

POWER QUALITY IMPROVEMENT USING CUSTOM POWER DEVICE: REVIEW

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ABSTRACT

Power quality issues have grown increasingly complicated during the past ten years at every stage of the power system. Power electronics controllers are becoming more concerned these days about supplying customers and power suppliers with high-quality electricity. Different power filtering technologies, including as hybrid, active, and passive filters, have been used occasionally to help consumers with their power quality issues, but they haven't been able to completely satisfy them. Today, a novel idea called "custom power" is applied to ensure client happiness. To make the most of our appliances and gadgets, we need to improve the quality of the power they consume. There are several available tools that can enhance power quality. "Distribution Static Synchronous Compensator (DSTATCOM), Static VAR Compensator (SVC), Dynamic Voltage Restorer (DVR), and Unified Power Quality Compensator (UPQC)" are only a few examples of the equipment that may be used to improve power quality in industries. The UPQC is an illustration of an active power filter. It helps with power factor adjustment, the integration of renewable energy sources into the distribution network, and the reduction of PQ problems associated with voltage and current. A thorough analysis of bespoke power devices at the distribution level is presented in this research. Researchers addressing issues with power quality might find the classified references that are also provided to be of great use.

Keywords: Voltage sag; fuzzy adaptive control; fuzzy adaptive control; solar photovoltaic; unified power quality conditioner.

1. INTRODUCTION

A crucial concern in the distribution system is power quality. A characteristic of electricity is simply referred to as power quality, or the purity of the transferred energy. An electrical grid's main function is to deliver dependable power for usage by a variety of electrical equipment. The increased usage of power electronic controlled applications across various corporate sectors has caused a recent focus on power quality. These programmes control or transform AC electricity to provide electrical loads, among other things. Due to non-linear loads, issues with harmonic distortion limitations have emerged. Since nonlinear loads are so common, power quality problems will eventually show themselves. One effective way to protect sensitive loads is to install a unified power quality conditioner (UPQC) at the Point of Common Coupling (PCC). Whether in series or in shunt, every APF in a UPQC is linked to a common dc source. Almost all power quality problems, including voltage harmonics, voltage imbalance, voltage flickers, voltage sags and swells, current harmonics, current unbalance, reactive current, etc., may be fixed by this versatile device. The Unified Power Quality Conditioner (UPQC) has evolved into one of the most comprehensive custom power solutions available to address non-linear harmonic producing loads and the effects of utility voltage interruption on sensitive industrial loads.

Recently, Power quality problems have become an important issues for electricity consumers at all the level of usage. The deregulation of electric power energy has boosted the public awareness toward power quality among the different categories of users. The subject power quality and its problems related to electric power network has discussed in publications. To provide an active & flexible solution for power quality problems, various efforts have done from time to time. Among these power quality solution lossless passive filters consists of L-C tuned component have been widely used to suppress harmonic. Passive filters are advantageous as its initial cost is low and high efficiency. on the other hand it have various drawbacks of instability, fixed compensation, resonance with supply as well as loads and utility impedance. To overcome these limitations active power filters [14-16] have been used .active power filter has various configurations: shunt, series and hybrid. Hybrid is the combination of series and shunt types. Shunt APF is used for compensating current based distortions while series APF

compensates voltage based distortions. Hybrid APF [17-19] is applied for filtering high order harmonics. However, they have a problem that their rating is sometimes very close to load (up to load 80 %) in typical applications. Due to this reason, power quality level is not obtained. This causes power disturbances and customer dissatisfaction. According to contingency planning research company's annual study [20] a power disturbance in distribution system produces an economical losses is shown in Fig 1. To increase the reliability of the distribution system and face the power disturbance problems, an advanced power electronics controller devices have launched over last decades. The evolution of power electronics controller devices has given to the birth of custom power.

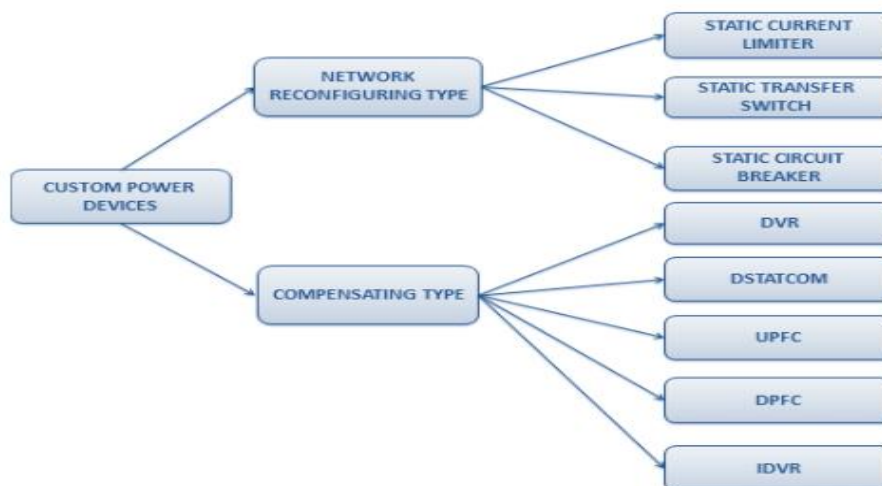


Figure-1 Types of Custom Power device

NETWORK RECONFIGURING TYPE CP DEVICES

These are GTO or Thyristor based devices, generally used for fast current limiting and current breaking. The main network reconfiguring type custom power devices are: solid state current limiter, static transfer switch, static breaker, ups,

A. Static Current Limiter

it is a GTO based device applied for high fault current limiting. It insert a limiting inductor in the fault circuit .when the fault is cleared, removes the inductor from circuit [25].

B. Static Transfer Switch

Static Transform Switch (STS) is used to protect sensitive load voltage sag or swell. It is composed of two parallel connected Thyristor or GTO blocks. Each block consists of three GTO or thyristor corresponding to the three phase of the system. The common configuration of STS in distribution system is shown in Fig 3.

C. Solid State Breaker

The solid state breaker is based on the GTO or thyristor switching technology. It is a high-speed switching device, applied to reduces the electrical fault and protect from large current in distribution system. It can be used in a single switch, static transfer switch, hybrid switch or a low level fault interrupter. The voltage and current rating of the breaker describes the requirement of no. of switching devices, cost and the losses of the breaker. It perform auto-reclosing function.

D. Uninterruptible Power Supply

Uninterruptible power supply (UPS) is the conventional response to circumvent production interruption and outage costs. The single line diagram of ups is shown in the Fig 4.

COMPENSATING POWER DEVICES

The compensating custom power devices are used for active filtering, load balancing, power factor improvement voltage regulating (sag/ swell) [33]. These devices are mainly three types: static shunt compensator, series and hybrid compensator. These are also called as DSTATCOM, DVR and UPQC respectively.

A. Distribution Static Compensator (DSTATCOM)

DSTATCOM is a Voltage source inverter (VSI) based static compensator device (STATCOM, FACTS controller) applied to maintain bus voltage sags at the required level by supplying or receiving of reactive power in the distribution system [33]-[34]. It is connected in shunt with distribution feeder with the help of coupling transformer. The single line diag. of DSTATCOM is shown in shown fig.5. The DSTATCOM consists of a VSI, dc energy storage device, an ac filter and coupling transformer.

B. Static Series Compensator

Commercially, static series compensator is known as Dynamic Voltage Restorer (DVR). It is a high-speed switching power electronic controlling device. The world's first DVR has been installed in the Dukey power distribution system to protect a sensitive textile customer from voltage dips on August 26, 1996 [42]. DVR is a series connected custom power device, designed to inject a dynamically controlled voltage in magnitude and phase in to distribution line via coupling transformer to correct load voltage. The generalized block diag. of DVR is shown in the Fig 9.

It consists of a energy storage device, a boost converter (dc to dc), voltage source inverter, ac filter and coupling transformer, connected in series. Here dc capacitor bank is used as energy storage device, which is interface by a boost converter. The boost converter regulates the voltage across the dc link capacitor that uses as a common voltage source for the inverters. The inverter generates a compensating voltage, which is inserted into distribution system through series matching transformer. In the case of voltage irreregulation, the DVR controllers generate a reference voltage, and compare it with source voltage and injects synchronized voltage to maintain the load voltage constant. The energy storage device provide the required power to synchronized injected voltage. The ac filter overcome the effects on winding of coupling transformer and switching losses of

control signal generating techniques for VSI. Principle of operation: The simplified single phase equivalent circuit of DVR connected distribution feeder is shown in the Fig.

C. Unified Power Quality Compensator (UPQC)

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. Here Since energy is a need for daily living, it must be delivered to consumers in a consistent, high-quality manner. Due to rising increase in consumption and power generation, the transmission of electricity in the connected cooperative electrical system is gradually expanding. Worldwide transmission systems are constantly changing and being reorganised. They are getting weighed down more and more. For the transmission networks to respond to more varied generation and load patterns, they must be adaptable. The three control parameters that regulate the flow of power in the transmission system are voltage magnitudes, phase angles, and line reactance. When two locations are connected by a symmetrical, lossless transmission line (Fig. 1), the power flow P in the line can be stated as follows:

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.

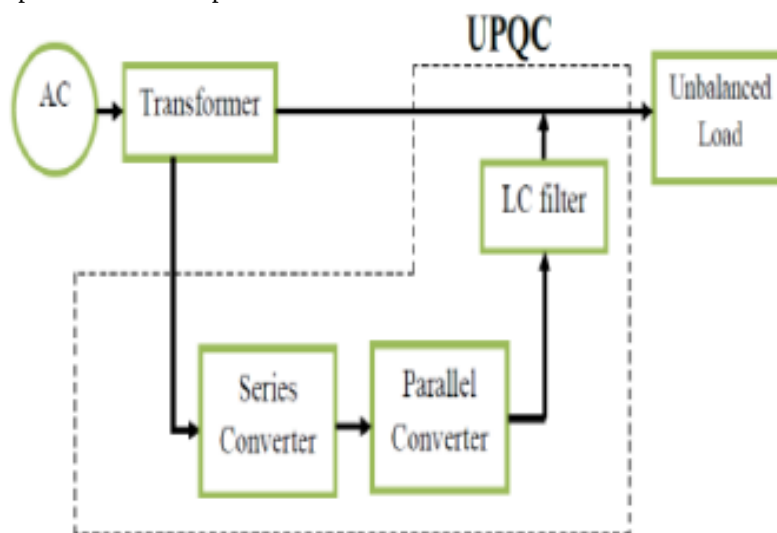


Figure:2 Block Diagram of UPQC

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.

APPLICATIONS OF EACH CUSTOM POWER DEVICES

Custom Power Devices	Applications
Static Shunt Compensator (D-STATCOM)	➤ Power factor improvement ➤ Current Harmonic compensation ➤ Load current balancing ➤ Flicker effect compensation
Static Series Compensator (DVR)	➤ Voltage sag and swell protection ➤ Voltage balancing ➤ Voltage regulation ➤ Flicker attenuation
Unified Power Quality Compensator (UPQC)	➤ Voltage sag and swell correction ➤ Voltage balancing ➤ Voltage regulation ➤ Flicker attenuation ➤ VAR compensation ➤ Harmonic suppression ➤ Current balancing ➤ Active and reactive power control
Static transfer switch (STS)	➤ Voltage sag and swell protection
Solid state breaker	➤ Fault current protection and limitation

2. LITERATURE REVIEW

A. Javadi, L. Woodward, and K. Al-Haddad, 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, 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.

R. Pea-Alzola, D. Campos-Gaona, P. F. Ksiazek, and M. Ordonez, 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, 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 frequency 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.

B. Singh, C. Jain, S. Goel, A. Chandra, and K. Al-Haddad, in their work “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. Parchure, S. J. Tyler, M. A. Peskin, K. Rahimi, R. P. Broadwater, and M. Dilek, in their paper titled “Investigating PV generation induced voltage volatility for customers sharing a distribution service transformer,” discusses that the 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, 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.

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).

A. Javadi, A. Hamadi, L. Woodward, and K. Al-Haddad, 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, in their paper titled “Residential demand side management under high penetration of rooftop photovoltaic units,” have stated that in 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.

3. PROPOSED METHODOLOGY

Over the years, a great deal of time and effort has been expended by researchers searching for real-world applications of UPQC and ways to increase its efficacy. The ideal shunt/series correction is made possible by UPFC in a transmission system that is completely stable and distortion-free. On the other hand, the environment in which UPQC operates must include DC components, voltage harmonics, and current harmonics as sources of imbalances and distortions. The main objective of the UPQC is to reduce the active power injected through series and shunt APFs in order to restrict the amount of active power in circulation. PVA assists the UPQC in supplying active and reactive power to the grid by being connected to the DC connection. Separate controllers for shunt and series converters will be built using feedback from the source and load voltages and currents.

The SRF controller maintains both converters in phase with the input voltage by the use of sinusoidal PWM. Many methods will be employed to determine the precise location of the UPQC in order to reduce power loss throughout the distribution system.

4. CONCLUSION

Because of its architecture, which combines both series active and shunt active power filters, the Unified Power Quality Conditioner (UPQC) is one of the most promising power electronic circuit modules for addressing voltage sag and total harmonic distortion issues. The effectiveness and practicality of most power quality conditioner control techniques have been investigated. This study shows how UPQC and related control techniques have become quite popular recently. This is brought about by the broad availability of appropriate power-switching technology and the falling cost of computer hardware, such as DSPs and micro controllers. Power quality issues related to supply voltage and load current may be addressed while integrating RES into the current power system thanks to the UPQC. This study provides data that might be useful to researchers, producers, and utilities doing power system analysis in addition to background information on the UPQC.

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