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# Mitigation of Voltage Sag and Swell using D-STATCOM to improve Power Quality

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## Abstract

This paper shows the modelling and simulation procedure for power quality improvement using D-STATCOM for voltage sag and swell mitigation in an unbalanced distribution system's-STATCOM is here to replace the SVC (Static Variable Compensator).Power quality is an occurrence manifested as many types of disturbance in voltage current or frequency, sensitive industrial loads that results in a failure of end user equipment. So this paper represents the` techniques for the improvement in sag and swell and interruption in a distributed system power based equipment called D- STATCOM (Distributed Static Compensator).It is most effective and efficient power electronic device used in power distribution network. It injects a current into the system to mitigate the sag, swell interruption. The control over VSC is done by SPWM. D-STATCOM has high speed control of reactive power for providing voltage stabilization. It provides protection to distribution system against voltage sag which is caused by rapid variation of reactive current demand. During transient, it provides balancing of load, correction of power factor & leading & power to active system stability.

## INTRODUCTION

In the present era power quality concern is very important .As we all see modern industrial device are mostly based on electronic devices and these device are very sensitive to disturbance. It is less tolerant to problems like voltage sag and swell harmonics to power quality problems .Electrical power is perhaps the most necessary or essential raw material used by commerce and industry in today's era. Voltage sag exhibit 85% of power quality problem that exist in power system. The most severe disturbance to industrial equipment is caused by voltage dips. So FACTS devices are used to improve the quality of power. FACTS controller enables the power to flow through such line under normal and fault condition as well. Voltage support at a load can be done by injecting reactive power 'at a load point of common coupling so that mitigation of voltage sag is reduced.

D-STATCOM is a device which gives high speed & controlling of reactive power so that problem of voltage sag and swell can be removed and to give stability or to give suppression in harmonics. It is basically a power device which provides reliable power quality distribution.

It is a device which not only provides distribution of power quality with the help of simulation software but also gives voltage sag mitigation, voltage stabilization, control of harmonics, correction and improvement of power factor % prevention of voltage flicker.

It is a device which employ a shunt of voltage boost technology with DC link capacitor so that it is capable of generating and absorbing reactive power & compensate voltage sag and swell. Voltage sag is an RMS reduction in AC voltage at a power frequency from half cycle to few seconds. It is caused by faulty in system, a fault at customer's facility or due to sudden rise in load current. High current voltage drop occurs. So D-STATCOM provides application for sensitive loads that is affected by voltage fluctuations of the system.

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## 1. POWER QUALITY EVENTS

| Electrical Disturbance | Cause of Disturbance |
|---|---|
| Impulsive Transients (Surges or Spikes) Oscillatory | • motors in air conditioners, HVAC equipment, elevators, water coolers, fans • lightning • photocopiers and laser printers • static discharge • routine utility activity • electronic air ionizers • kitchen appliances |
| Noise | • HVAC equipment • kitchen appliances • radios, telephones • light dimmers • overhead lines • electronic lighting • building transformers • electronic air ionizers • vacuum cleaners |
| Harmonic Distortion | • computers • televisions, video cassette recorders • electronic lighting |
| Sag | • motors in air conditioners, HVAC equipment, elevators, water coolers, fans • photocopiers and laser printers • routine utility activities |
| Swell | • motors in air conditioners, HVAC equipment, elevators, water coolers, fans • photocopiers and laser printers |
| Undervoltage | • improper wiring and grounding • improper voltage tap adjustment • defective building transformer |
| Overvoltage | • improper wiring and grounding • improper voltage tap adjustment • defective building transformer • crossed power lines |
| Interruption | • lightning • tripped circuit breaker, blown fuse • downed power lines |

Figure 1.1

### 1.1 POWER QUALITY TERMS

**1. Voltage fluctuation:** It is a variation of the voltage waveform in a systematic way or random voltage changes in series.

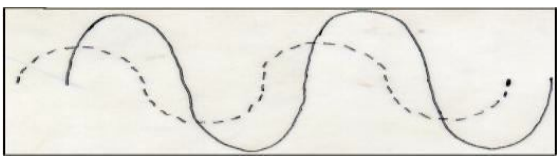


Figure 1.1.1

**2. Harmonic:** It is the clipping of the fundamental sine wave at frequencies that are multiples of the fundamental voltage varies sinusoidally at a specific frequency, usually 50 or 60 Hertz.

Odd order Harmonics: Odd harmonics have odd numbers (e.g., 3, 5, 7, 9, and 11).

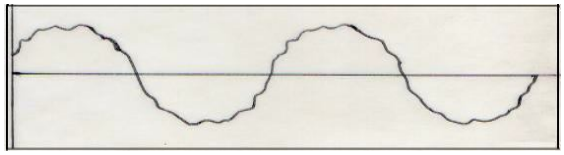
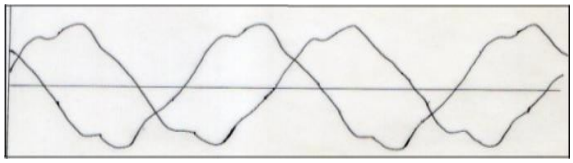


Figure 1.1.2

Even order Harmonics: Even harmonics have even numbers (e.g., 2, 4, 6, and 8)



**3. Inter harmonic:** Inter harmonic is a type of distortion in waveform which is usually a result of the signal imposed on supply voltage by equipment such as static frequency converter etc.

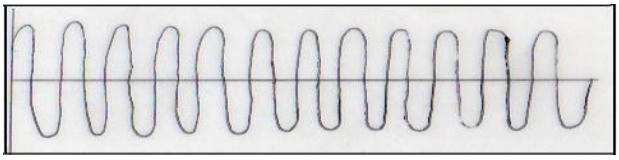


Figure 1.1.3

**4. Electrical noise:** It is a high frequency interference which is caused by a number of factors, including the operation of some electrical motor or welding of arc. This is unwanted noise on the current waveform or the power system voltage.

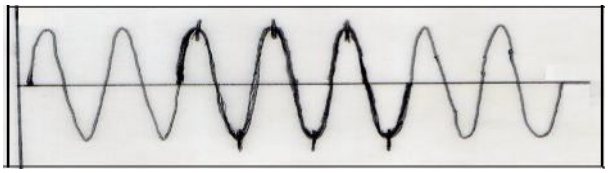


Figure 1.1.4

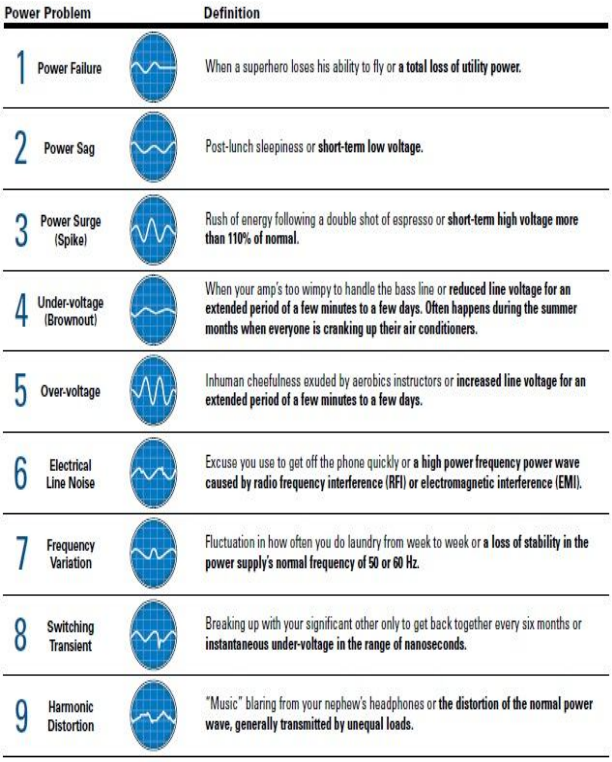



Figure 1.2

**Transients:** It is also called "surges". It varies in magnitude and it is sub cycle disturbances of a very short duration.

**Voltage Sag**: Sag is a decline of AC voltage at a particular frequency for the duration of 0.5 cycles to 1 minute's interval. **Voltage sag** is caused by sudden increase in load such as short circuits or faults, electric heaters turning on, or motors starting, or they are caused by unexpected increases in the source impedance, which is typically caused by loose connections.

**Voltage Swell: Voltage swell** is almost always caused by an abrupt fall in the load on a circuit with a damaged or poor voltage regulator, although, they can similarly be caused by a loose or damaged neutral connection.

**Noise - Random Transients:** Electrical impulses which are carried alongside standard AC current. Turning on a refrigerator, the florescent lights overhead, laser printers or working during lightning storms can all introduce line noise into the system.

## 2. POWER QUALITY PROBLEMS

It is a very grave problem in power engineering in the present time. For sensitive devices, even a very minor disturbance can cause the system to crash, interruption in the communication, flicker, impulse transients, harmonics and finally end user equipment.

It basically means to sustain sinusoidal waveform of bus voltage at rated voltage and frequency. It is basically a quality of voltage rather than electric current or power. Power quality issues can be divided into short, long and continuous durations.

Some power quality related problems are:

1. Grounding and Bonding
2. Efficiency decrease
3. Internally generated power disturbances.
4. Flicker
5. Reduced process quality
6. Interference
7. Equipment overheating due to which losses occur which results in reduction in the lifetime of the equipment.
8. Process stoppage
9. Damage to the Equipment

Problems with powering and grounding can cause data and processing errors that affect production & service qualities.

Problems like internally generated power disturbances there are much chance that the internally generated power can affect the device or the system so the overall efficiency of the system will decrease. This may be affected by flicker, interference, transients etc.

This reduces the life of equipment and finally process stoppage occurs.

**Voltage quality:**

Voltage quality is the quality of the product delivered by the utility to the customers. It is concerned with changes of the voltage waveform from the standard sinusoidal waveform. Voltage quality problems, it enforces a wide range of disturbances and production losses which is very important factor.In this Section, the following voltage quality problems are defined and briefly discussed.

**Short Interruption:**

A short interruption is the complete loss of the supply voltage with a time period of 0.5 cycle up to **3** seconds [IEEE- 1 159- 1995]. Another definition is found in literature, an interruption occurs when supply voltage or the load current decreases to less than zero.1pu for **a** period time not exceeding 1 minute. The causes of short interruptions are the same as for long interruptions, fault clearing by the protection, incorrect protection intervention, etc..

**Voltage unbalance:**

Voltage imbalance is defined as change in magnitude & phase (or phase-to- phase) voltage of the three-phase system. On percent basis it is defined by the national electrical manufacturing association (NEMA) as the maximum deviation from average to the average of the three phase-to-phase voltage. To characterize the voltage unbalance, symmetrical components are used which gives an index for describing the system unbalance.

**Phase Angle jump:**

It is basically a change or jump in the angle of phase of system voltage and of system current. current.

## 3. POWER QUALITY PROBLEM EVALUATION

A power quality issue is very important and serious issue in power system. For this we have to identify the problem due to which power quality is arising and find out the problem characterization. For this we have to find range of solutions so that we can evaluate the solution for the same. Finally we will evaluate optimum and economic solutions.

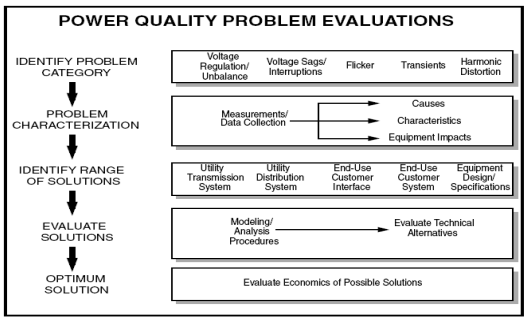



Figure 3.1

### 3.1 METHODS TO SOLVE POWER QUALITY PROBLEMS

1. **Grounding & bonding integrity:** Grounding is a method by which an electrical circuit is connected to earth. Bonding is a method in which we do intentional electrical interconnections of conductive paths in order to ensure common electrical potential between the bonded parts.
2. **Proper wiring:** An inspection of equipment for ensuring proper wiring within a limit. The entire system must check for loose, missing or improper connections at panels.
3. **Restoring technologies:** It is used for improving the power quality problem by connecting electrical loads. For example: Voltage sag, Transients, Frequency variation.
4. **VOLTAGE SAG DUE TO SLG FAULT**

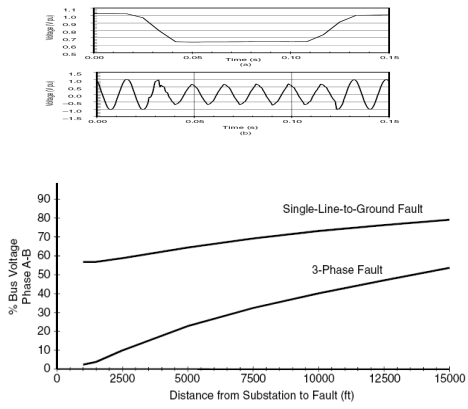



Figure 3.2

### 4.1 EFFECT OF DISTANCE ON VOLTAGE SAG

**Effect of voltage swells on equipment behaviour:** Problems in equipment may be seen during a voltage swell event include failure of sensitive electrical components or drop out of electrical components. Voltage swells may reduce the life of transformers, cables, current transducers (CTs), bus, switchgear, power transducers (PTs), & motors. The magnitude and duration are the main problems that may be observed. Voltage swells may increase the visible light output of some lighting devices.

**Causes and characterization of voltage dips:**
A Voltage dip is the important factor for power quality disturbances with electrical system of disturbances. Dips, on basis of the duration or we can say that on severity, it can cause system resetting of computers, tripping of adjustable speed drives, memory loss and this in turn leads to cease of the production process.

### 4.2 TYPE OF VOLTAGE SAG

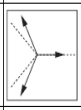
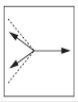
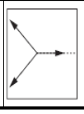
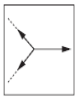
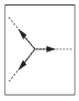
| Phase Shift | Number of Phases | | |
|---|---|---|---|
| | 1 | 2 | 3 |
| Angle |  Sag Type D: One-phase sag, phase shift |  Sag Type C: Two-phase sag, phase shift | Note: Three-phase sags should lead to relatively balanced conditions; therefore, sag type A is a sufficient characterization for all three-phase sags. |
| None |  Sag Type B: One-phase sag, no phase shift |  Sag Type E: Two-phase sag, no phase shift |  Sag Type A: Three-phase sag |

Figure 4.3.1

## 5. FACTS DEVICES AND ITS USE

It is a system which is composed of static equipment used for AC transmission of electrical energy & to enhance c controllability & increase the transfer of power flow of the network. It is a system based on power electronics.

FACTS technology is a collection of controller which can be applied individually or in co-ordination with others to control one or more of the interrelated systems parameter such as series important, shunt impedance, current, voltage & damping of oscillations.

The concept of Flexible AC transmission system has been proposed in 1995, which is called FACTs. The basic idea of FACTs is to install the power electronic devices at the high-voltage side according to the system of the power grid to make the whole system electronically controllable

These devices are able to provide reactive power and active power to the power grid rapidly. The power compensation achieved by FACTs devices could adjust the voltage of the whole system and the power flow could be satisfactorily controlled.

Generally, the FACTs devices and technology could be divided into two generations:

### 5.1 FACTS ON THE BASIS OF GENERATION

**1) Dynamic devices and fixed capacitance devices:** This comes to the category of first generation of the FACTs devices. In this generation, the devices are tap changing and phase changing transformer, series capacitors & synchronous generator. These devices are mainly controlled at the generation side of the power grid and they are expensive. The drawback of this device it could hardly be omitted.

**2) Static state compensator:** This is the second generation of the FACTs devices. It could be classified into two categories: Thyristor-based devices and fully-controlled devices based compensator. The Thyristor, called half-controlled device, because it can only be controlled to switch on but not to cut off. Static Var Compensator (SVC) and Thyristor-Controlled Series Capacitor (TCSC) come in this category. The fully controlled devices is called Gate turn Off.

The main difference between first and second generation is the capacity to generate reactive power and to interchange active power.

**FIRST GENERATION FACTS DEVICES**

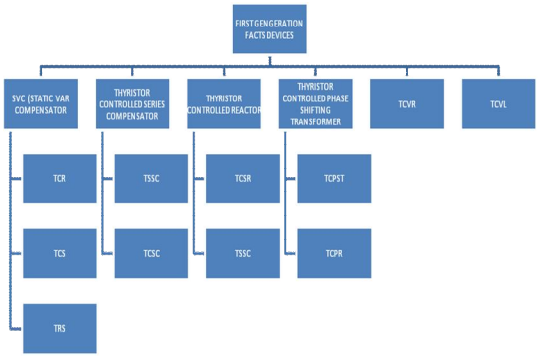



Figure 5.1.1

**SECOND GENERATION FACTS DEVICES**

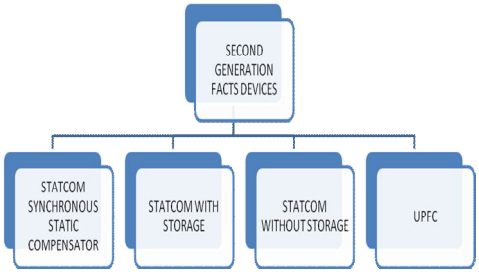


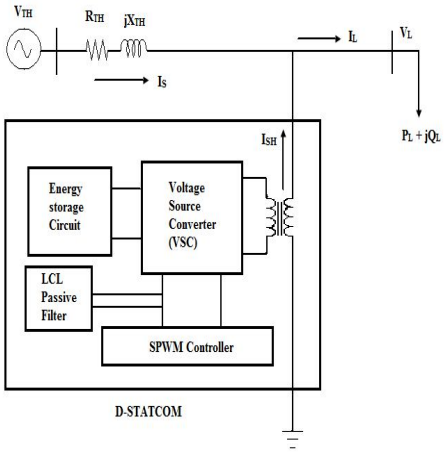

Figure 5.1.2

## 6. MODELLING OF FACTS CONTROLLERS

It will mainly introduce the second generation of the FACTs controllers. As compare to the dynamic controllers, second generation of FACTs controllers can be easily installed at any place .Although the capacitor bank can also achieve this advantage, second generation is the capacity to generate reactive power and to interchange active power.

### 6.1Shunt-connected voltage source converter (DSTATCOM)

The D-STATCOM is a combination of a3 components named as voltage source converter (VSC), output filter and the important factor is dc energy source. The DSTATCOM is basically based on that the device voltage controlled source generates a AC voltage source which is controllable by so that we can get reactive power between the DSTATCOM and important factor the distribution system. DSTATCOM has a great advantage that it can able to exchange power specially active power with distribution system which enables it to give compensation to voltage dips.




## CONCLUSION

In this report we can see that we can mitigate voltage sag and swell by using D-STATCOM. (Distribution static synchronous compensator ). In order to achieve good power quality we can use D-STATCOM which is connected through distribution system.

The report show that the voltage sags and voltage swells (such as LG, LL,) can be mitigate by injecting current through D-STATCOM to the distribution system.. The power factors increases and reaches to unity. Thus, it can be concluded that by adding D-STATCOM with LCL filter the power quality of the system increases.

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