Research Journal of Applied Sciences 11 (8): 617-623, 2016
ISSN: 1815-932X

Mitigation of Voltage Fluctuation in Power Distribution System Using D-STATCOM

S.K. Elsayed, M.A. Mehanna and Yahia M. Esmail
Department of Electrical Engineering, Faculty of Engineering,
University of AL-Azhar, Cairo, Egypt

Abstract: Power quality is a major concern both electric utilities and customers. Voltage fluctuations is a major power quality problem has a significant impact on both the equipment and production environment. This research describes the voltage control technique of mitigation of voltage fluctuations and clearing fault using Distribution Static Synchronous Compensator (D-STATCOM). The test system used is the IEEE 9-bus distribution system clarified the optimal location of D-STATCOM by using an Artificial Neural Network (ANN). A simulation was done using MATLAB/Simulink Software.

Key words: Power quality, voltage fluctuation, D-STATCOM, power distribution system, ANN

INTRODUCTION

Power quality has been a major focus of attention in the power industry since the late 1980s (Dugan *et al.*, 2003). Voltage fluctuation is the main power quality importance 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 0.9-1.1 (per unit with frequencies <25 Hz and its typical duration is intermittent. In this study D-STATCOM to mitigate voltage fluctuation and clear fault in IEEE-9 bus power distribution system. The D-STATCOM 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 (Sharma, 2014). D-STATCOM is connected in shunt with the main distribution line for compensation of voltage fluctuations (Dey, 2015).

The operation of the D-STATCOM is as follows (Sajedihir *et al.*, 2011). 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 (Mokhtari *et al.*, 2014). In this study, the test and simulation of D-STATCOM are using MATLAB/Simulink Software in order to regulate and mitigate voltage fluctuations on IEEE 9-bus certified system. feedforward Artificial Neural Network (ANN) based approach has been used to find optimal location of D-STATCOM. Then, we test the system with and without D-STATCOM in 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 D-STATCOM for mitigation voltage fluctuations and clearing faults.

MATERIALS AND METHODS

D-STATCOM is used to regulate voltage on a 22-KV IEEE 9-bus distribution network (Sajedihir *et al.*, 2011). The structure of D-STATCOM and its equivalent circuit is shown in Fig. 1. 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 Fig. 1:

- A 22/1.25 kV coupling transformer which ensures coupling between the PWM inverter and the network

Corresponding Author: S.K. Elsayed, Department of Electrical Engineering, Faculty of Engineering, University of AL-Azhar, Cairo, Egypt

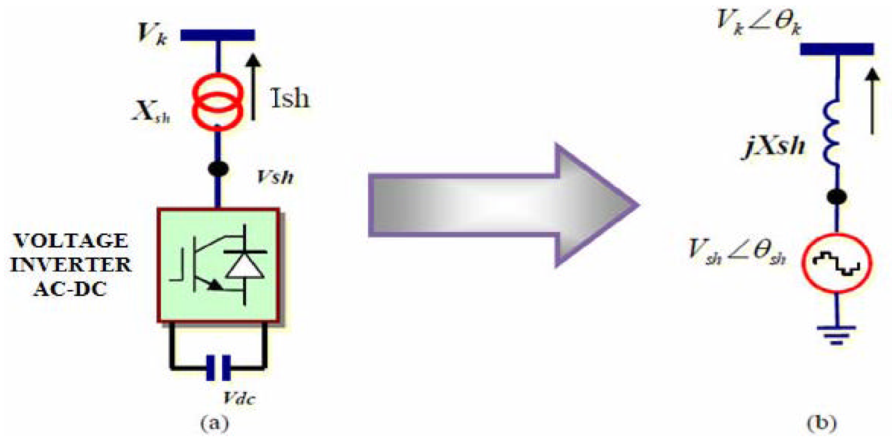

Fig. 1: a) Structure of D-STATCOM and b) equivalent circuit

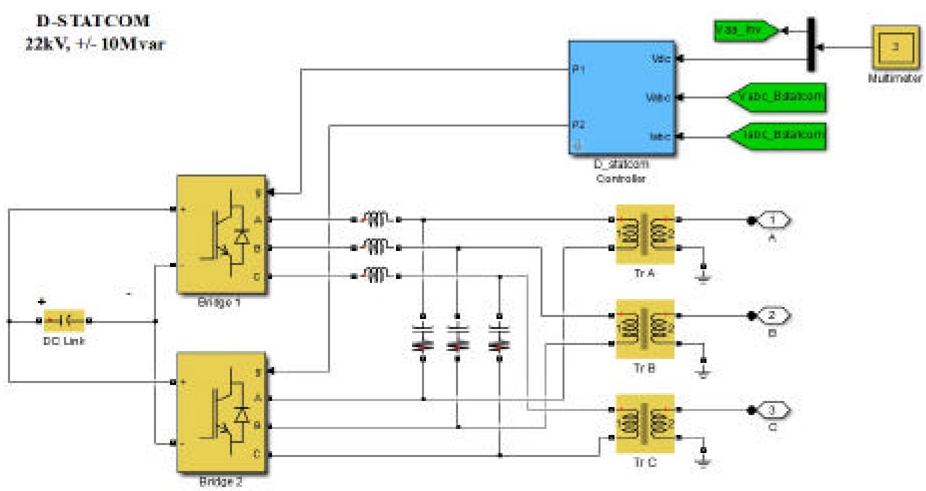

Fig. 2: Simulink model of D-STATCOM components

Table 1: The parameter values of IEEE 9-bus system

Parameters	Values
Source voltage	22 KV/50 Hz
Source values	Source (1):13.8 KV, 128 MVA with13.8/22 KV Trans. Source (2):18 KV, 192 MVA with 18/22 KV Trans. Source (3):16.5 KV, 247 MVA with 16.5/22 KV Trans
Load values	Load (1): 30 MW, 3.5 MVAR Load (2): 32 MW, 3 MVAR Load (3): 35 MW, 5 MVAR
Coupling Trans. of D-STATCOM	22 kV/1.25 kV
D-STATCOM value	+/-10 MVAR
Reference voltage of D-STATCOM	1 up
Simulation time	1 sec

- A voltage-sourced converter consisting of two IGBT bridges. This twin inverter configuration produces fewer harmonics than a single bridge
- LC dumped 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
- D-STATCOM control system

In our research, we used modified IEEE 9-bus in order to agree with Native Power Distribution System. So, it comprises a 22 KV, 50 HZ and 6 lines with three loads at buses (8, 6 and 5) as shown in Fig. 2. The parameter values of IEEE 9-bus system as shown in Table 1. Then we test the system with and without D-STATCOM in 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 D-STATCOM for mitigation voltage fluctuations and clearing faults (Fig. 2 and Table 1).

Optimal placement of D-STATCOM in IEEE 9-bus: In this part, feedforward Artificial Neural Network (ANN) with back propagation algorithm has been used to find the optimal location for D-STATCOM placement (Tanti *et al*., 2012, 2011). The architecture of this network (Artificial Neural Network) has been shown in Fig. 3. The mean square error (mean of squared deviation of post-fault bus voltages from target value) is calculated for different load buses by ANN. The bus having highest Mean Square Error (MSE) is considered as the optimal placement of D-STATCOM. The aim is getting mean square error (deviation of post-fault bus voltages from pre-faults voltages) resulting from the different type of short circuits (Faults) at all load buses (bus 8, 6, 5) in IEEE 9-bus. This model is used to find the three phase voltages in per unit (pu). The voltage database in per unit was prepared by creating a single Line to Ground (L-G), Line to Line (L-L) and three phase (L-L-L or L-L-L-G) faults at different load buses during the period 0.1-0.2.

Target bus voltages are pre-faults voltages before any faults. Input data is post-fault voltages (before making any type of faults). Post-fault voltages have been used to train a feedforward Artificial Neural Network with back propagation algorithm.

The training process is done with a large number of inputs and output target data Now, MSE (Mean Square Error) were calculated at each load buses using target data (pre-faults voltages) and input data (Post-fault voltages) by ANN as shown in Table 2. It is observed from Table 2 that bus-8 has the highest value of mean square error. Consequently, bus-8 was considered as the optimal location for the placement of D-STATCOM.

Table 2: Training performance of ANN at different buses

Bus no.	MSE
Load bus (8)	0.048292
Load bus (6)	0.045625
Load bus (5)	0.042972

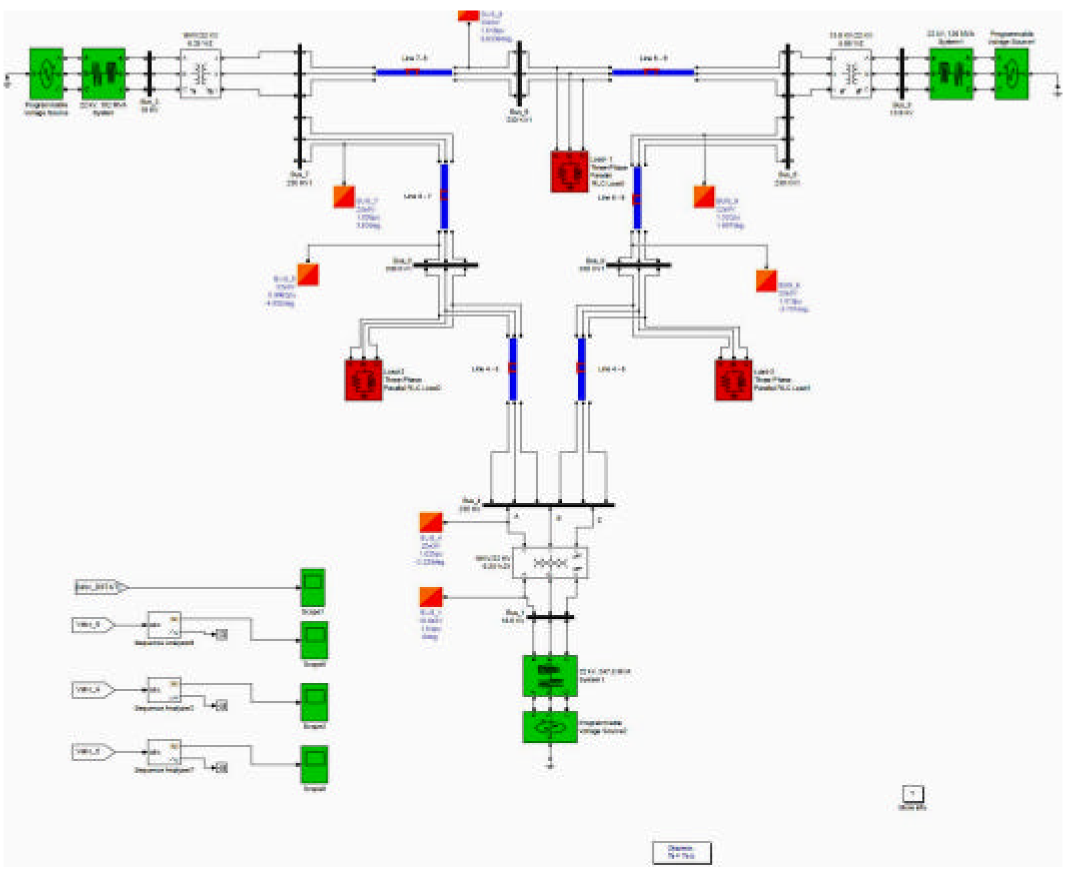

Fig. 3: IEEE 9-bus distribution system

RESULTS AND DISCUSSION

In this term, we test and simulate D-STATCOM using Matlab/simulink Software in order to mitigate voltage fluctuations on 22-kV IEEE 9-bus distribution system as shown in Fig. 4. The simulation time is 1 sec. In this simulation we test the system with and without D-STATCOM in many cases such as fluctuated source, fluctuated load, fault occurrence and all of this cases together in IEEE 9-bus system. D-STATCOM used in this simulation +/-10 MVAR (Fig. 5).

Test system at fluctuated source only: In this case, the system without and with installing D-STATCOM is displayed when voltage fluctuation comes from all supply sources and show the effect of inserting D-STATCOM on voltage quality of the distribution system as shown in Fig. 6.

Test system at fluctuated load only: In this case, the system without and with installing D-STATCOM is displayed when voltage fluctuation comes from customer load only. And show the effect of inserting

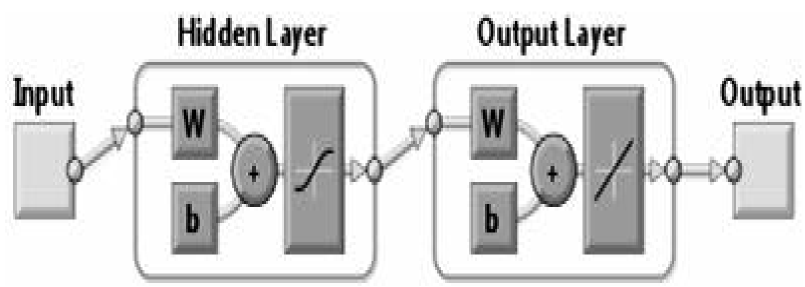

Fig. 4: Artificial neural network architecture

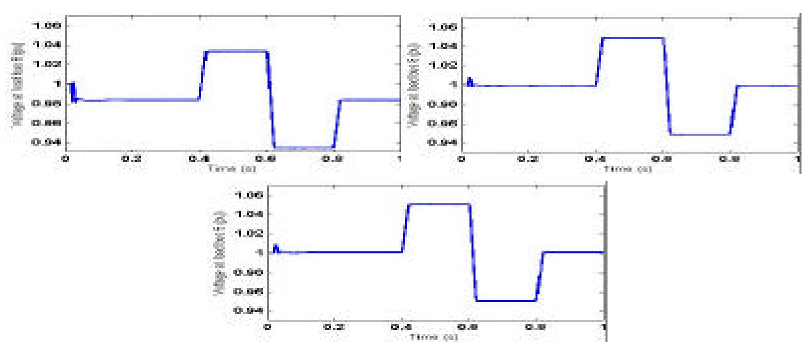

Fig. 5: Terminal voltage at load buses without D-STATCOM (Dugan *et al*., 2003) Load bus 8, 6 (Sharma, 2014), Load bus 5

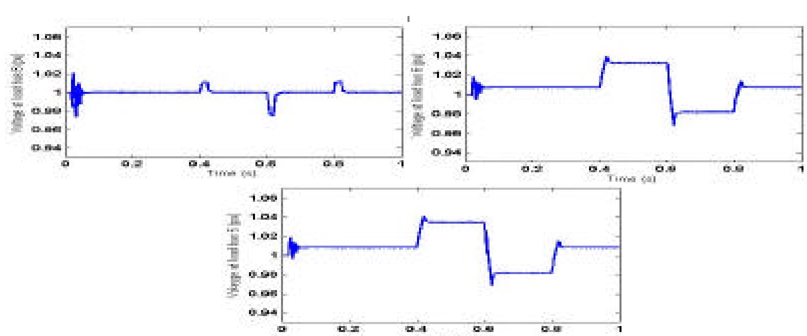

Fig. 6: Terminal voltage at load buses with D-STATCOM (Dugan *et al*., 2003) Load bus 8, 6 (Sharma, 2014), Load bus 5

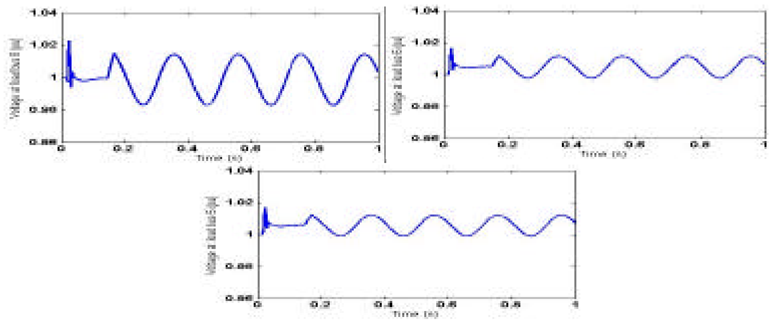

Fig. 7: Result of terminal voltage system at load buses without D-STATCOM (Dugan *et al.*, 2003) Load bus 8, 6 (Sharma, 2014), Load bus 5

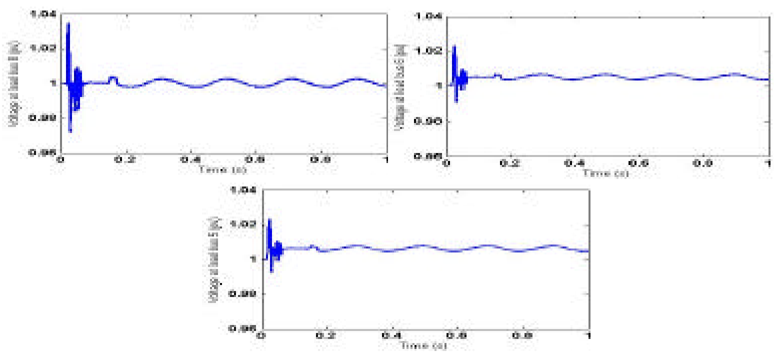

Fig. 8: Result of terminal voltage system at load buses with D-STATCOM (Dugan *et al.*, 2003) Load bus 8, 6 (Sharma, 2014), Load bus 5

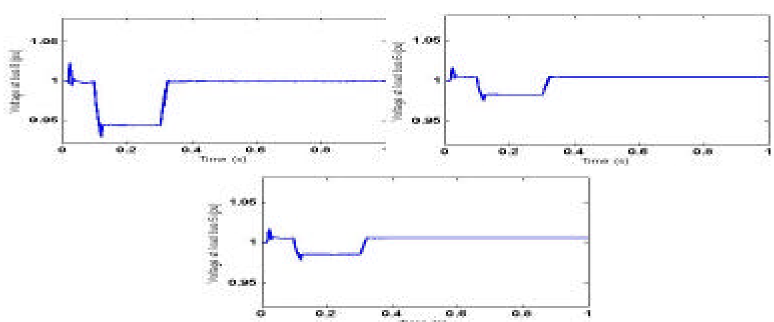

Fig. 9: Test system of terminal voltage at load buses without D-STATCOM (Dugan *et al.*, 2003) Load bus 8, 6 (Sharma, 2014), Load bus 5

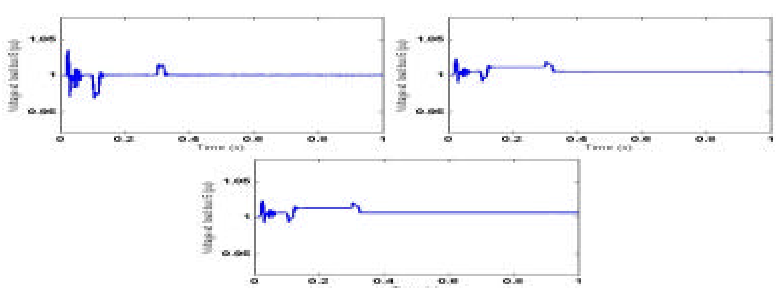

Fig. 10: Test system of terminal voltage at load buses with D-STATCOM (Dugan *et al.*, 2003) Load bus 8, 6 (Sharma, 2014), Load bus 5

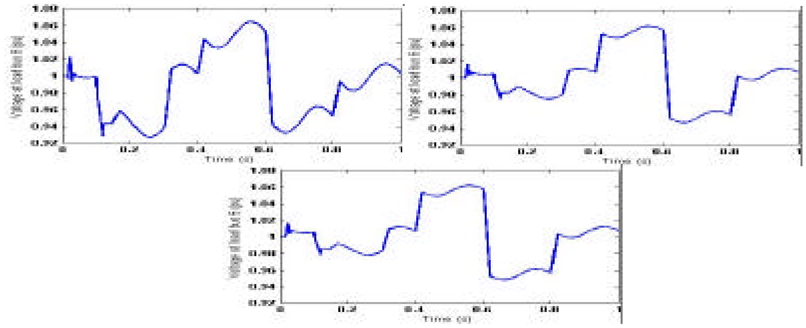

Fig. 11: Phase description of terminal voltage at load buses without D-STATCOM (Dugan *et al*., 2003) Load bus 8, 6 (Sharma, 2014), Load bus 5

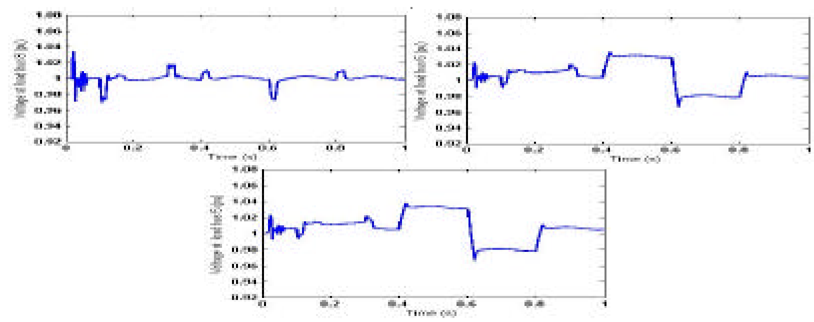

Fig. 12: Terminal Voltage at load buses with D-STATCOM (Dugan *et al*., 2003) Load bus 8, 6 (Sharma, 2014), Load bus 5

D-STATCOM to mitigate voltage fluctuations resulting from fluctuated load at the bus (8) as shown in Fig. 7 and 8.

Clearing three phase fault to ground: In this case, the system without and with installing D-STATCOM is displayed where a three phase fault to ground applied at load bus (8). And display the effects of inserting D-STATCOM on a three phase fault mitigation of the IEEE 9-Bus distribution system as shown in Fig. 9 and 10.

Test simulation system at fluctuated source and fluctuated load applying three phase fault to ground together: In this case, the system without and with installing D-STATCOM is displayed during the occurrence of all cases mentioned above together. Displaying the effect of installing D-STATCOM on voltage fluctuation mitigation of the distribution system as shown in Fig. 11 and 12.

CONCLUSION

In this study D-STATCOM is used to mitigate voltage fluctuation and flicker in IEEE 9-bus distribution system. Artificial Neural Network (ANN) based approach has been used in this paper to find optimal location of D-STATCOM. This study presents a fast response reaction by using D-STATCOM to overcome voltage fluctuations.

After reviewing this paper you have the ability to define voltage fluctuation and overcome voltage fluctuation problems in your native power distribution network.

REFERENCES

Dey, S., 2015. Application of distribution static synchronous compensator in electrical distribution system. Int. J. Innovative Res. Electr. Electron. Instrum. Control Eng., 3: 144-149.

Dugan, R.C., S. Santoso, M.F. McGranaghan and H.W. Beaty, 2003. Electrical Power Systems Quality. 2nd Edn., McGraw-Hill, New York, ISBN-10: 007138622X, Pages: 528.

Mokhtari, A., F.Z. Gherbi, C. Mokhtar and K. DE, 2014. Study analysis and simulation of a static compensator D-Statcom for distribution systems of electric power. Leonardo J. Sci., 1: 117-130.

Sajedihir, M., Y. Hoseinpoor, P.A. Mosadegh, T. Pirzadeh and I. Bilasuvar, 2011. Analysis and simulation of a D-Statcom for voltage quality improvement. Aust. J. Basic Appl. Sci., 5: 864-870.

Sharma, A., 2014. Power quality improvement for D-Staton in distribution system abstract. Int. J. Innovative Res. Dev., 3: 264-268.

Tanti, D.K., B. Singh, M.K. Verma and O.N. Mehrotra, 2011. An Ann based approach for optimal placement of dstatcom for voltage sag mitigation. Int. J. Eng. Sci. Technol. (IJEST.), 3: 827-835.

Tanti, D.K., M.K. Verma, B. Singh and O.N. Mehrotra, 2012. Optimal placement of custom power devices in power system network to mitigate voltage sag under faults. Int. J. Power Electron. Drive Syst., 2: 267-276.