MANTECH Publications

Journal of Electrical Power System Engineering & Technology
Volume 7, Issue 1, January-April, 2022

A Review Paper on Power Quality Issues & Improvement Using Power Devices

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Abstract

The term electric power quality (PQ) is generally used to assess and to maintain the good quality of power at the level of generation, transmission, distribution, and utilization of AC electrical power. Nonlinear loads. Therefore, power quality is quantified in terms of voltage, current, or frequency. In this paper power quality problems can be viewed as the difference between the quality of power supplied and the quality of power required for reliable operation of the load equipment The new concept of advanced power electronic based Custom Power Devices (CPDs) mainly distributed static synchronous compensator (D-STATCOM), dynamic voltage restorer (DVR) and unified power quality conditioner (UPQC) have been developed due to lacking the performance of traditional compensating devices to minimize power quality disturbances.

Keywords: *Power generation, seebeck effect, Thermo-electric generator, waste-heat, recovery, alternative green technology, direct energy conversion, thermal heat*

INTRODUCTION

Basically Power Quality as the ability of a system or equipment to function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic disturbances to anything in that environment. Power Quality mainly deals with Continuity of the supply and Quality of the voltage.

Classification of Power Quality Issues:-

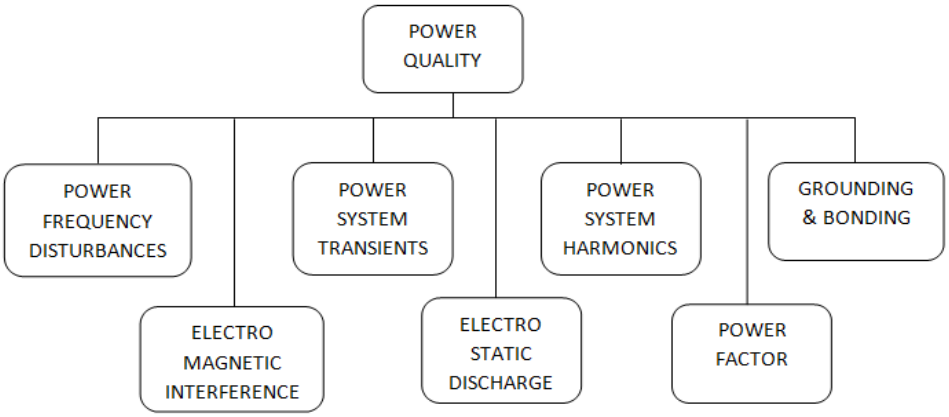


Fig. 1 Classification of Power Quality Issues

1 Power Frequency Disturbances:-

It is a low frequency phenomenon that result in voltage sag & swell. Power frequency disturbances are generally source or load generated due to fault or switching operation in power system.

2. Power System Transient:-

It is a very fast but very short duration events that produce distortion, and distortion is in terms of Notching, Ringing and Impulse. The mechanism by which transient energy is propagated in power lines transfer to other electrical circuits and eventually dissipated at different from the factors that affects the power frequency disturbances.

3. Power System Harmonics:-

It is low frequency phenomena characterized by waveform distortion which introduces harmonics frequency component. Voltage and current harmonics have adverse effect on power system operation as well power system components.

4. Grounding and Bonding:-

The primary objective of grounding is Safety, to provide low impedance path for the flow of fault current. Another objective of grounding is to create ground reference plane called Signal Reference Ground (SRG).

5. Electro-magnetic Interference (EMI):-

Electro-magnetic interference i.e. interaction between electrical & magnetic field and sensitive electronic circuits & devices. Other interference known is called Radio Frequency Interference. It is very distinct phenomenon compare to EMI.

6. Radio Frequency Interference (RFI):-

Radio frequency interference i.e. interaction between radio frequency field

7. Electrostatic Discharge (ESD):-

Electrostatic discharge i.e. sudden discharge between two electrically charged bodies. It causes malfunctioning & damage to electronic equipments.

8. Power Factor:-

Low power factor is responsible for equipment damage due to component overload. As a power factor is a economical consideration in power system.

Power Quality Problems:-

1. Voltage Sag (or Dip)
2. Voltage Swell
3. Voltage Fluctuation
4. Harmonic Distortion
5. Short Interruption
6. Long Interruption
7. Voltage Spikes
8. Noise
9. Voltage Imbalance

1. Voltage sag:-

Definition:

Voltage sag is a reduction in the RMS voltage in the range 0.1 to 0.9 p.u. for duration greater than half a main cycle and less than 1 minute.

Causes:

1. Sudden increasing in loads
2. Short circuits
3. Faults

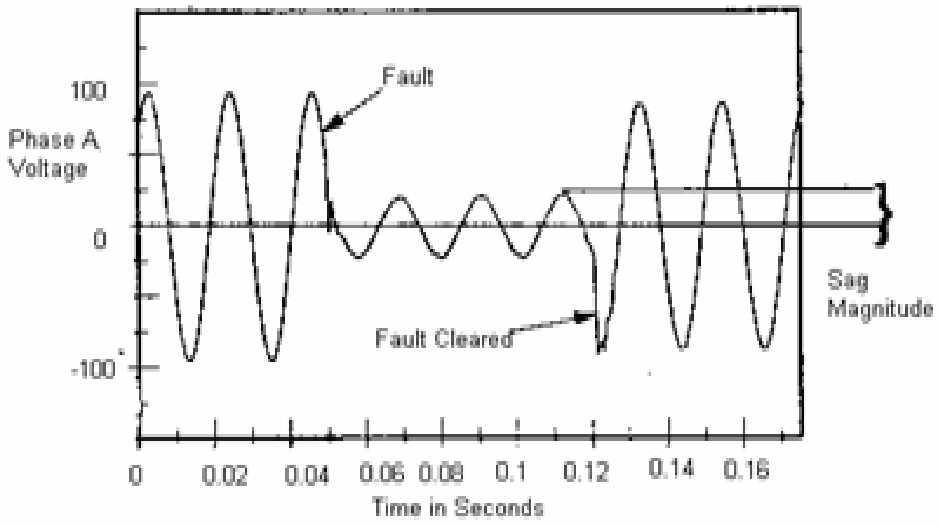


Fig.2.VoltageSag

2. Voltage swell:-

Definition:

A voltage swell is an increase in the RMS voltage in the range 1.1 to 1.8 p.u. for duration greater than half a main cycle and less than 1 minute.

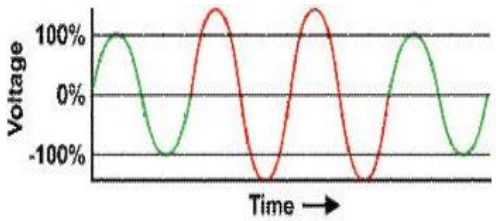


Fig. 3 Voltage Swell

Causes:

1. Sudden reduction in loads.
2. Energizing a large capacitor bank.
3. Switching off large inductive loads.

3. Voltage Fluctuations

Definition:

Voltage fluctuations are systematic variations of the voltage to a value between 0.9 to 1.1 pu

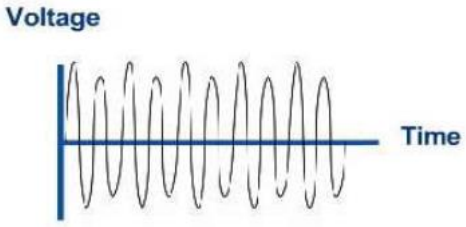


Fig. 4 Voltage Fluctuation

Causes:

Loads with continuous variation in current.

4 Power Frequency Variations:-

Definition:

Deviation of the power system fundamental frequency from it specified nominal value (e.g., 50 or 60 Hz)

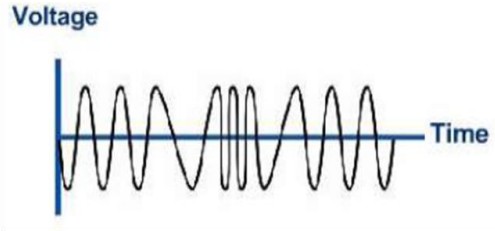


Fig. 5 Power Frequency Variation Max Permissible Range 49.2 to 50.3 Hz

Causes:

Poor speed regulation of alternator

Effects

1. System crash
2. Speed variation in motors

Solution

1. Power Conditioners.
2. VDF, UPS

5. Waveform Distortion

Definition

Waveform distortion is defined as a steady-state deviation from an ideal sine wave of power frequency principally characterized by the spectral content of the deviation.

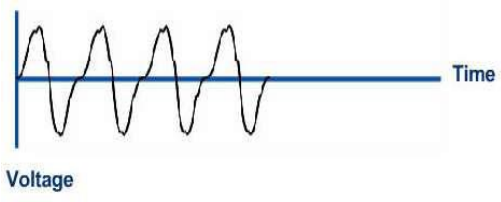


Fig. 6 Waveform Distortion

Types:

- Harmonics
- Inter Harmonics
- DC offset
- Notching
- Noise

HARMONICS

Harmonics are sinusoidal voltages or currents having frequencies that are integer multiples of the fundamental frequency.

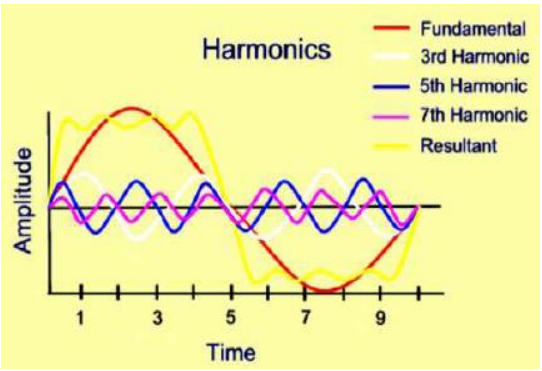


Fig. 7 Harmonics and Inter-harmonics

Inter Harmonics:

Voltages or currents having frequency components that are not integer multiples of the fundaments frequency are called inter harmonics.

Causes:

1. Non-linear loads.
2. SMPS used by personal computers.
3. VFD.
4. Electronics Devices

1. Effects:

1. Overheating conductors and transformers.
2. Decreased efficiency.
3. Increases losses

2. Solution:

1. Power Conditioners.
2. Harmonic filters.

DC OFFSET:-

Definition:

The presence of a dc voltage or current in an ac power system is termed dc offset.

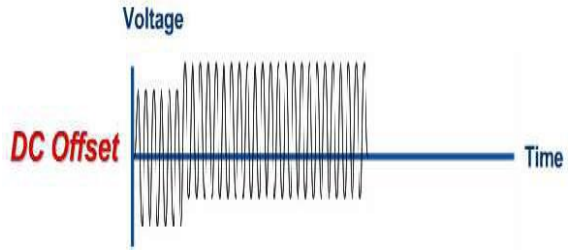


Fig. 8 DC Offset

Causes:

1. Fault in power
2. Electronic devices.

Effects:

1. Overheating of transformers.

2. Saturation of transformer core
3. Reduction in transformer life.

Solution:

DC Filters

NOTCHING:-

Definition:

Periodic voltage disturbance caused by the normal operation of power electronic devices.

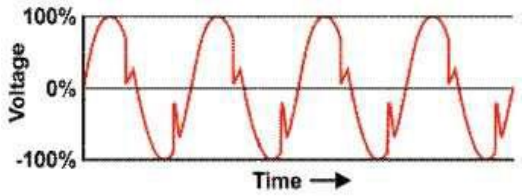


Fig.9. Notching

Causes:

3-phase power electronic converter

Effects

1.Injects harmonics to the supply.

2.Causes over heating

Solution:

Isolation of sensitive devices

NOISE

Definition:

Unwanted electrical signals with broadband spectral content lower than 200 kHz superimposed upon the power system voltage or current in phase conductors, or found on neutral conductors or signal lines.

Fig. 10 Noise

Causes:

Power electronic devices.

Control circuits

Arcing equipments

SMPS

Effects:

1. Injects harmonics to the supply.
2. Disturbance in micro controller, computers and PLC.

Solution

1. Isolation of sensitive devices.
2. Filters.
3. Power conditioners

Power Conditioning Equipment:-

These devices may be connected at the source side or in the transmission network, or at the load end. In general, these devices are connected at the Point of Common Coupling (PCC) where the load is

connected to the supply. This is done as the cost of the power conditioning device increases from load end to source side.

Power Quality Solutions:-

1. Line Voltage Regulator: Tap Changing Transformers, CVT's, Buck-Boost Regulators etc.
2. SVC (Static Var Compensator)
3. UPS (Uninterruptible Power Supplies
4. Custom Power Devices: Dynamic Voltage Regulator (DVR), D-STATCOM, Autotransformer Filters

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 a quality 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 fig. 11:

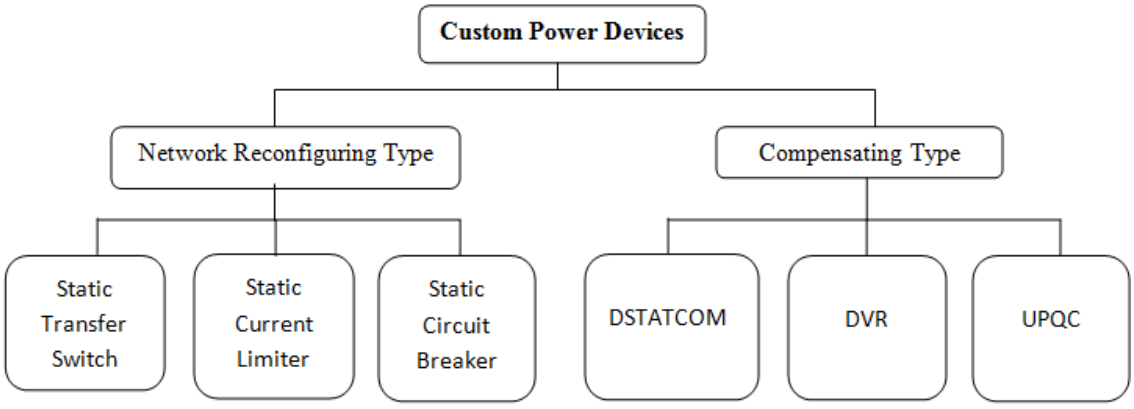


Fig 11.Custom power devices

Power quality issue

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

1. **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 12.

As shown in the Fig. 12 STS 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 a faulty 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.

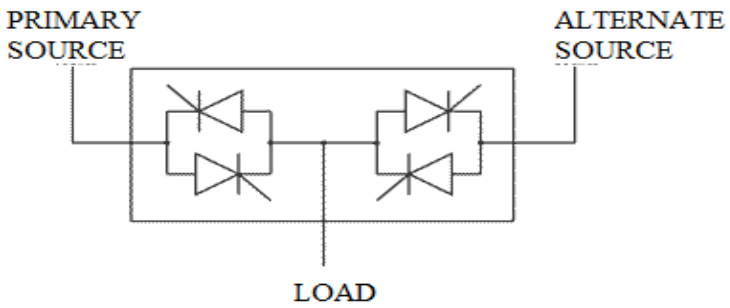


Fig.12 Static Transfer Switch (STS)

Which means it supplied an uninterrupted power at distribution level to customers. The limitation of this switches 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 13.

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.

2. 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.

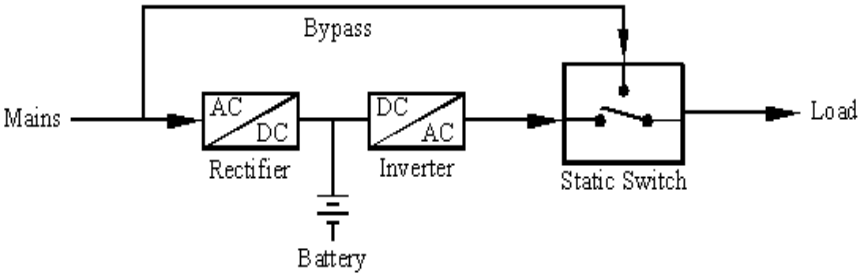


Fig.13 single line diagram of UPS

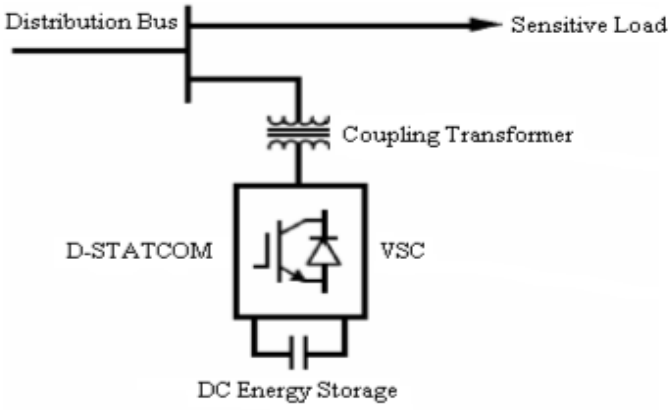


Fig 14 Single line diagram for DSTATCOM

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 15.

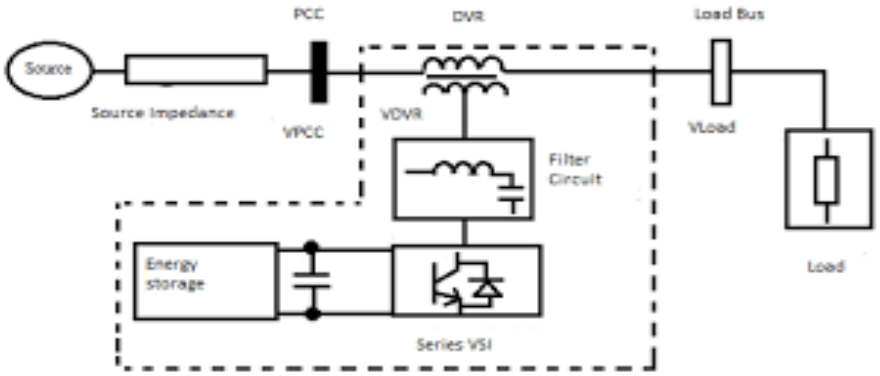


Fig.15 Block diagram for DVR

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.

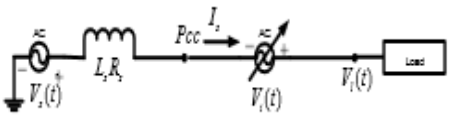


Fig.16. simplified equivalent circuit DVR

Where,

Vs(t) supply voltage,

Vi(t) injection voltage of DVR, and

Vl(t) load voltage are connected in series.

From Fig 8 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 17. 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).

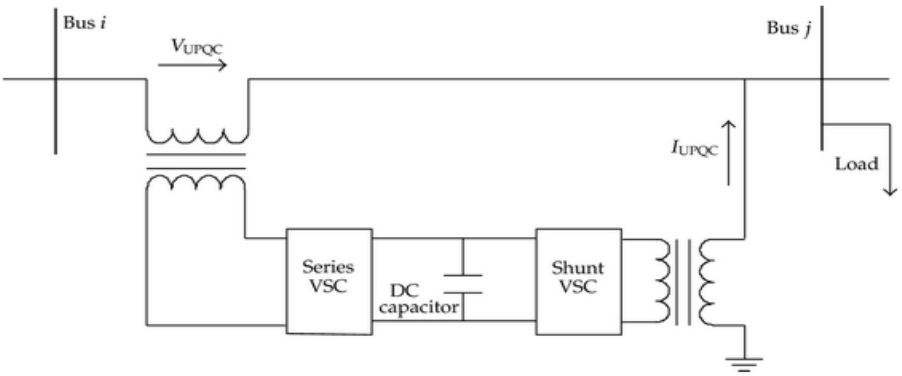
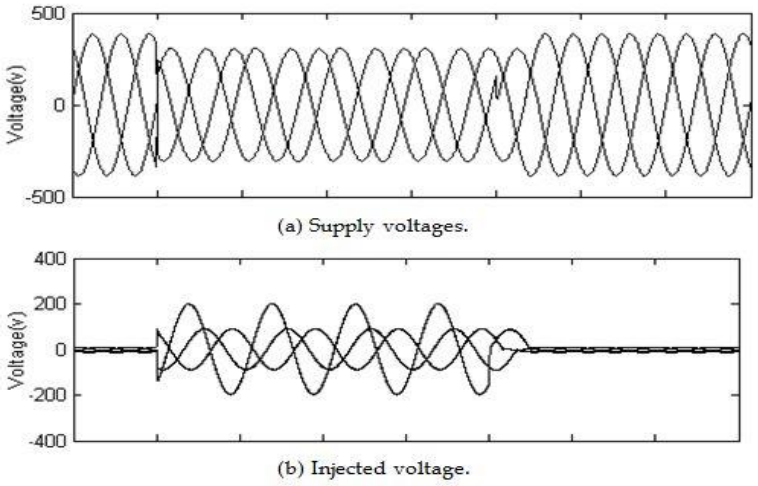
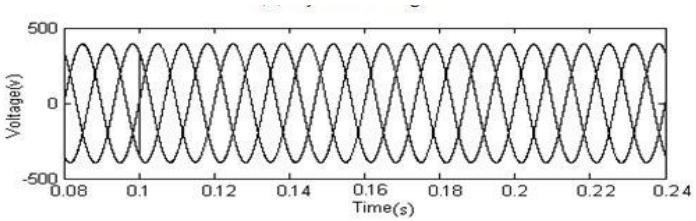


Fig.17 Single line diagram of UPQC

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





(c) Load voltage, V_L.

Fig.18: Simulation result of DVR response to a balance voltage (SAG)

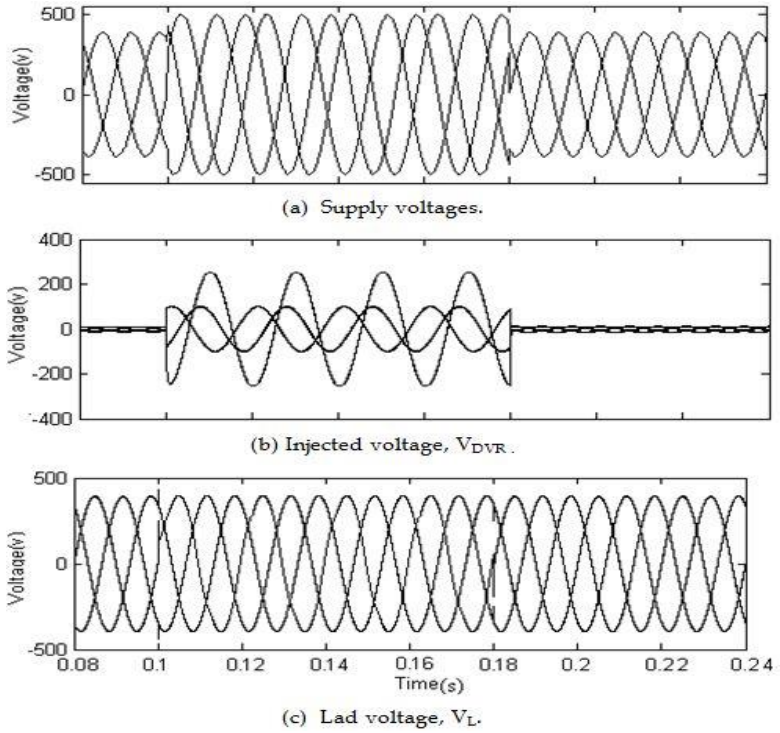


Fig. 19: Simulation result of DVR response to a balance voltage (swell)

Table-1: Applications of Custom Power Device

Sr. No.	Custom Power Devices	Application's
1	Static transfer switch (STS)	Voltage sag and swell protection Transfer of power from different feeder (transfer load)
2	Static current limiter /Static Circuit Breaker (SCL)	Fault Current Limitation Break Faulted Circuit
3	Distribution Static Compensator (D - STATCOM)	Load current balancing Flicker effect compensation Power factor improvement Current Harmonic compensation

4	Dynamic Voltage Restorer (DVR)	Voltage regulation Flicker attenuation Voltage sag and swell protection Voltage balancing
5	Unified Power Quality Compensator (UPQC)	VAR compensation Harmonic suppression Current balancing Active and reactive power control Voltage balancing Voltage regulation

IMPACTS ON ENVIRONMENT AND SOCIETY:-

1. The mitigation of all the power quality related issues leads to the economic operation of the power system.

2. A technically sound quality of power will be supplied to the equipments, thereby leading to their smooth operation and ensuring a long life for them.

3. The elimination of harmonics and other issues leads to the proper operation of the system, thereby eliminating the unwanted vibrations and keeping the system stable.

4. The reactive power is compensated at an acceptable and affordable cost and thus, the system efficiency improves.

5. The power factor is improved; this leads to a heavy savage in the costs of electricity bills.

6. Above all, the problem of power pollution is eliminated.

CONCLUSION

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 investigation to ward new technologies and issues in power quality," in Proc. 9th Int. Conf Harmon. Qual. Power, vol. 2, 2000, pp. 444-449.

2. Arindam Ghosh, Gerard Ledwich, "Power Quality Enhancement Using Custom Power Devices" 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 DSTATCOM, " 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 Energy conversion, " in Proc of the International Conference on Electricity Dstribution 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. Conf Exhib. on Electricity Distribution, 2001, vol.2, June 2001.

10. Gurlaskie, McCormick, Williams, "Dynamic Restoration of Voltage Sags Due to 12 kV Distribution System Faults" .IASTED Conference, October 1997.

11. Abi-Samra, Sohn, Legro, Malcolm, and Sundararm, "Analysis of Voltage Sags on Distribution 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