary modeling extending from the primary feeder to the service transformer and all the way through the distribution secondary connections and service drops.

A. R. Malekpour, A. Pahwa, A. Malekpour, and B. Natarajan,[6] in their paper titled **"Hierarchical architecture for integration of rooftop PV in smart distribution systems,"** deals with the design and performance analysis of a three-phase single stage solar photovoltaic integrated unified power quality conditioner (PV-UPQC). The PV-UPQC consists of a shunt and series connected voltage compensators connected back to back with common DC-link. The shunt compensator performs the dual function of extracting power from PV array apart from compensating for load current harmonics. An improved synchronous reference frame control based on moving average filter is used for extraction of load active current component for improved performance of the PVUPQC.

B. Singh, C. Jain, S. Goel, A. Chandra, and K. Al-Haddad,[7] in their wor**k "A multifunctional grid-tied solar energy conversion system with anf-based control approach,"** presents a two stage three-phase grid-interfaced solar photovoltaic energy conversion system with an adaptive notch filter based control algorithm that consists of a multifunction grid-interfaced SPV energy conversion system, which along with the conversion of dc-power from SPV to ac mains is capable of reactive power compensation, harmonics currents elimination, and load balancing in a three-phase ac distribution system. Compared with multiple devices with different functionalities, a multifunction grid-interfaced SPV energy conversion system is capable of saving substantially capital investment, space, and maintenance cost on behalf of multifunctional features.

A. Javadi, A. Hamadi, L. Woodward, and K. Al-Haddad,[8] in their paper **"Experimental investigation on a hybrid series active power compensator to improve power quality of typical households,"** have implemented a transformer less hybrid series active filter using a sliding-mode control algorithm and a notch harmonic detection technique on a single-phase distribution feeder which provides compensation for source current harmonics coming from a voltage fed type of nonlinear load (VSC) and reactive power regulation of a residential consumer. The realized active power filter enhances the power quality while cleaning the point of common coupling (PCC) from possible voltage distortions, sags, and swells initiated through the grid.

E. Yao, P. Samadi, V. W. S. Wong, and R. Schober, [9] in their paper titled **"Residential demand side management under high penetration of rooftop photovoltaic units,"** have stated that **i**n a residential area where many households have installed rooftop photovoltaic (PV) units, there is a reverse power flow from the households to the substation when the power generation from PV units is larger than the aggregate load of the households. This reverse power flow causes the voltage rise problem. This paper showcases the use of demand side management to mitigate the voltage rise problem by proposing an autonomous energy consumption scheduling algorithm, which schedules the operation of deferrable loads to jointly shave the peak load and reduce the reverse power flow.

Y. Yang, P. Enjeti, F. Blaabjerg, and H. Wang,[10] in their review paper titled **"Wide-scale adoption of photovoltaic energy: Grid code modifications are explored in the distribution grid,"** have stated that the relative share of renewable energy, specifically the solar photovoltaic, is increasing exponentially in the world electric energy sector. This is a cumulative result of reduction in the cost of solar panels, improvement in the panel efficiency, and advancement in the associated power electronics. Among different types of PV plants, installation of small-scale rooftop PV is growing rapidly due to direct end-user benefits and lucrative governmental incentives. There are various standards developed in regards to grid integration of PVs and other distributed generations (DGs).

3. Proposed Methodology

Researchers have spent a lot of time and energy over the years looking for practical uses for UPQC and strategies to boost its effectiveness. UPFC functions best in a perfectly stable and distortion-free transmission system, allowing for optimal shunt/series correction. In comparison, UPQC must function in a setting where DC components, voltage harmonics, and current harmonics all contribute to imbalances and distortions. The primary goal of the UPQC is to limit the active power in circulation by lowering the active power injected through series and shunt APFs. PVA is linked to the DC connection and helps the UPQC inject active and reactive power into the grid. Feedback from the source and load voltages and currents will be used to construct separate controllers for shunt and series converters. The sinusoidal PWM approach used by the SRF controller keeps both converters in step with the input voltage. In order to minimise power loss across the distribution system, several algorithms will be used to pinpoint where exactly the UPQC should be implemented.

4. Conclusion

Due to its design combining both series active and shunt-active power filters, the Unified Power Quality Conditioner (UPQC) is one of the promising power electronic circuit modules for addressing voltage sag and total harmonic distortion issues. The effectiveness and practicality of most power quality conditioner management techniques have been analysed. This research shows that UPQC and related control approaches have recently received a great deal of attention. Reasons for this include the decreasing cost of computing hardware (microcontrollers and DSPs) and the widespread availability of appropriate power-switching devices.

With the UPQC, renewable energy sources (RES) may be integrated into the existing power grid while also being compensated for supply voltage and load current power quality issues. In addition to providing background on the UPQC, this document includes statistics that might be useful to researchers, manufacturers, and utilities engaged in power system analysis.

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