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A brief review on various topologies of custom power devices

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ABSTRACT

Poor power quality reduces the system efficiency and increases the losses as well as the electricity consumption cost. Power electronic based customized power conditioning devices presents efficient and cost effective solution to various power quality problems. This paper presents a brief overview on one such power quality compensating device which can at the same time mitigates voltage as well as current related irregularity in system. UPQC is designed with shunt converter to mitigate current harmonics and series converter to regulate system voltage. Also UPQC has been energized through PV voltage to make the system eco-friendly.

Keywords: *Active Power Filter (APF), Custom Power Devices (CPD), Power Quality (PQ), Unified Power Quality Conditioner (UPQC), Power Electronics Devices (PED) Dynamic Voltage Restorer (DVR)*

1. INTRODUCTION

The first published Energy Networks Association Recommendation G5/4, in 2001 has intention to ensure that the levels of harmonics in the Electricity Supply of Public network do not disband a problem for other users of that supply. G5/4 is a regulatory Recommendation for distribution network used for planning of adding new loads and capacity to an existing utility [1]. While expanding an installation there is a restriction to limit harmonic emissions for nonlinear loads and generation plant onto the electrical supply system. This requirement if accomplished will limit voltage distortion in the network connected to.

Non-linear loads are the primary factor of high harmonics in the distribution network. G5/4 specifies the limits of harmonics in the network as shown in table 1 to facilitate the connection of non-linear equipment, having manifesto for limiting the overall voltage distortion, which in turn are set to achieve compatibility to the network against power quality (PQ) issues [2]. The brief overview on various PQ issues is presented in table 2. Innovative solutions are rapidly evolving which employs power electronics devices (PED) for rapid response in a way to suppress or counteract the disturbances. Two general approaches are opt to mitigate the PQ problems [3]. One is load conditioning to ensure that the connected equipment is less sensitive to disturbances, which can allow ride through the disturbances. The other is the installation of conditioning devices so as to ensure suppression or counteracts the PQ issues. Commercially available PED tends to protect against a group of PQ problems. These devices vary in size and can be installed at all voltage levels of a power system [4, 5]. This paper presents an overview on such devices.

Table 1: International Standards or Guidelines for voltage harmonic limits

Voltage Harmonic		
Order (h)	**IEC 61000-2-12 2003 1 to 35 kV**	**ER G5/4 6.6 to 20 kV**
3	5	3
5	6	3
7	5	3
9	1.5	1.2
11	3.5	2
13	3	2
15	0.4	0.3
17	2	1.6
19	1.76	1.2
21	0.3	0.2
23	1.41	1.2
27	0.2	0.2
29	1.06	0.63
31	0.97	0.6
33	0.2	0.2
35	0.83	0.55
37	0.77	0.53
39	0.2	0.2
41	0.67	0.5
43	0.62	0.49
45	0.2	0.2
47	0.55	0.46
49	0.51	0.45
THD	8% up to 50th	4% up to 50th

2. CUSTOM POWER DEVICES (CPD)

Topologies which are proposed / presented with an exclusive claim of reducing the PQ problems in a network connected to are termed as CPD. Custom Power is a concept for application

of power electronic controllers in the distribution system to supply value-added, reliable and high quality power to end-consumer of the network connected to. CPDs are APFs and DVRs having capability to perform harmonic mitigation and voltage compensation functions in a distribution system leading to more reliable and/or power quality [6, 7]. For a small system with simple loading, selection for an appropriate CPD is fairly straight forward. However, for large interconnected system having versatile loading pattern, all aspects of the network characteristics must be considered carefully. Merit of any given CPD can be primarily judged based on the application for which it has to be employed.CPD can be broadly categorized as network reconfiguring type (NRT) or compensating type (CT) [9]. The NRT are switchgear type which includes current limiting, circuit breaking, current transferring devices, Static Circuit Breaker and Static Transfer Switch (STS). The CT primarily compensate for a load related PQ issues and correct its power factor, unbalance or improve the quality of supplied voltage. CT are Active Power Filter (APF), Dynamic Voltage Restorer (DVR) and Unified Power
Quality Conditioner (UPQC) [10].

Table 2: Various PQ issues

Power Quality Problems	Reasons	Consequences
Transient	Lightning, Turning major equipment on or off.	Tripping, Processing error, Data loss, Component failure.
Voltage Dip	Starting of large Motors, Incorrect VAR compensation, Faults on the transmission/ distribution network.	Dim lights, Shrinking display screens, Equipment shutdown.
Voltage Swell	Switching off a large load, incorrect VAR compensation.	Bright lights, Racing or blinking of digital clock.
Harmonics	IT equipment, Fluorescent lighting and any non linear load.	Line current increases, Higher losses, Conductor overheating, instruments malfunctioning.
Voltage Interruption	Faults (Short circuit), Equipment failures, insulator failure, lightning, Control malfunctions.	Equipment trips off, Programming is lost, Computer shut down, Disk drive crashes

3. ACTIVE POWER FILTER

The circuit topology of APF is shown in Figure 1. APF is generally shunt connected that can eliminate the nonlinear load harmonics compensating for load reactive current. APF supplies reactive power required to mitigate load current harmonics generated by nonlinear loads. In this case, only a small portion of the energy is processed hence overall energy efficiency is increased [11]. APF can be subdivided as shunt/series APFs, hybrid-APF and other probable combinations which have made it possible to mitigate some of the major PQ issues.

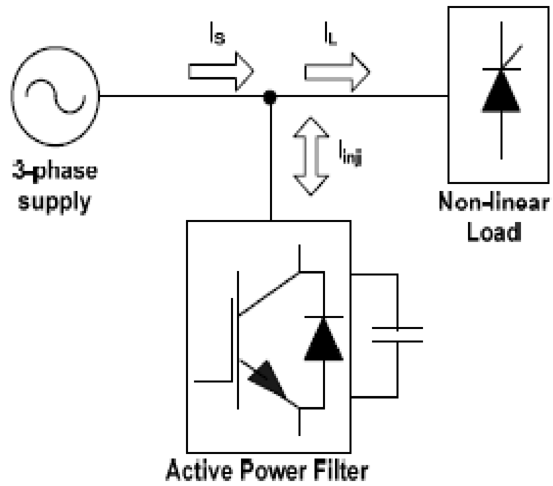

Fig. 3: Schematic of APF

4. DYNAMIC VOLTAGE RESTORER

DVR is a type of CPD which is connected in series. It is used for protecting a sensitive load that is connected downstream against source sag/swell. It can also regulate the bus voltage at the load terminal. DVR and STS are common types of CPD compensating for voltage sag [12, 13]. DVR is usually designed to mitigate voltage dips with magnitude lower than 50% while STS can limit the duration of interruptions and voltage sags/swells to less than one half-cycle which it does by transferring the load from the affected line to a back-up feeder [14]. The topologies of DVR and STS are shown in Figure 2 and 3.

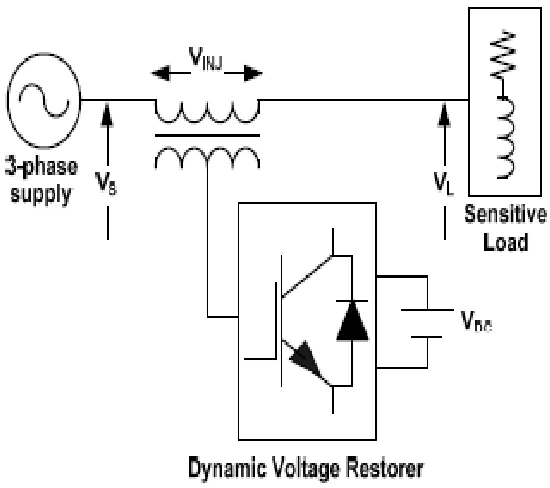

Fig. 4: Circuit Topology of DVR.

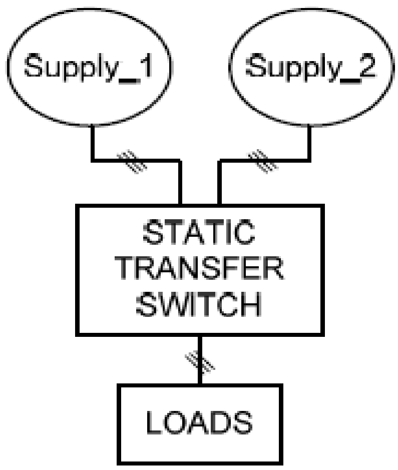

Fig. 5: Circuit Topology of STS.

5. UNIFIED POWER QUALITY CONDITIONER

UPQC consists of two voltage source inverters. It can simultaneously perform the tasks of APF and DVR [15, 16]. The basic circuit diagrams of UPQC are shown in Figure 4. UPQC protect the loads against voltage sag, swell, voltage unbalance, harmonics and poor power factor. UPQC is a combination of a shunt-series connected APF and DVR respectively inter-linked by a common DC link capacitor [17]. An improvise to the UPQC is to energize it via PV-DC power as shown in Figure 5 so as to increase the green element into the network connected. Integrating PV-array to UPQC has put together dual technical benefits of clean energy generation along with universal active filtering. This unique combination of green source with PED that is PV-UPQC has been reported in [18]–[20]. Compared to conventional CPDs mentioned in this paper before PV-UPQC has numerous benefits such as improving PQ of the grid, protecting critical loads from grid side disturbances apart from increasing the fault ride through capability of converter during transients also preventing non-linearities of load but to interrupt the source. With the increased emphasis on distributed generation and micro-grids, there is a renewed interest in UPQC systems [21], [22]. The basic functionality of PV fed UPQC is presented in. The PV-UPQC can perform two functions. Firstly the PV-array can energies the electrical distribution system, as well as to the load. Secondly it can provide power only to the load, similar to an uninterruptible power supply.

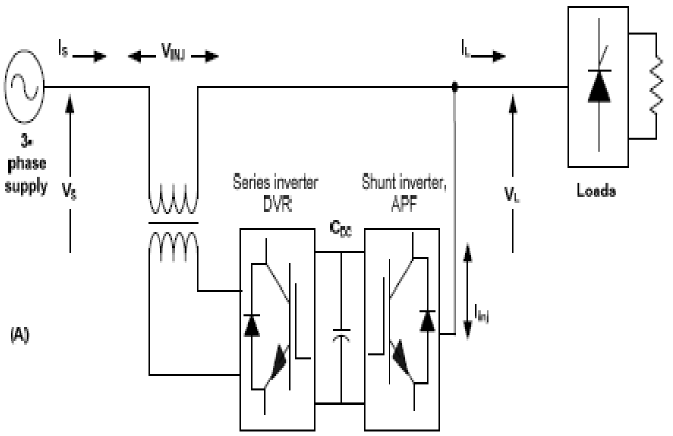

Fig. 6: Circuit Topology of UPQC

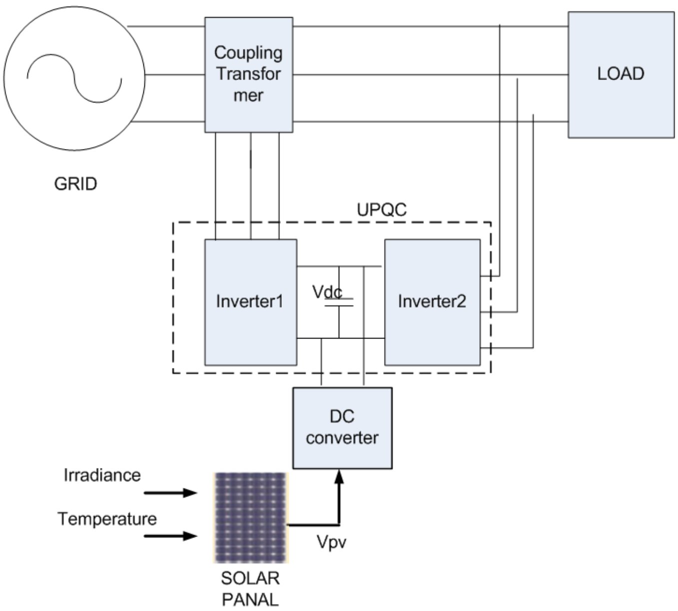

Fig. 7: PV-UPQC Topology

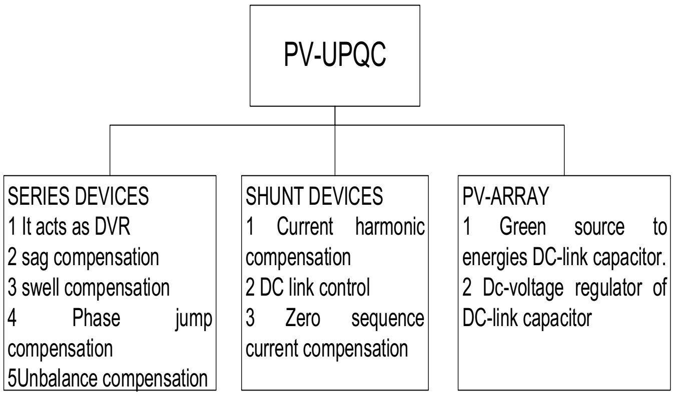

Fig. 8: Features of PV-UPQC

6. CONCLUSION

The paper presents the comprehensive review on various CPD topologies to improve the performance efficiency the network connected with non-linear loads, unbalanced loading and source unbalanced leading to sag/swell events of voltages. In literature numerous topologies of CPD with circuit topologies is available. This paper presents there comparison and advantages. Based on the review a new class of CPD namely PV-UPQC is also introduced which can mitigate various PQ issues and also greening the network. It has been reported in literature that PV-UPQC is a good solution for distributed generation based distribution system by reducing carbon traces power quality improvement.

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