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Brief Review Paper on the Custom Power Devices for Power Quality Improvement

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Abstract

During Last decade power quality problems has become more complex at all level of power system. Recently, the Power electronics controllers are gaining concern to provide the quality of power for both power suppliers and consumers. Various power filtering technology i.e. passive filters, active power filters, hybrid filters have applied from time to time for giving the solution of power quality problems to users, But could not fully satisfied them. Now day's a new concept of custom power is used for customers' satisfaction. This paper present a comprehensive survey of custom power devises in distribution level.

Keywords: Custom power, Distribution Static Compensator (DSTATCOM), Dynamic Voltage Restorer (DVR), Unified Power Quality Compensator (UPQC).

Introduction

Power quality problems have become important issues for electricity consumer sat 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 has various drawbacks of instability, fixed compensation, resonance with supply as well as loads and utility impedance. To overcome these limitations active power filters 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 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. 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.

Custom power devices

Custom power is a strategy, which is intended principally to convene the requirement of industrial and commercial consumers. The concept of the custom power is tools of application of power electronics controller devices into power distribution system to supply aquality of power, demanded by the sensitive users.

These power electronics controller devices are also called custom power devices because through these valuable powers is applied to the customers. They have good performance at medium distribution levels and most are available as commercial products. For the generation of custom power devices VSI is generally used, due to self-supporting of dc bus voltage with a large dc capacitor. The custom power devices are mainly divided into two groups: network reconfiguring type and compensating type. The complete classification of custom power devices is shown in the figure.

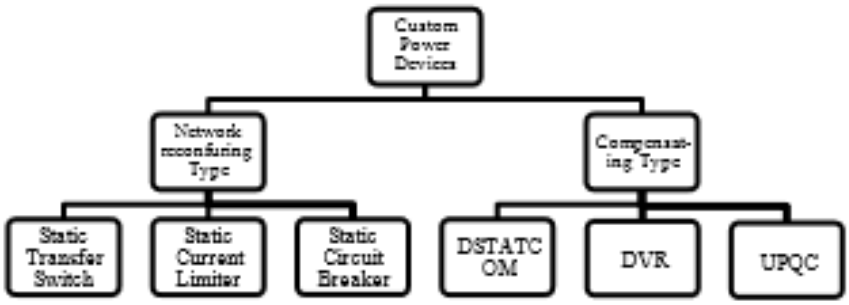

Fig 1. Custom power devices

Power quality issue

Various power quality problems:-Power surge, voltage spikes, notching, blackout, brownout, voltage flickering, harmonic, and voltage unbalance.

Network reconfiguring type custom power 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 series connecting devices that reduces fault current level by inserting series inductance in faulty path.it consists of pair of GTO with snubber circuit and inductor.

B. Static Transfer Switch.
Static Transfer 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 2.

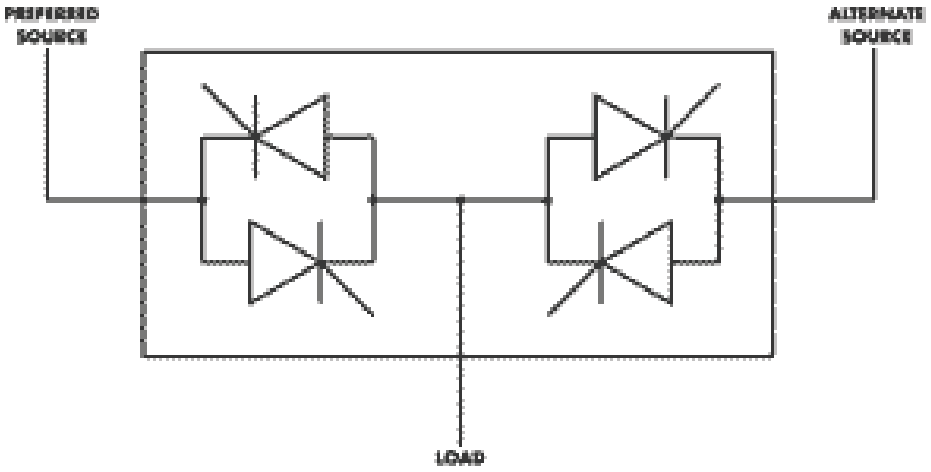

Fig.2 static transfer switch (STS)

As shown in the Fig 2STS are connected in the bus tie position and contain two pairs of anti-parallel thyristors to allow fast transfer of power from faulty feeder to an alternative feeder within the time scale of milliseconds When fault occurs primary source affected, and then load is fed from alternating source through switch 2. The STS are effective devices to protect sensitive loads against power quality disturbance, to ensure rapid transfer between afaulty feeder and healthy feeder, a make-before break or break-before-make switching strategy is implemented in STS controller circuit to reduce negative switching impacts on load. Which means it supplied an uninterrupted power at distribution level to customers. The limitation of this switch is that, in high power application the load current leads the conducting losses. The conducting losses are in the range of 0.5 to 1% of the load power. A hybrid STS has been proposed in this switch a conservative circuit breaker is connected in shunt with thyristors or GTO's.

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 3.

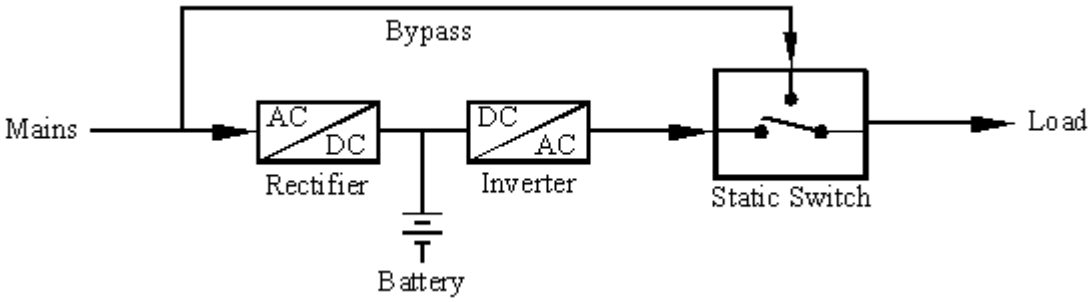

Fig.3 single line diagram of UPS

In UPS load has received the power from source via two stage operation: conversion (ac/dc) and inversion (dc/ac). During voltage dip or an interruption, the load voltage is made constant by energy, generated through battery. The performance of ups is depending on energy storage capacity of battery. For high power load financially, it is not suitable because of two conversions the maintenance cost of battery has become too high.

Compensating power devices

The compensating custom power devices are used for active filtering, load balancing, and power factor improvement voltage regulating (sag / swell). 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. 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.4. The DSTATCOM consists of a VSI, dc energy storage device, an ac filter and coupling transformer.

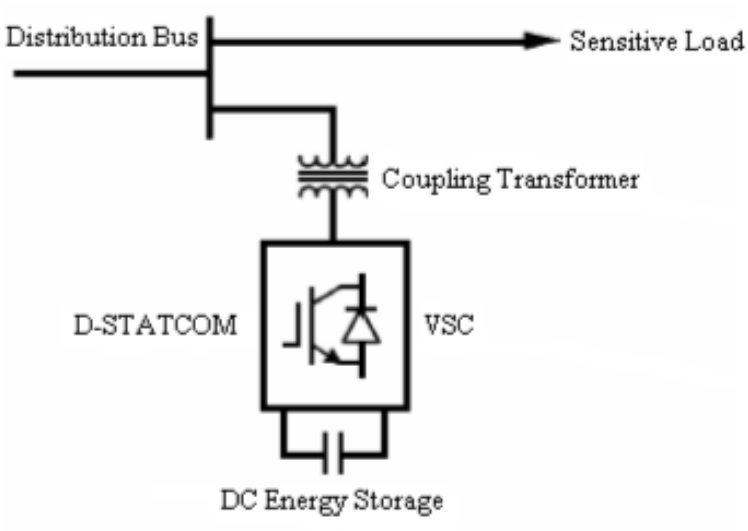

Fig 4. single line diagram for DSTATCOM

In the power circuit, VSI converts DC voltage into controllable ac voltage, synchronized by ac filter and connected to AC distribution line through coupling transformer. The DSTATCOM can also rely and absorbed active power, by using energy storage in sufficient amount. The operating principle of DSTATCOM that it continuously monitors the load voltages and currents, determines the amount of compensation required by distribution system for a verity of disturbances. In this scheme the active power flow is controlled by the angle between the ac system and VSI voltages, the reactive power flow is controlled by the difference between the magnitudes of these voltages. The DSTATCOM operates in both current and voltage control modes.

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. Also known as series voltage booster.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 7.

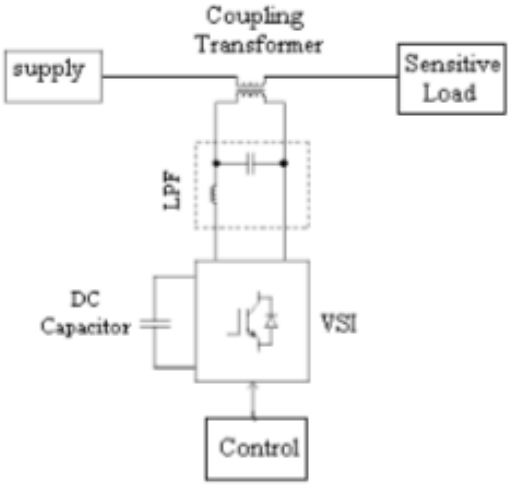

Fig.7 Block diagram for DVR

It consists of an 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 irregulation, the DVR controllers generate a reference voltage, and compare it with source voltage and inject synchronized voltage to maintain the load voltage constant. The energy storage devices provide the required power to synchronized injected voltage. The ac filter overcomes the effects on winding of coupling transformer and switching losses of control signal generating techniques for VSI.

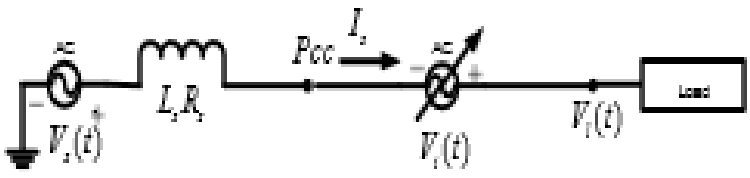

Fig.8 simplified equivalent circuit DVR

Where Vs(t) supply voltage, Vi(t) injection voltage of DVR, and Vl(t) load voltage are connected in series. From Fig 9 the load voltage is given as:

Vl(t)=Vi(t)+Vs(t)

Therefore DVR is supposing as an external voltage source of controlled amplitude, frequency, and phase angle. The aim of using DVR is to maintain the amplitude, and phase angle of fixed load voltage.

C. Unified Power Quality Compensator (UPQC).

It is a common operation of series and shunt active conditioner. Shunt active power filter capability of the current compensation, series active power filter capability of voltage compensation allow mitigation of various power quality problem. The single line diagram of unified power quality compensator is shown in Fig 9. To compensate under voltage shunt connected active conditioner need to absorb active power injected by series conditioner in series. to compensate overvoltage active conditioner absorb active power keeping DC link charged. Two type of are UPQC are suggested in literature surveys. One is called Left- Shunt UPQC and another is known as Right-Shunt UPQC. The overall performance of right-shunt UPQC is better than left-shunt UPQC. When UPQC is connected between two feeders then, called Interline Unified Power Quality Compensator (IUPQC).

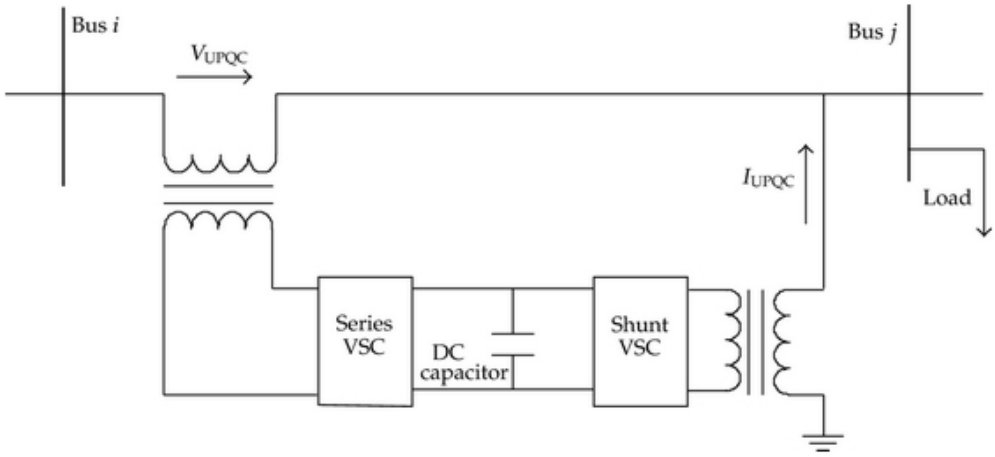

Fig.9 Single line diagram of UPQC

Simulation (sample): Sample simulation result for voltage sag /swell using DVR with MATLAB/Simulink.

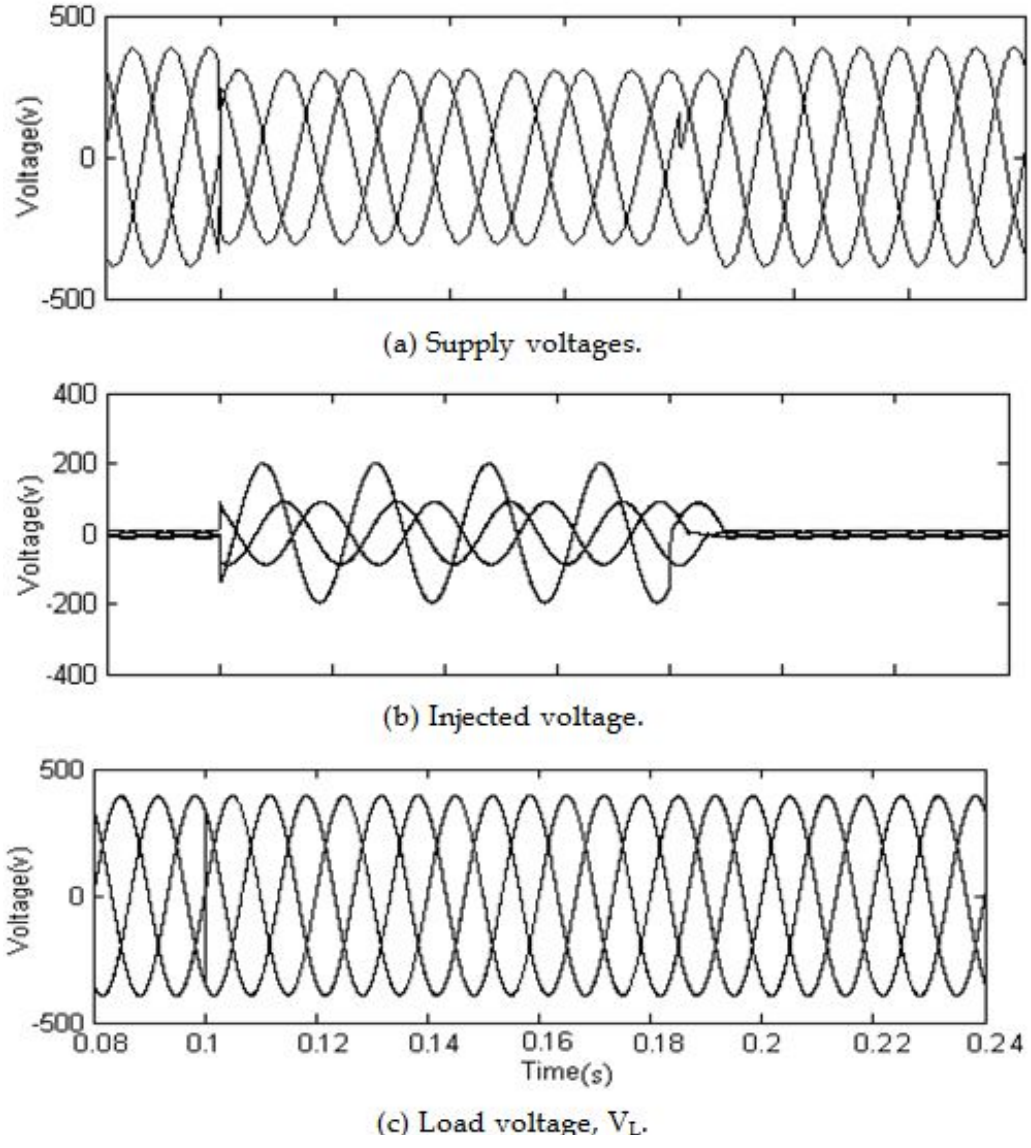

Fig.10: Simulation result of DVR response to a balancevoltage (SAG)

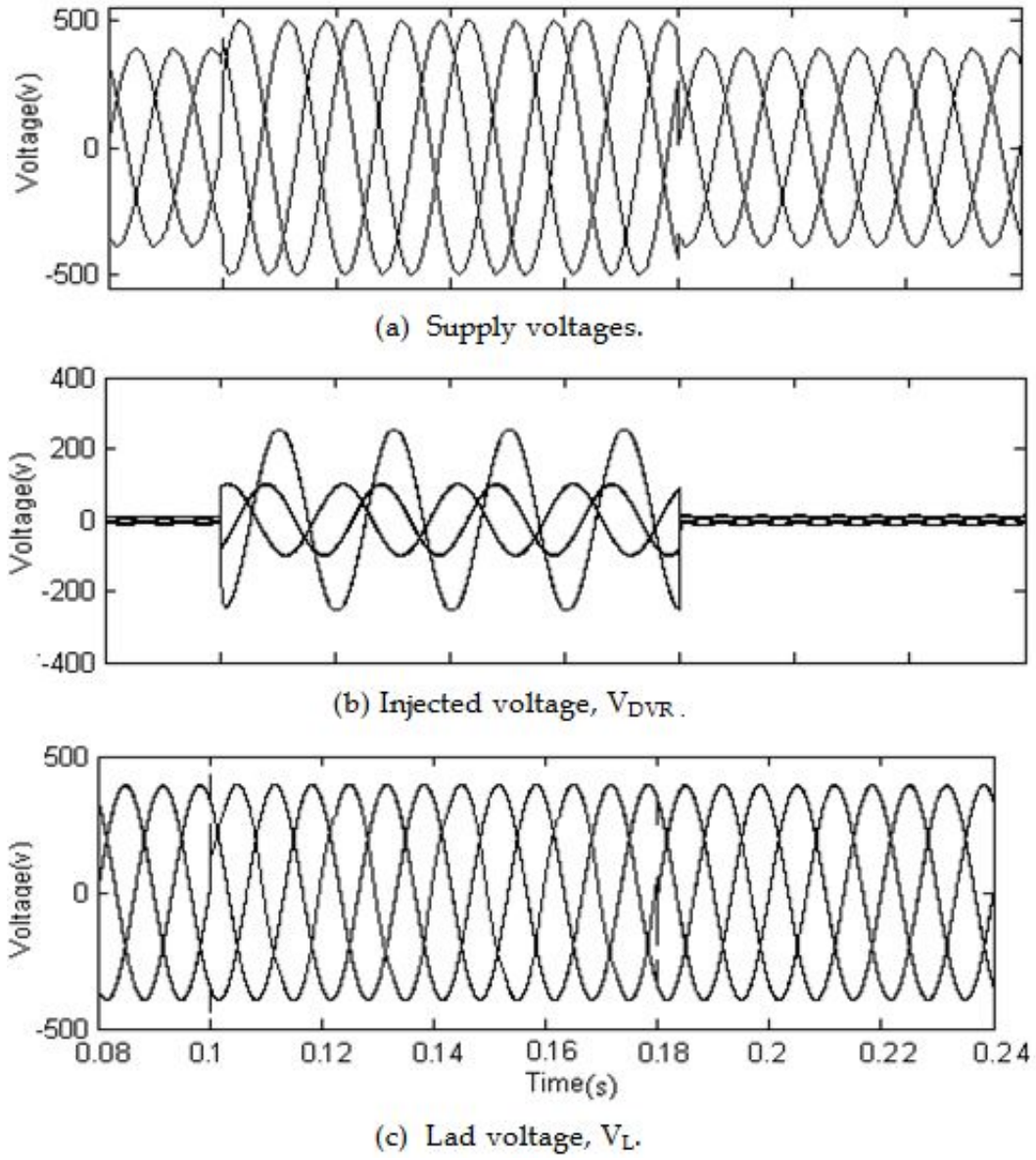

Fig. 11: Simulation result of DVR response to a balance voltage (swell)

Table-I: Applications of Custom Power Device

Custom Power Devices	**Application's**
Static transfer switch (STS)	• Voltage sag and swell protection • Transfer of power from different feeder (transfer load)
Static current limiter /Static Circuit Breaker (SCL)	• Fault Current Limitation • Break Faulted Circuit
Distribution Static Compensator (D -STATCOM)	• Load current balancing • Flicker effect compensation • Power factor improvement • Current Harmonic compensation
Dynamic Voltage Restorer (DVR)	• Voltage regulation • Flicker attenuation • Voltage sag and swell protection • Voltage balancing
Unified Power Quality Compensator (UPQC)	• VAR compensation • Harmonic suppression • Current balancing • Active and reactive power control • Voltage balancing • Voltage regulation

Conclusions

This paper provides a brief review of custom power devices which has been installed in power distribution system to eliminate various power quality disturbances; voltage sag/swells, flicker, dip, current harmonics, power factor reduction. This devices applied at the distribution system with purpose of protect entire plant, feeder, loads. The DSTATCOM, which is connected in shunt can provide good power quality in both transmission and distribution level. UPQC is the key of custom power devices, can compensate both voltage and current related problems at the same time. This entire device integrated to form custom power park. The entire customers are benefit from high quality of power. Custom power devices for power quality improvement further analyzed by using MATLAB/SIMULINK.

References

[1] C. Alvarez, J. Alamar, A. Domijan Jr., A. Montenegro, and Song, *"An investigationtowardnew technologies and issues in power quality, "* in Proc. 9th Int. Conf Harmon. Qual. Power, vol. 2, 2000, pp. 444-449.

[2] ArindamGhosh, Gerard Ledwich, *"Power Quality Enhancement Using Custom PowerDevices"* Kluwer Press, 2002.

[3] M. L. Crow, *"Power quality enhancement using custom power devices*, " IEEE Power and Energy Magazine, vol.2, pp.50, April 2004
[4] M.H. Haque, "*Compensation of distribution system voltage sag by DVR and D-STATCOM*, " in Proc. IEEE Power Tech., vol.1, pp.5, Sept.2001.
[5] H. Mehta, V. H. Tahiliani, J. E. Sullivan, *"Custom Power: an opportunity for energyconversion, "* in Proc of the International Conference on Electricity Distribution CIRED 1993, pp. 5.23/1- 5.23/6.
[6] C. Sankaran, "*Power quality*, " (CRC Press, New York, 2001).
[7] J. Stones and A. Collinson, *"Power quality, "* Power Eng. Journal, vol.15, pp.58-64, April 2001.
[8] M. H. J. Bollen, "*What is power quality?"* Electric Power Systems Research, vol.66, pp.5-14, July 2003.
[9] A.ElMofty, K. Youssef, *"Industrial power quality problems*, " in Proc. on IEE Int. ConfExhib. on Electricity Distribution, 2001, vol.2, June 2001.
[10] Gurlaskie, McCormick, Williams, *"Dynamic Restoration of Voltage Sags Due to 12 kVDistribution System Faults"* .IASTED Conference, October 1997.
[11] Abi-Samra, Sohn, Legro, Malcolm, and Sundararm, *"Analysis of Voltage Sags on Disfribution Systems-Part 2"* Proceedings of the 9th International Conference on Power Quality Solutions/Alternative Energy, September 1996.
[12] D.M. Vilathgamuwa, A.A.D.R. Perera, S.S. Choi, *"Voltage Sag Compensation with Energy Optimized Dynamic Voltage Restorer"*, IEEE Trans. on Power Del., Vol. 11, No. 3, pp. 928-936, July 2003.
[13] P. Boonchiam, N. Mithulananthan, *"Understanding of Dynamic Voltage Restorers through Matlab Simulation"*, Thammasat Int. J. Sc. Tech., Vol. 11, No. 3, July-Sept. 2006.
[14] "*Custom Power-State of the Art"* Cigre WG14.31, 2000. 22.
[15] N. G. Hingorani, "*Introducing custom power, "* vol.32, pp.41-48, June1995 23.
[16] Guide for Application of Power Electronic Guide for Application of Power Electronics for *Power Quality Improvement on Distribution Systems Rated*] kV through 38 kV, IEEE P1409 Distribution Custom Power Task Force, 2003