

Mitigation of Voltage Fluctuation in Power Distribution System using D-STATCOM in Egypt

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Abstract

Electrical power quality is becoming intensity concerned from both electric utilities and customers. Voltage fluctuation is a major power quality problem as it has a significant impact on both the equipment and production environment. This work describes the voltage control technique of mitigation of voltage fluctuations and clearing fault using distribution static synchronous compensator (DSTATCOM). The test system used is Egyptian native power distribution system. A simulation was done using MATLAB/Simulink software.

Keywords: power quality, voltage fluctuations, DSTATCOM

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1. Introduction

The power quality has become one of the most focus of attention in the power industry since the late 1980s [1]. Power quality is defined as any power problem detected in voltage, current, or frequency deviations that results in failure or misdirection of customer equipment [2]. Voltage fluctuation is the main power quality regard for both power utility and customers. Voltage Fluctuations are defined as a series of random voltage changes, the magnitude of which does not normally exceed the voltage ranges specified by ANSI C84.1 of [0.9 to 1.1] per unit with frequencies less than 25 Hz and its typical duration is intermittent [3]. Voltage fluctuation at the load can be caused by events at many different points in the power system as distribution system from most consumers, power generation and transmission lines because of different conditions [4]. Voltage fluctuations affect on impressible equipment such as light sources (flicker), electrical machines, electro-heat equipments and many other troubles [5].

In this paper D-STATCOM was utilized to mitigate voltage fluctuation in Egyptian native power distribution system. The DSTATCOM is a fast response power quality device, which installed in the distribution system for reactive power compensation and mitigation of voltage fluctuation and many of other power quality troubles such as reducing Harmonics and power factor correction [6]. In our work D-STATCOM is connected in shunt with the main distribution line for compensation of voltage fluctuations [7].

DSTATCOM is the best shunt connected FACTS devices [8]. The operation of the D-STATCOM is as follows, the Voltage Source Converter (VSC) voltage is compared with the AC bus voltage system, When the AC bus voltage magnitude is above that of the VSC magnitude voltage; the AC system sees the D-STATCOM as inductance connected to its terminals and it absorbs the increasing of nominal voltage. Also, if the VSC voltage magnitude is above that of the AC bus voltage magnitude, the AC system sees the D-STATCOM as a capacitance to its terminals and injecting require voltage. If the voltage magnitudes are equal, the reactive power exchange is zero [9]. In this paper the test and simulation of DSTATCOM are using MATLAB/SIMULINK software in order to regulate and mitigate voltage fluctuations on Egyptian native power distribution system. In this paper the system was tested with and without DSTATCOM at many cases such as fluctuated source, fluctuated load, fault occurrence and all of this cases together in order to mitigate voltage and display a high response of DSTATCOM for mitigation voltage fluctuations and clearing faults.

2. Methodology and Model Description

DSTATCOM is used to regulate voltage on a 22-KV real Egyptian native power distribution system. The structure of DSTATCOM and its equivalent circuit is shown in figure 1 [10]. The D-STATCOM regulates voltage by absorbing or injecting reactive power. This reactive power transfers through the leakage reactance of the coupling transformer. The D-STATCOM consists of the following components as shown in figure 1:

- ✓ A 22 kV/1.25kV coupling transformer which ensures coupling between the PWM inverter and the network.
- ✓ A voltage-sourced PWM converter consisting of two IGBT bridges. This twin inverter configuration produces fewer harmonics than a single bridge
- ✓ LC damped filters connected at the inverter output. Resistances connected in series with capacitors.
- ✓ A 10000-microfarad capacitor represents a DC voltage source for the converter
- ✓ A PWM pulse generator.
- ✓ Anti-aliasing filters used for voltage and current acquisition.
- ✓ DSTATCOM control system

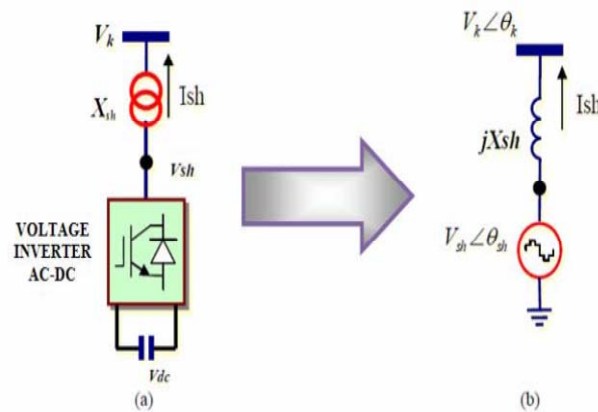


Figure 1. (a) Structure of DSTATCOM, (b) Equivalent circuit

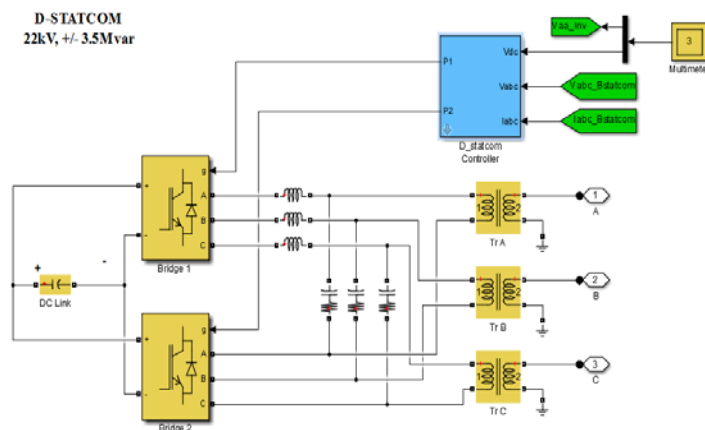


Figure 2. Simulink model of DSTATCOM components.

In our work, part of real Egyptian native power distribution system was studied for utilizing DSTATCOM to regulate voltage on a 22-KV our distribution network as shown in figure. Two feeders (21 km and 2 km) transmit power to loads at buses B2 and B3. A shunt capacitor is used for power factor correction at bus B2. The load is equivalent to a section of medium

voltage distribution panel (22 KV) where the feeders come out as shown in figure 4.3. One of these feeders represents the (400-V and 2MW) load of the factory which it and its distribution panel connected to bus B3 through a 22kV/400V, 4 MVA transformer. The factory is producing voltage fluctuations and flicker. This factory connected to the distribution panel through a 22kV/400V, 4 MVA transformer. This distribution panel connected to bus B3. The variable load current magnitude of the factory is modulated at a frequency of 5 Hz while keeping a 0.9 lagging power factor. The run time for the whole system is half second (0.5 s).

Then we test the system with and without DSTATCOM at many cases such as fluctuated source, fluctuated load, fault occurrence and all of this cases together in order to mitigate voltage and display a high response of DSTATCOM for mitigation voltage fluctuations.

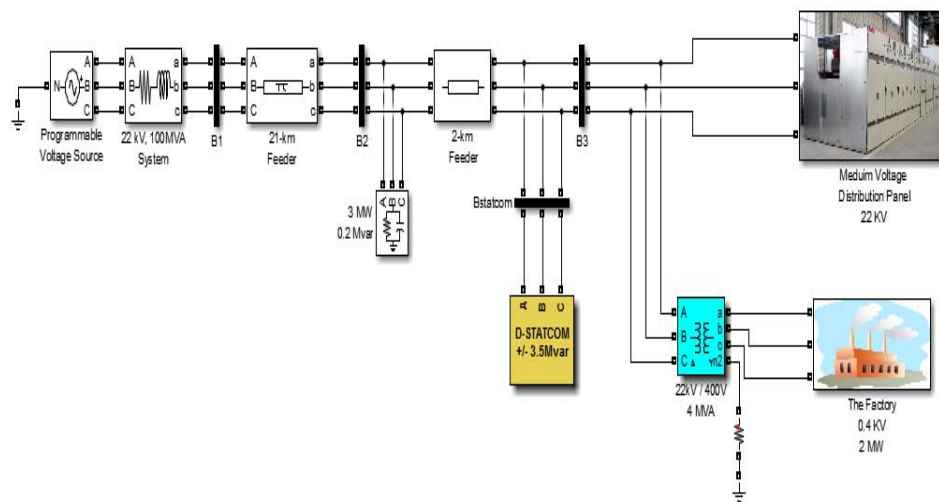


Figure 3. Part of real Egyptian native power distribution system with DSTATCOM

Table 1. The parameter values of the system

Parameters	Values
Source voltage	22KV/ 50Hz
Source Power	100MVA
Line Length	23 Km
Coupling transformer	22 kV/1.25kV
DSTATCOM value	3.5 MVAR
Distribution Power Transformer	4 MVA
Reference Voltage of DSTATCOM	1 pu

3. Result and Discussion

In this term we test and simulate DSTATCOM using MATLAB/SIMULINK software in order to mitigate voltage fluctuations on 22-kV real Egyptian native power distribution system as shown in figure 3. The simulation time is one second. In this simulation we test the system with and without DSTATCOM at many cases such as fluctuated source, fluctuated load, fault occurrence and all of this cases together. DSTATCOM used in this simulation +/- 3.5 MVAR.

3.1. Test System at Fluctuated Source Only

In this case, the system without and with installing DSTATCOM is displayed when voltage fluctuation comes from supply (sources) and display the effect of inserting DSTATCOM on voltage quality of the distribution system as shown in figure 4.5.

At $t = 0.2$ s, the source voltage is increased by 7%. The D-STATCOM compensates for this voltage increase by absorbing reactive power from the network ($Q = +2.9$ MVAR). At $t = 0.3$ s, the source voltage is decreased by 7%. The D-STATCOM must generate reactive power to maintain a (1 pu) voltage (Q changes from +2.9 MVAR to -3.4 MVAR). Note that when the D-

STATCOM changes from inductive to the capacitive operation, the reversing of reactive power is very fast.

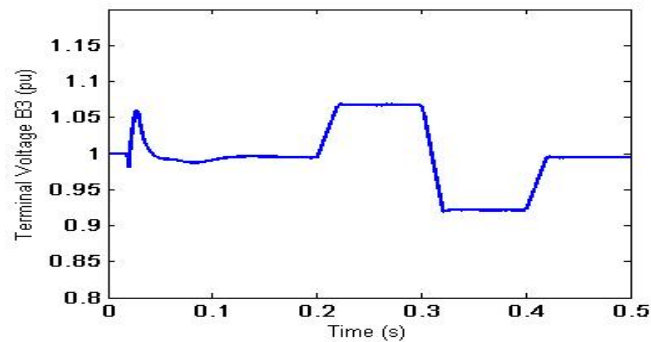


Figure 4. Terminal Voltage at load bus B3 without DSTATCOM

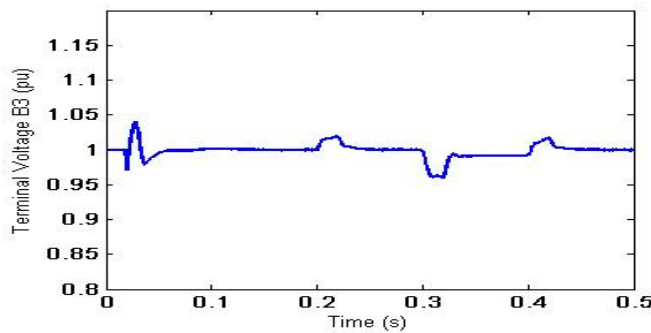


Figure 5. Terminal Voltage at load buses with DSTATCOM

3.2. Test System at Fluctuated Load Only

In this case, the system without and with installing DSTATCOM is displayed when voltage fluctuation comes from customer load only. And show the effect of inserting DSTATCOM to mitigate voltage fluctuations resulting from fluctuated load bus B3 as shown in figures 6,7. In this case the reactive power of DSTATCOM's compensation changed from +1.6 MVAR to -2.3 MVAR to mitigate voltage fluctuations by the high response.

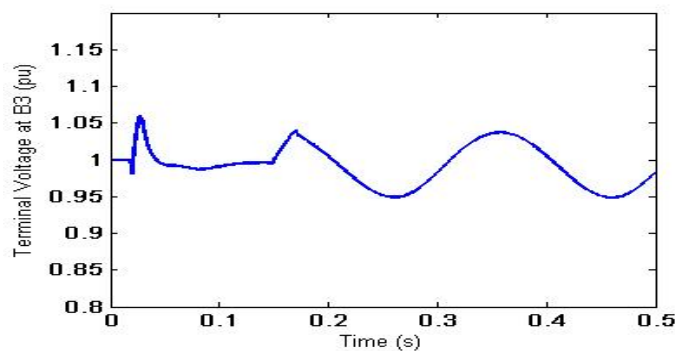


Figure 6. Terminal Voltage at load buses without DSTATCOM

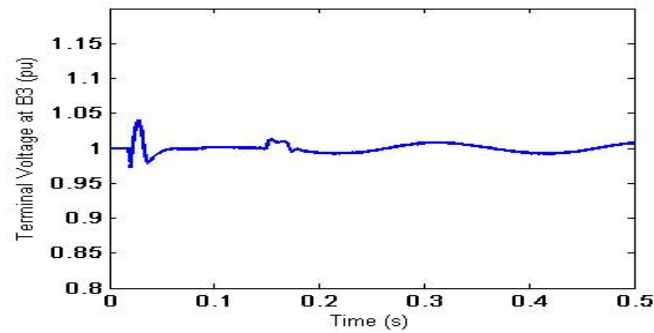


Figure 7. Terminal Voltage at load bus B3 with DSTATCOM

3.3. Clearing Three Phase Fault to Ground

In this case the transient fault occurs between 0.1 s to 0.2 s. The 3-ph to a ground fault by a fault resistance of 79 Ω which affects the load voltage stability at B3. DSTATCOM acts a capacitor which compensates this voltage decrease by injecting reactive power by (- 3.3 MVAR) at time 0.1 s to 0.2 s and clearing transient fault as shown in Figure as shown in figure 8,9.

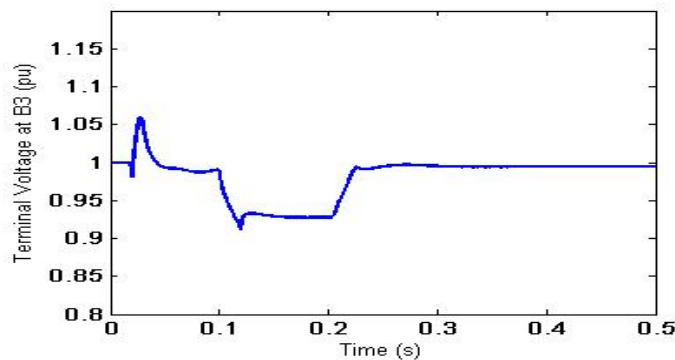


Figure 8. Terminal Voltage at load buses without DSTATCOM

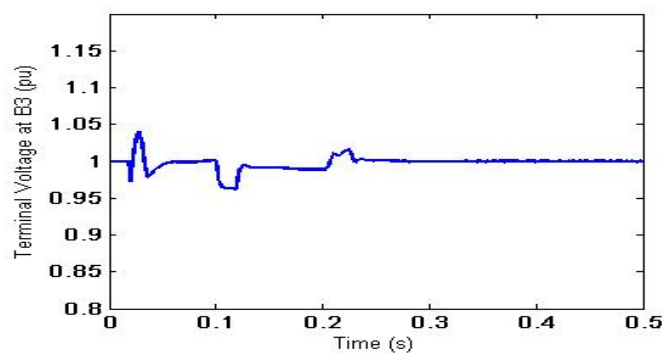


Figure 9. Terminal Voltage at load buses with DSTATCOM

3.4. Test Simulation System at Fluctuated Source and Fluctuated Load Applying Three Phase Fault to Ground Together

This case considers a worst case. In this case the voltage at load fluctuates between (1.06 to 0.92) pu. The system without and with installing DSTATCOM is displayed during the occurrence of all cases mentioned above together. Displaying the effect of installing

DSTATCOM on voltage fluctuation mitigation of the distribution system as shown in figures 10,11. The compensated Reactive Power (MVAR) by DSTATCOM as follow, DSTATCOM acts a capacitor which compensates voltage decrease which it caused by a transient 3-ph fault to ground- by injecting reactive power (-3.3 MVAR) at time 0.1 s to 0.2 s. At $t = 0.2$ s, the voltage is increased by 6% . The D-STATCOM compensates for this voltage increase by absorbing reactive power from the network ($Q = +2.6$ MVAR). At $t = 0.3$ s, the source voltage is decreased by 8% . The D-STATCOM must generate reactive power to maintain a (1 pu) voltage (Q changes from $+2.6$ MVAR to -3.3 MVAR). Note that when the D-STATCOM response is very fast where between (3-6) msec.

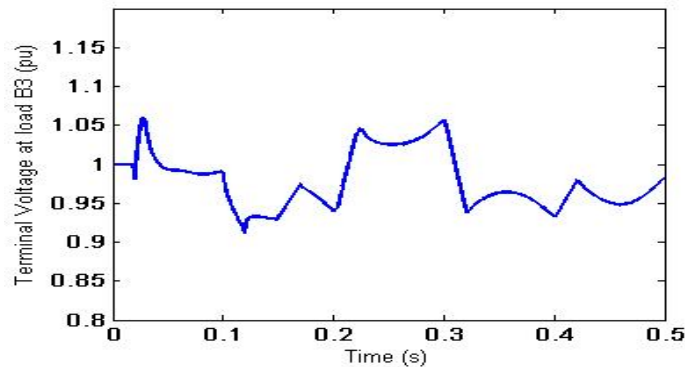


Figure 10. Terminal Voltage at load base B3 without DSTATCOM

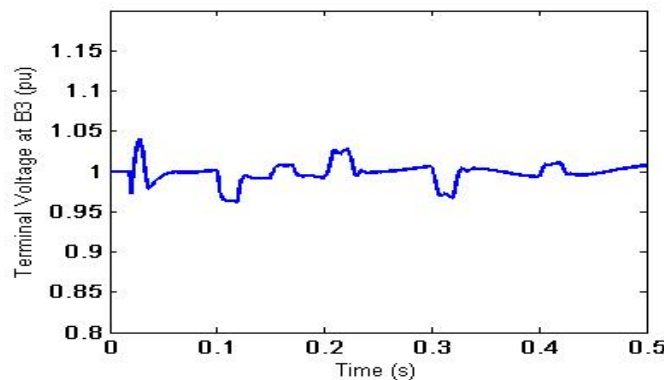


Figure 11. Terminal Voltage at load base B3 with DSTATCOM

4. Conclusion

In this paper D-STATCOM is used to mitigate voltage fluctuation and flicker in Egyptian native power distribution system. This paper presents a fast response reaction by using D-STATCOM to overcome voltage fluctuations in comparison to other FACTS device as shown in previous figures. After reviewing this paper you have the ability to define voltage Fluctuation and overcome voltage fluctuation problems in your native power distribution network with latest techniques.

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