Mitigation Techniques of Power Quality Issues in Electrical Power System

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Abstract - *With the increased use of sophisticated electronics, high efficiency variable speed drive, power electronic controllers and also more & more non-linear loads Power Quality has become an increasing concern to utilities and customers. This paper presents the problems associated with the power quality or power quality issues and their mitigation techniques.*

In this paper the main power quality (PQ) problems are presented with their associated causes and consequences. The economic impacts associated with PQ are characterized. Also this paper tries to give the solution for reducing the losses produced because of harmonics and increasing the quality of power at consumers' side.

Key Words: Power Quality, Harmonics, Transients, Filters, Power Quality Cost etc.

1. Introduction

The electric power network has undergone several modifications from the time of its invention. The modern electric power network has many challenges that should be met in order to deliver qualitative power in a reliable manner. There are many factors both internal and external that affect the quality and quantity of power that is being delivered.

This paper discusses the different power quality problems, their causes its consequences & their mitigation techniques.

1.1 Power Quality

The quality of electric power delivered is characterized by two factors namely- "continuity" of supply and the "quality" of voltage. As indicated by IEEE standard 1100, Power Quality is characterized as-

"The idea of controlling and establishing the touchy supplies in a manner that is suitable for the operation of the gear."[9]

1.2 Necessity of Power Quality Audit

a) Newer generation load equipment with microprocessor based controls and power electronics devices are more sensitive to power quality variations.

b) Any user has increase awareness of power quality issues. Such as interruptions, sags and switching transients.

c) Many things are now interconnected in a network. Failure of any component has more consequences.

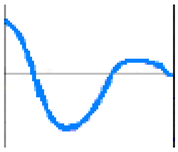
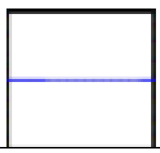
d) Power quality problem can easily cause losses in the billions of dollars. So entire new industry has grown up to analyze and correct these problems.

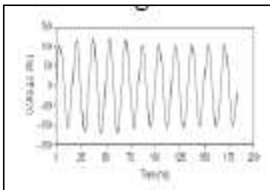
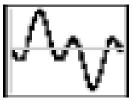
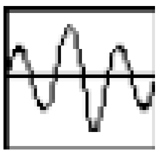
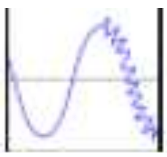
e) The increase in emphases on overall power efficiency has resulted in continuous growth of application. Such as high efficiency adjustable speed motor drives capacitor use for power factor correction. These results in increase harmonic level which degrade the Power quality.

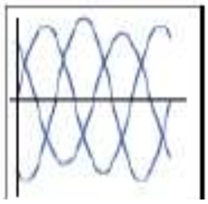
2. Power Quality Problems

There are many reasons by which the power quality is affected. The occurrence of such problems in the power system network is almost indispensable. Therefore, to maintain the quality of power care must be taken that suitable devices are kept in operation to prevent the consequences of these problems. Here an overview of different power quality problems with their causes and consequences is presented [3].

Table -I: Causes & Consequences of Issues of Power Quality[1], [2]

1. **Voltage Sag (dip)** 	**Description:** A decrease of the normal voltage level between 10 and 90% of the nominal rms voltage at the power frequency, for durations of 0.5 cycles to 1 minute. **Causes:** Faults on the transmission or distribution network (most of the times on parallel feeders). Faults in consumer's installation. Connection of heavy loads and start-up of large motors. **Consequences:** Malfunction of information technology equipment, namely microprocessor-based control systems (PCs, PLCs, ASDs, etc) that may lead to a process stoppage. Tripping of contactors and electromechanical relays. Disconnection and loss of efficiency in electric rotating machines.
2. **Very short Interruptions** 	**Description**: Total interruption of electrical supply for duration from few milliseconds to one or two seconds. **Causes**: Mainly due to the opening and automatic reclosure of protection devices to decommission a faulty section of the network. The main fault causes are insulation failure, lightning and insulator flashover. **Consequences**: Tripping of protection devices, loss of information and malfunction of data processing equipment. Stoppage of sensitive equipment, such as ASDs, PCs, PLCs, if they're not prepared to deal with this situation.
3. **Long interruptions** 	**Description:** Total interruption of electrical supply for duration greater than 1 to 2 seconds **Causes:** Equipment failure in the power system network, storms and objects (trees, cars, etc) striking lines or poles, fire, human error, bad coordination or failure of protection devices. **Consequences:** Stoppage of all equipment.
4. **Voltage Spike** 	**Description:** Very fast variation of the voltage value for durations from a several microseconds to few milliseconds. These variations may reach thousands of volts, even in low voltage. **Causes:** Lightning, switching of lines or power factor correction capacitors, disconnection of heavy loads. **Consequences:** Destruction of components (particularly electronic components) and of insulation materials, data processing errors or data loss, electromagnetic interference.
5. **Voltage swell**	**Description:** Momentary increase of the voltage, at the power frequency, outside the normal tolerances, with duration of more

	than one cycle and typically less than a few seconds. **Causes:** Start/stop of heavy loads, badly dimensioned power sources, badly regulated transformers (mainly during off-peak hours). **Consequences:** Data loss, flickering of lighting and screens, stoppage or damage of sensitive equipment, if the voltage values are too high.
6. Harmonic distortion 	**Description:** Voltage or current waveforms assume non-sinusoidal shape. The waveform corresponds to the sum of different sine-waves with different magnitude and phase, having frequencies that are multiples of power-system frequency. **Causes:** *Classic sources*: Arc furnaces, welding machines, rectifiers, and DC brush motors. *Modern sources*: All non-linear loads, such as power electronics equipment including ASDs, switched mode power supplies, data processing equipment, high efficiency lighting. **Consequences:** Increased probability in occurrence of resonance, neutral overload in 3- phase systems, overheating of all cables and equipment, loss of efficiency in electric machines, electromagnetic interference with communication systems, errors in measures when using average reading meters, nuisance tripping of thermal protections.
7. Voltage fluctuation 	**Description:** Oscillation of voltage value, amplitude modulated by a signal with frequency of 0 to 30 Hz. **Causes:** Arc furnaces, frequent start/stop of electric motors (for instance elevators), oscillating loads. **Consequences:** Most consequences are common to under voltages. The most perceptible consequence is the flickering of lighting and screens, giving the impression of unsteadiness of visual perception.
8. Noise 	**Description:** Superimposing of high frequency signals on the waveform of the power-system frequency. **Causes:** Electromagnetic interferences provoked by Hertzian waves such as microwaves, television diffusion, and radiation due to welding machines, arc furnaces, and electronic equipment. Improper grounding may also be a cause. **Consequences:** Disturbances on sensitive electronic equipment, usually not destructive. May cause data loss and data processing errors.
9. Voltage Unbalance	**Description:** A voltage variation in a three-phase system in which the three voltage magnitudes or the phase angle differences between them are not equal. **Causes:** Large single-phase loads (induction furnaces, traction loads), incorrect distribution of all single-phase loads by the three phases of

	the system (this may be also due to a fault). **Consequences:** Unbalanced systems imply the existence of a negative sequence that is harmful to all three phase loads. The most affected loads are three-phase induction machines.

The power quality issues such as voltage sags, swells, harmonics ,transients and their mitigation techniques those are suitable for different types of voltage sags , filter deign for reducing harmonic distortion and surge arrester sizing for location of transients.

The main objective of this paper is:

I. To investigate the suitable mitigation techniques.

II. The power quality mitigation analysis is made by using Mi Power Software.

III. Observe the effectiveness of Static VAR Compensator (SVC), Distribution Static Compensator (DSTATCOM), Passive harmonic filter and surge arrester .

3. Power Quality Mitigation Techniques:

There are different solutions to mitigate Power Quality problems. The solution adopted will be tailored specifically to the problem and site.

The measures used in this paper to deal with Power Quality disturbances are:

- Static VAR Compensator (SVC)
- Distribution Static Compensator (DSTATCOM)
- Passive harmonic filters
- Surge arresters

A. Static VAR Compensator (SVC):

SVC is a shunt device, which is a family member of flexible a.c. transmission system (FACTS) uses power electronics equipment to control reactive power flow.

The term static is used to differentiate SVCs from rotating var compensators (synchronous motors or generators). The SVC regulates the voltage at its terminals by controlling the amount of reactive power injected into or absorbed from the power system.

When the system voltage is low, the SVC generates reactive power (capacitive behavior). In this manner, the demand of reactive power of the load is provided by the SVC and the feeding lines are relieved. As a result, the voltage drop decreases and the voltage at the load terminals increase. Similarly, when the system voltage is high, the SVC absorbs reactive power (inductive behavior) [5].

There are two types of SVC:

1. Fixed Capacitor-Thyristor Controlled Reactor

(FC-TCR)

2. Thyristor Switched Capacitor – Thyristor Controlled Reactor (TSC- TCR).

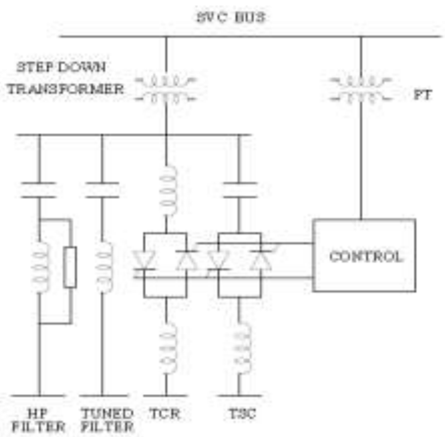


Figure1. Typical static var system

B. Distribution Static Compensator (DSTATCOM):

The Distribution Static Compensator (DSTATCOM), previously referred to as a static condenser (STATCOM) or advanced static VAR compensator (ASVC) or self commutated static VAR compensator is a shunt connected reactive compensation equipment which is capable of generating and/or absorbing reactive power whose output can be varied as to maintain control of specific parameters of the electric power system. The term static indicates that it is based on solid state power electronic switching devices with no moving or rotating components. The terms synchronous and compensator indicate that it is analogous to an ideal synchronous machine generating a balanced set of 3 sinusoidal phase voltages at fundamental frequencies [8].

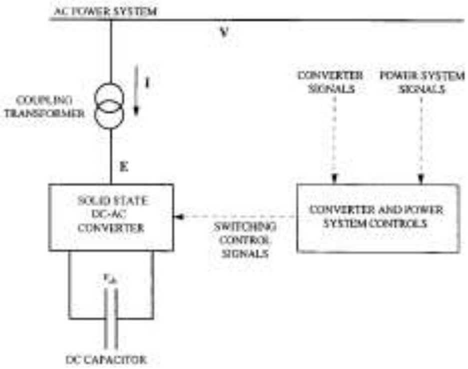


Figure2. Typical DSTATCOM overview

C. Harmonic Filters:

One of the most common methods of controlling harmonic distortion is to place a passive shunt harmonic filter close to the harmonic producing load(s), which is a source of harmonic current. The objective of the harmonic filter is to shunt some of the harmonic current from the load into the filter, thereby reducing the amount of harmonic current that flows into the power system. The simplest type of shunt harmonic filter is a series inductance/capacitance (LC) circuit [6].

D. Surge Arrester:

Arresters and TVSS (Transient Voltage Surge Suppressers) devices protect equipment from transient overvoltage by limiting the maximum voltage. However, TVSSs are generally associated with devices used at the load equipment. A TVSS will sometimes have more surge-limiting elements than an arrester, which most commonly consists solely of Metal Oxide Varistors (MOV) blocks. An arrester may have more energy-handling capability. Overvoltage protection devices or surge protectors protect facilities and equipment against transient voltage surges produced by lightning (μs), electrostatic discharges (ns), switching (ms) or long voltage deviations at power frequency(s). They limit or eliminate voltage surges up to acceptable limits, blocking or shorting them to earth.

4. Conclusions

The demand for electric power is increasing at an exponential rate and at the same time the quality of power delivered became the most prominent issue in the power sector. Thus, to maintain the quality of power the problems affecting the power quality should be treated efficiently. Among the different power quality problems, voltage sag is one of the major one affecting the performance of the end user appliances. In this project the methods to mitigate the voltage sag are presented. From this project, the following conclusions are made-

- Among the different methods to mitigate the voltage sag, the use of FACT devices is the best method.
- The FACT devices like DVR, D-STATCOM are helpful in overcoming the voltage unbalance problems in power system.
- DVR is a series connected device and injects voltage to compensate the voltage imbalance.
- D-STATCOM is a shunt connected device and injects current into the system.
- These devices are connected to the power network at the point of interest to protect the critical loads.
- These devices also have other advantages like harmonic reduction, power factor correction.
- The amount of apparent power infusion required by D-STATCOM is higher than that of DVR for a given voltage sag.
- DVR acts slowly but is good in reducing the harmonic content.
- Both DVR and D-STATCOM require more number of power electronic switches and storage devices for their operation.
- To overcome this problem, PWM switched auto-transformer is used for mitigating the voltage sag.
- Here the number of switches required is less and hence the switching losses are also reduced.
- The size and cost of the device are less and hence PWM switched auto transformer is an efficient and economical solution for voltage sag mitigation.

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