MITIGATE VOLTAGE SAG/SWELL CONDITION AND POWER QUALITY IMPROVEMENT IN DISTRIBUTION SYSTEM USING STATCOM

Zalak N. Shah
P.G. Student (Electrical Power System)
Prof. Mr. Bhavik Prajapati , Vadodara(Gujarat),India

Abstract— **The quality of power supplied is affected by various internal and external factors of the power system. The presence of harmonics, voltage and frequency variations deteriorate the performance of the system. In this project the frequently occurring power quality problem- voltage variation is discussed. The voltage sag/dip is the most frequently occurring problem. To overcome the problem related to power quality many power devices are introduced. A number of power quality solutions are provided by these power devices. At present, a wide range of very flexible controllers, which capitalize on newly available power electronics components, are emerging for power applications. Among these, the static compensator is use in the present work. The fast response of static compensator makes it the efficient solution for improving power quality in distribution system. STATCOM can use with different types of controllers. The device consider in this work is Static Synchronous Compensator (STATCOM) to improve the power quality under different abnormal conditions like single line to ground fault, double line to ground fault in distribution networks with static linear and static non-linear loads.**

Keywords— Power quality, Static Synchronous Compensator (STATCOM), p-q, Harmonics

I. INTRODUCTION

Electrical energy is the most efficient and popular form of energy and the modern society is heavily dependent on the electric supply. The life cannot be imagined without the supply of electricity. At the same time the quality and continuity of the electric power supplied is also very important for the efficient functioning of the end user equipment. Most of the commercial and industrial loads demand high quality uninterrupted power. Thus maintaining the qualitative power is of utmost important.

The quality of the power is affected if there is any deviation in the voltage and frequency values at which the power is being supplied. This affects the performance and life time of the end user equipment. Whereas, the continuity of the power supplied is affected by the faults which occur in the power system. So to maintain the continuity of the power being supplied, the faults should be cleared at a faster rate and for this the power system switchgear should be designed to operate without any time lag.

The power quality is affected many problems which occur in transmission system and distribution system. Some of them are like-harmonics, transients, sudden switching operations, voltage fluctuations, frequency variations etc. These problems are also responsible in deteriorating the consumer appliances. In order to enhance the behavior of the power system, these all problems should be eliminated.

With the recent advancements in power electronic devices, there are many possibilities to reduce these problems in the power system. One of them is the use of Flexible AC Transmission System (FACTS) devices. STATCOM, DVR, ACTIVE FILTERs, UPFC, UPQC etc are some of the devices we are capable to reduce the problem related to power quality. In this project the mitigation of voltage sag/swell using STATCOM is studied and analyzed.

II. POWER QUALITY

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, tomaintain the quality of power care must be taken that suitable devices are kept inoperation to prevent the consequences of these problems. Here an overview of differentpower quality problems with their causes and consequences is presented.

1. Interruptions:

It is the failure in the continuity of supply for a period of time. Here the supply signal(voltage or current) may be close to zero. This is defined by IEC(International Electrotechnical Committee) as “lower than 1% of the declared value” and by the

IEEE(IEEE Std. 1159:1995) as "lower than 10%". Based on the time period of the interruption, these are classified into two types [9]-

A. Short Interruption:

If the duration for which the interruption occurs is of few mille seconds then it iscalled as short interruption.

Causes:

The causes of these interruptions are-

- Opening of an Automatic Re-closure
- Lightening stroke or Insulation Flash over

Consequences:

- The data storage system gets affected
- There may be malfunction of sensitive devices like- PLC's, ASD's

B. Long Interruptions:

If the duration for which the interruption occur is large ranging from few milleseconds to several seconds then it is noticed as long interruption. The voltage signal during this type of interruption is shown in Fig. 2.1.

Causes:

The causes of these interruptions are-

- Faults in power system network
- Human error
- Improper functioning of protective equipment

Consequences:

This type of interruption leads to the stoppage of power completely for a period of time until the fault is cleared.

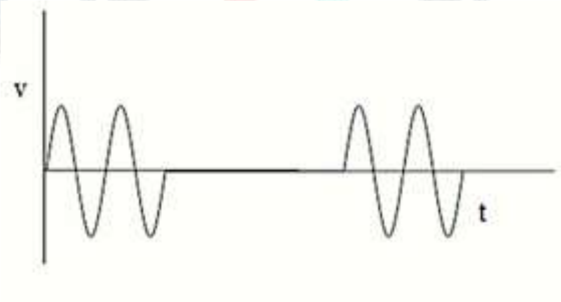


Fig.1 Voltage Signal with Long Interruption

2. Waveform Distortion:

The power system network tries to generate and transmit sinusoidal voltage andcurrent signals. But the sinusoidal nature is not maintained and distortions occur in thesignal. The cause of waveform distortions are [8]-

• **DC Offset:** The DC voltage which is present in the signal is known as DC offset.Due to the presence of DC offset, the signal shifts by certain level from its actual reference level.

• **Harmonics:** These are voltage and current signals at frequencies which are integral multiples of the fundamental frequency. These are caused due to the presence of non-linear loads in the power system network.

• **Inter Harmonics:** These are the harmonics at frequencies which are not theintegral multiples of fundamental frequency.

• **Notching:** This is a periodic disturbance caused by the transfer of current fromone phase to another during the commutation of a power electronic device.

• **Noise:** This is caused by the presence of unwanted signals. Noise is caused due tointerference with communication networks.

3. Frequency Variations:

The electric power network is designed to operate at a specified value (50 Hz) offrequency. The frequency of the framework is identified with the rotational rate of the generators in the system. The frequency variations are caused if there is any imbalance in the supply and demand. Large variations in the frequency are caused due to the failure of a generator or sudden switching of loads.

4. Transients:

The transients are the momentary changes in voltage and current signals in the power system over a short period of time. These transients are categorized into two types-impulsive, oscillatory. The impulsive transients are unidirectional whereas the oscillatory transients have swings with rapid change of polarity.

Causes:

There are many causes due to which transients are produced in the power system. They are-

- Arcing between the contacts of the switches
- Sudden switching of loads
- Poor or loose connections
- Lightening strokes

Consequences:

- Electronics devices are affected and show wrong results
- Motors run with higher temperature
- Failure of ballasts in the fluorescent lights
- Reduce the efficiency and lifetime of equipment

5. Voltage Sag:

The voltage sag is defined as the dip in the voltage level by 10% to 90% for a period of half cycle or more. The voltage signal with sag in shown in Fig. 2.2.

Causes:

The causes of voltage sag are-

- Starting of an electric motor, which draws more current
- Faults in the power system
- Sudden increase in the load connected to the system

Consequences:

- Failure of contactors and switchgear
- Malfunction of Adjustable Speed Drives (ASD's)

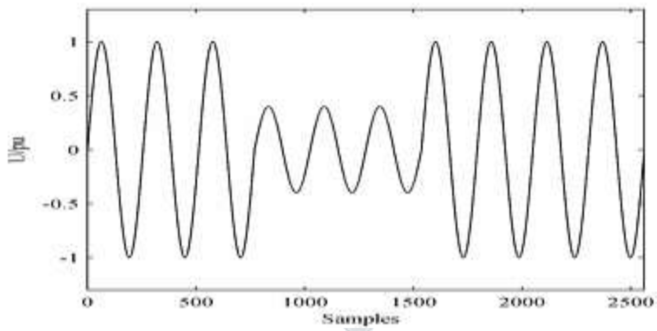


Fig.2 Voltage Sag

6. Voltage Swell:

Voltage swell is defined as the rise in the voltage beyond the normal value by 10%to 80% for a period of half cycle or more. The voltage signal with swell in shown inFig.2.3.

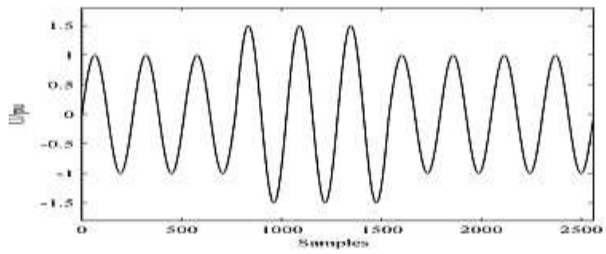


Fig.3 Voltage Swell

Causes:

- De-energization of large load
- Energization of a capacitor bank
- Abrupt interruption of current
- Change in ground reference on ungrounded phases

Consequences:

- Electronic parts get damaged due to over voltage
- Insulation breakdown
- Overheating

7. Voltage Unbalance:

The unbalance in the voltage is defined as the situation where the magnitudes and phase angles between the voltage signals of different phases are not equal.

Causes:

- Presence of large single-phase loads
- Faults arising in the system

Consequences:

- Presence of harmonics
- Reduced efficiency of the system
- Increased power losses
- Reduce the life time of the equipment

8. Voltage Fluctuation:

These are a series of a random voltage changes that exist within the specified voltage ranges. Fig. 2.4 shows the voltage fluctuations that occur in a power system.

Causes:

These are caused by the

- Frequency start/ stop of electric ballasts
- Oscillating loads
- Electric arc furnaces

Consequences:

- Flickering of lights
- Unsteadiness in the visuals

Fig.4 Voltage Fluctuation

Among the different power quality problems discussed, the under voltage or voltage sag is the prominent one as it occurs often and affects the power system network largely. Therefore, in this project main focus is given on voltage sag and its mitigation techniques

.

III. STATCOM

It is a power electronic converter based device used to protect the distribution bus from voltage unbalances.

1. Basic Structure:

STATCOM is a shunt connected device designed to regulate the voltage either by generating or absorbing the reactive power. The schematic diagram of a D-STATCOM is as shown in Fig. 4.1. It contains-

- DC Capacitor
- Voltage Source Inverter (VSI)
- Coupling Transformer
- Reactor

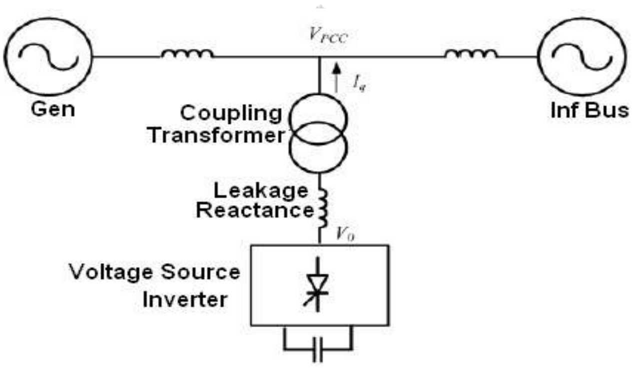


Fig.5 Schematic Diagram of STATCOM

The VSI generates voltage by taking the input from the charged capacitor. It uses PWM switching technique for this purpose. This voltage is delivered to the system through the reactance of the coupling transformer. The voltage difference across the reactor is used to produce the active and reactive power exchange between the STATCOM and the transmission network [10]. This exchange is done much more rapidly than a synchronous condenser and improves the performance of the system.

2. Operating Principle:

The basic operating principle of a STATCOM in voltage sag mitigation is to regulate the bus voltage by generating or absorbing the reactive power. Therefore, the STATCOM operates either as an inductor or as a capacitor based on the magnitude of the bus voltage.

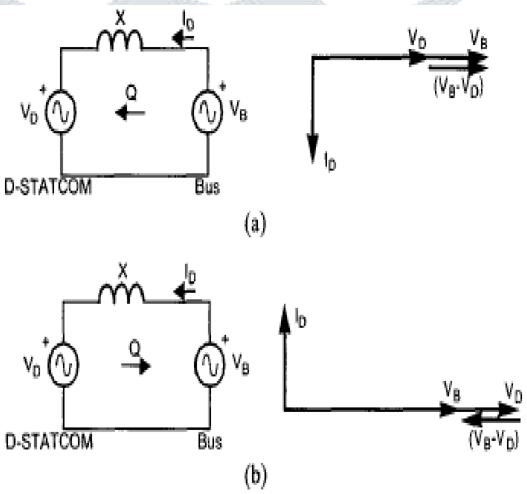


Fig 6 STATCOM operation

a). Inductive Operation b). Capacitive Operation

The reactive power transfer is done through the leakage reactance of the coupling transformer by using a secondary voltage in phase with the primary voltage (network side). This voltage is provided by a voltage-source PWM inverter. The STATCOM operation is illustrated by the phasor diagrams shown in Fig. 4.2. When the secondary voltage (V_D) is lower than the bus voltage (V_B), the STATCOM acts like an inductance absorbing reactive power from the bus. When the secondary voltage (V_D) is higher than the(V_B), the STATCOM acts like a capacitor generating reactive power to the bus.

IV. SIMULATION AND RESULTS

1. Test system using Generalized fryze method:

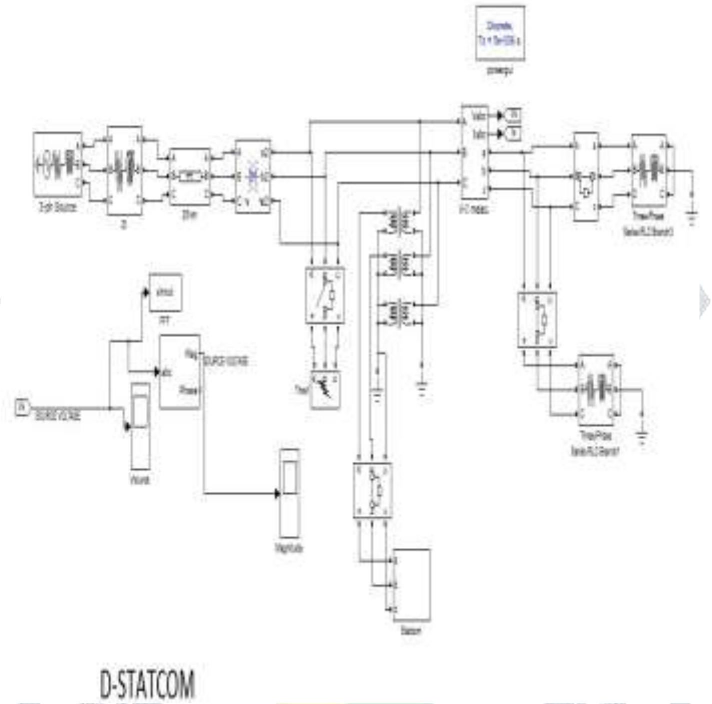


Fig 7 Test system

2. Subsystem

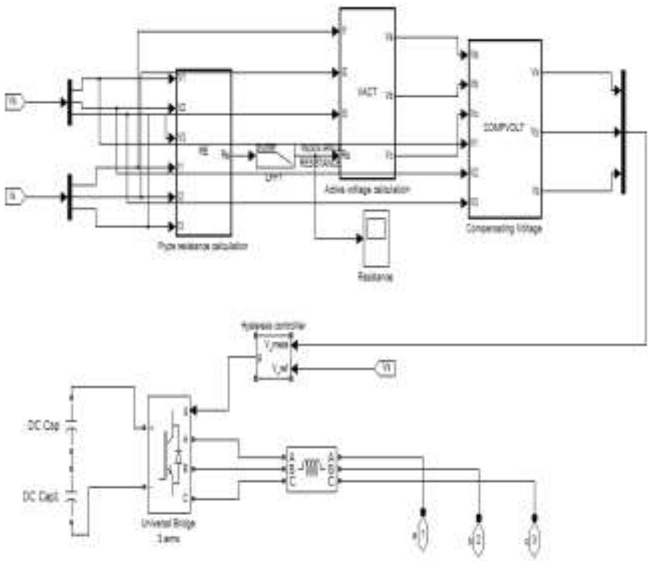


Fig. 8 Subsystem

3. Case study:

(a) <u>During voltage sag:</u>

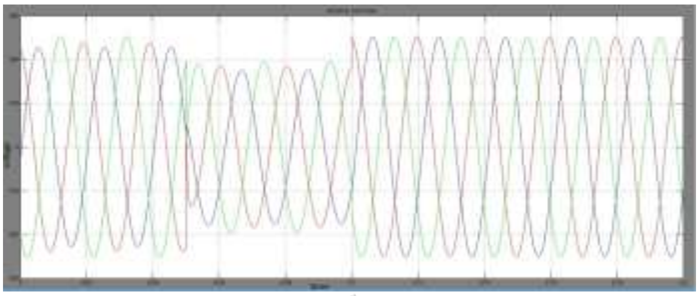


Fig .9 Waveform of voltage sag condition

Fig 10 Waveform of magnitude of voltage sag condition

(b) <u>During voltage swell condition:</u>

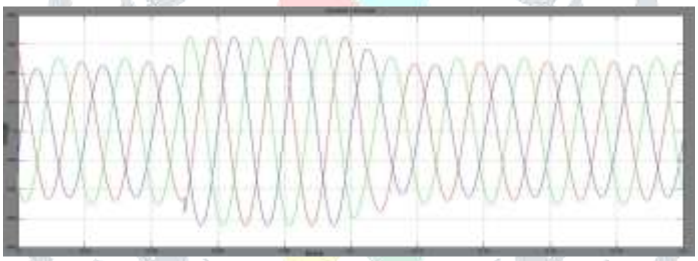


Fig 11 Waveform of voltage swell condition

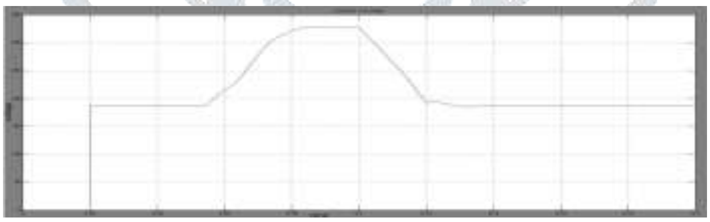


Fig 12 Waveform of magnitude of voltage swell condition

(c) <u>One phase to ground fault:</u>

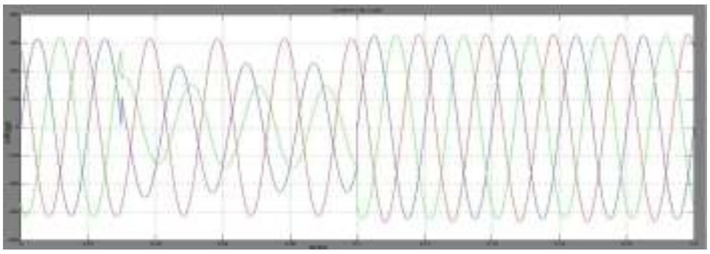


Fig 13 Waveform of one phase to ground fault condition

(d) Two phase to ground fault:

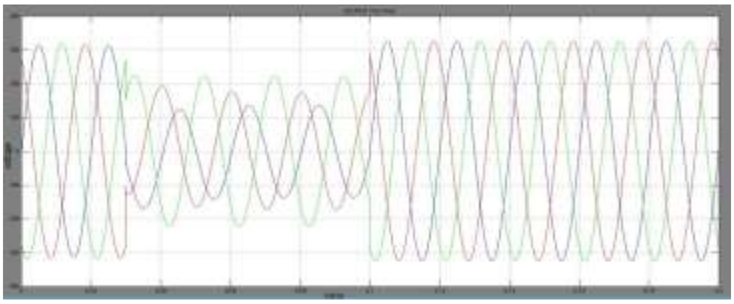


Fig 14 waveform of two phase to ground fault condition

(e) Line to line fault:

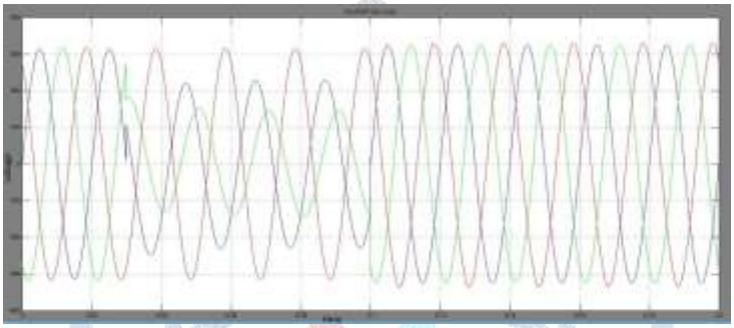
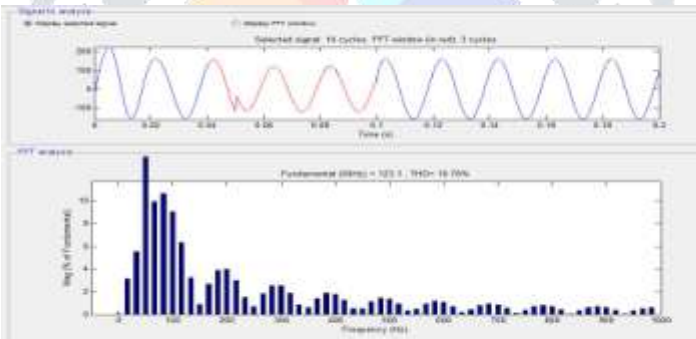
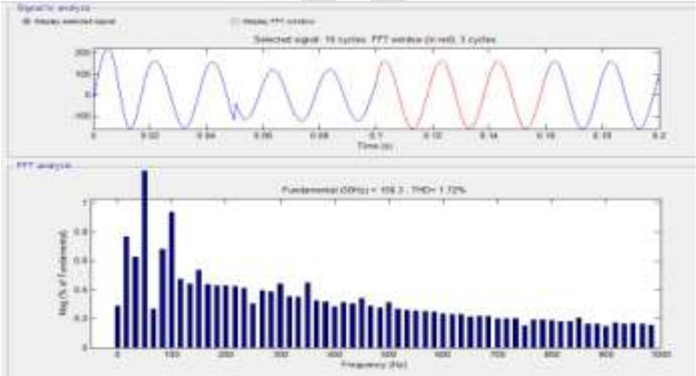


Fig 15 waveform of line to line fault condition

(f) FFT analysis for voltage sag condition without D- STATCOM:



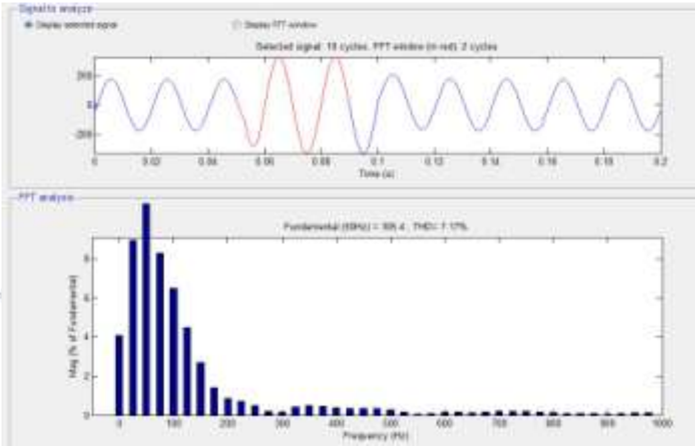
(g) FFT analysis for voltage sag condition with D- STATCOM:



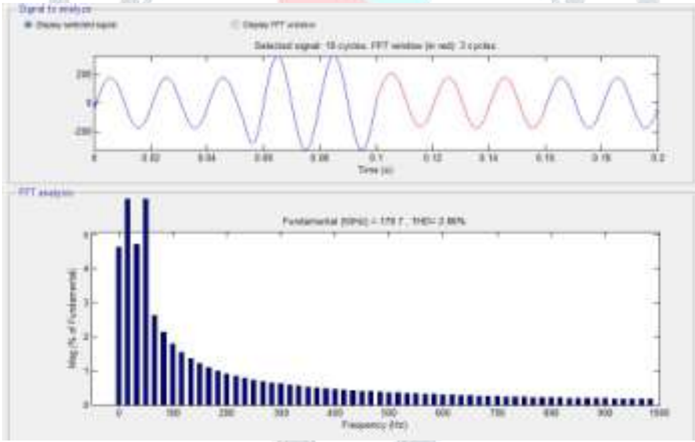
Result Table:

THD without STATCOM	10.76%
THD with STATCOM	1.72%

(h) FFT analysis for voltage swell condition without D-STATCOM:



(i) FFT analysis for voltage swell condition with D-STATCOM:



Result Table:

THD without STATCOM	7.17%
THD with STATCOM	2.86%

V. CONCLUSION

By simulating D-STATCOM using Generalized fryze method, it can be concluded that, it can give the best performance against voltage sag, voltage swell, and different faults like one phase to ground, two phase to ground, line to line fault & THD is also reduced. The Generalized fryze method eliminates Clarke transformation so it can take less computation time since it has less calculation.

Appendix
Simulation parameters of D-STATCOM are given in Table.

Source side parameters	
Voltage	11kv
Frequency	50Hz
Resistance	0.01Ω
Inductance	1×10^{-6}H
Transmission line	π type , 25km long
Distribution transformer, line to line voltage ratio	11kv/400v
Load side parameters	
Resistance	1000
Inductance	0.5H
Coupling inductor	1×10^{-6}H

References

[1] Pragtijyotishi and proff. Deeparamchandani, "mitigate voltage sag/swell condition and power quality improvement in distribution line usingd-statcom",published at int. Journal of engineering research and applications, vol. 3, issue 6, nov-dec 2013.
[2] S. Elango and dr. E. Chandra sekarana " mitigation of voltage sag using distribution static compensator (d-statcom)" 2011 IEEE.
[3] C. Sharmeela, G. Uma and M. R. Mohan "multi-level distribution STATCOM for voltage sag and voltage swell reduction" , IEEE 2005
[4]HendriMasdi;NornanMariun;SenanMahmud;AzahMohamed and SallehhudinYusuf "Design of a Prototype D-Statcom for Voltage Sag Mitigation"2004 IEEE.
[5] Aminnazarloo*, student member, ieee, meisamsadeghi**, student member, ieee, seyedhosseinhosseini*, member, ieee, and ebrahimbabaei*, member, ieee "mitigation of voltage sag in a sample distribution system using flexible d-statcom"
[6] RavillaMadhusudan"*, Student Member, IEEE, G. Ramamohan Rao2 "Modeling and Simulation of a Distribution STATCOM (D-STATCOM) for Power Quality Problems-Voltage Sag and Swell Based on Sinusoidal Pulse Width Modulation (SPWM)" IEEE- International Conference On Advances In Engineering, Science And Management (ICAESM -2012) March 30, 31,2012

[7] S. H. Hosseini, A. Nazarloo and E. Babaei "Application of D-STATCOM to Improve Distribution System Performance with Balanced and Unbalanced Fault
Condition" 2010 IEEE

[8] Jovica V. Milanovic, Follow, IEEE, and Yan Zhang "Modeling of FACTS devices for voltage sag mitigation_studies in large power system" , IEEE 2010

[9] Bollen, M. H J, "Characteristic of voltage dips (sags) in powersystems," Harmonics and Quality of Power Proceedings, 1998. Proceedings. 8th International Conference On , vol.1, no., pp.555,560 vol.1, 14-18 Oct 1998

[10] Elango, S.; Chandra Sekaran, E., "Mitigation of Voltage Sag by Using Distribution Static Compensator (D-STATCOM)," Process Automation, Control and Computing (PACC), 2011 International Conference on , vol., no., pp.1,6, 20- 22 July 2011.

[11] Ledwich, G.; Ghosh, A., "A flexible DSTATCOM operating in voltage or current control mode," Generation, Transmission and Distribution, IEE Proceedings- , vol.149, no.2, pp.215,224, Mar 2002.