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Implementation of D-STACTOM for Improvement of Power Quality in Radial Distribution System

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ABSTRACT: *D-STATCOM (Distribution Static Compensator) is a shunt device which is generally used to solve power quality problems in distribution systems. D-STATCOM is a shunt device used in correcting power factor, maintaining constant distribution voltage and mitigating harmonics in a distribution network. D-STATCOM is used for Grid Connected Power System, for Voltage Fluctuation, for Wind Power Smoothening and Hydrogen Generation etc. This paper D-STATCOM is used in Electrical Power System for Power Quality Improvement. Relevant solutions which applied nowadays to improve power quality of electric network according to the five aspects of power quality- harmonics, fluctuation and flick of voltage, Voltage deviation, unbalance of 3-phase voltage and current frequency deviation. The D-STATCOM injects a current into the system to mitigate the voltage sags. LCL Passive Filter was then added to D-STATCOM to improve harmonic distortion and low power factor. The simulations were performed using MATLAB SIMULINK version R2009a.*

Key Words: *D-STATCOM, Voltage Sags, Voltage Source Converter (VSC), LCL Passive Filter, Total harmonics Distortion (THD).*

I. INTRODUCTION

In order to improve the survivability of a navy ship in battle condition, DSTATCOM or Distribution Static Compensator can be used, which reduces the impact of pulsed loads on the bus voltage and thus keeps the bus voltage at desired level. DSTATCOM is a voltage-source inverter (VSI) based shunt device generally used in distribution system to improve power quality. The main advantage of DSTATCOM is that, it has a very sophisticated power electronics based control which can efficiently regulate the current injection into the distribution bus. The second advantage is that, it has multifarious applications, e.g. a). Cancelling the effect of poor load power factor, b). Suppressing the effect of harmonic content in load currents, c). Regulating the voltage of distribution bus against sag/swell etc., compensating the reactive power requirement of the load and so on. The performance of the DSTATCOM is very much dependent on the DSTATCOM controller.

II. DISTRIBUTION STACTOM

i. Basic Principal of D-STACTOM: A DSTATCOM is a controlled reactive source, which includes a Voltage Source Converter (VSC) and a DC link capacitor connected in shunt, capable of generating and/or absorbing reactive power. The operating principles of a DSTATCOM are based on the exact equivalence of the conventional rotating synchronous compensator.

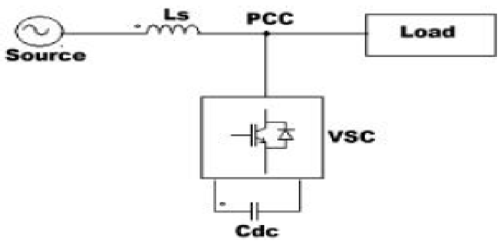

Fig. 1 Basic structure of D-STATCOM

The AC terminals of the VSC are connected to the Point of Common Coupling (PCC) through an inductance, which could be a filter inductance or the leakage inductance of the coupling transformer, as shown in Fig. 1. The DC side of the converter is connected to a DC capacitor, which carries the input ripple current of the converter and is the main reactive energy storage element. This capacitor could be charged by a battery source, or could be recharged by the converter itself. If the output voltage of the VSC is equal to the AC terminal voltage, no reactive power is delivered to the system. If the output voltage is greater than the AC terminal voltage, the DSTATCOM is in the capacitive mode of operation and vice versa. The quantity of reactive power flow is proportional to the difference in the two voltages. It is to be noted that voltage regulation at PCC and power factor correction cannot be achieved simultaneously. For a DSTATCOM used for voltage regulation at the PCC, the compensation should be such that the supply currents should lead the supply voltages, whereas, for power factor Correction, the supply current should be in phase with the supply voltages. The control strategies studied in this paper are applied with a view to studying the performance of a DSTATCOM for power factor correction and harmonic mitigation.

ii. Basic Configuration and operation of D-STATCOM

The D-STATCOM is a three-phase and shunt connected power electronics based device. It is connected near the load at the distribution systems. The major components of a D-STATCOM are shown in Fig. 2. It consists of a dc capacitor, three-phase inverter (IGBT, thyristor) module, ac filter, coupling transformer and a control strategy. The basic electronic block of the D-STATCOM is the voltage-sourced inverter that converts an input dc voltage into a three-phase output voltage at fundamental frequency. The D-STACOM employs an inverter to convert the DC link voltage V_{dc} on the capacitor to a voltage source of adjustable magnitude and phase. Therefore the D-STATCOM can be treated as a voltage-controlled source. The D-STATCOM can also be seen as a current-controlled source. Fig. 2 shows the inductance L and resistance R which represent the equivalent circuit elements of the step down transformer and the inverter will is the main component of the D-STATCOM.

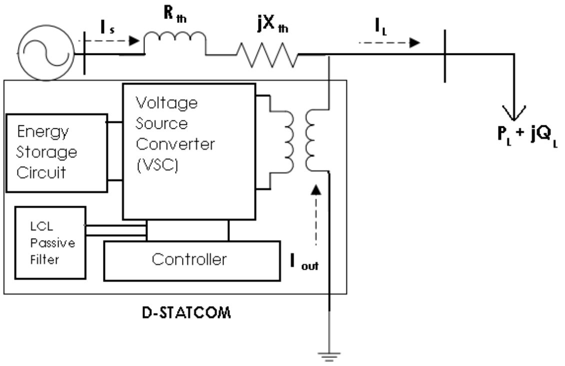

Fig. 2 Schematic diagram of a D-STATCOM

The voltage V_i is the effective output voltage of the D-STATCOM and δ is the power angle. The reactive power output of the D-STATCOM inductive or capacitive depending can be either on the operation mode of the DSTATCOM. The construction controller of the D-STATCOM is used to operate the inverter in such a way that the phase angle between the inverter voltage and the line voltage is dynamically adjusted so that the D-STATCOM generates or absorbs the desired VAR at the point of connection. The phase of the output voltage of the thyristor-based inverter, V_i, is controlled in the same way as the distribution system voltage, Vs.

iii. Compensation scheme of D-STATCOM

The D-STATCOM is a DC/AC switching power-converter composed of an air-cooled voltage source converter. Basically, the D-STATCOM is used to suppress voltage variations and control reactive power in phase with the system voltage. The D-STATCOM produces phase-synchronized output voltage, therefore, it can compensate for inductive and capacitive currents linearly and continuously. Active and reactive power trade between the power system and the D-STATCOM is accomplished by controlling the phase angle difference between the two voltages. If the output voltage of the D-STATCOM V_i is in phase with the bus terminal voltage V_t, and V_i is greater than V_t, the D-STATCOM provides reactive power to the system. If V_i is smaller than V_t, the D-STATCOM absorbs reactive power from the power system. Ideally, V_t and V_i have the same phase, but actually V_t and V_i have a little phase difference to compensate for the loss of transformer winding and inverter switching, so it absorbs some real power from system. Fig. 3 shows the D-STATCOM vector diagrams, which show the inverter output voltage V_i, system voltage V_t, reactive voltage V_L and line current I in correlation with the magnitude and phase α. Fig. 3(a) and Fig. 3(b) explain how V_i and V_t produce inductive or capacitive power by controlling the magnitude of the inverter output voltage V_i in phase with each other. Fig. 3(c) and Fig. 3(d) show that the DSTATCOM produces or absorbs real power with V_i and V_t having a phase difference ±α

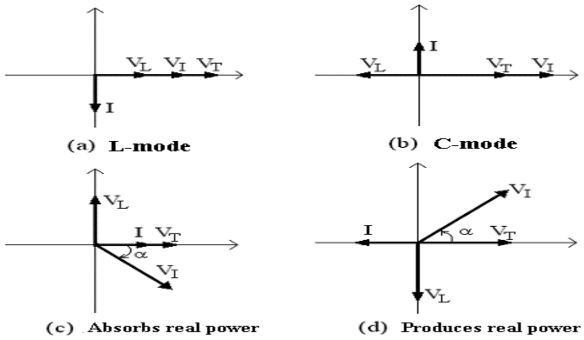

Fig. 3 Vector diagrams of D-STATCOM

Fig. 4 shows a radial type electric power distribution system feeding an unbalanced load. A DSTACOM is installed in parallel with the unbalance load for on-site load compensation. The reactive power output of the D-STATCOM in each phase, which is inductive or capacitive, can be independently controlled by the controller of the DSTATCOM for real-time load compensation

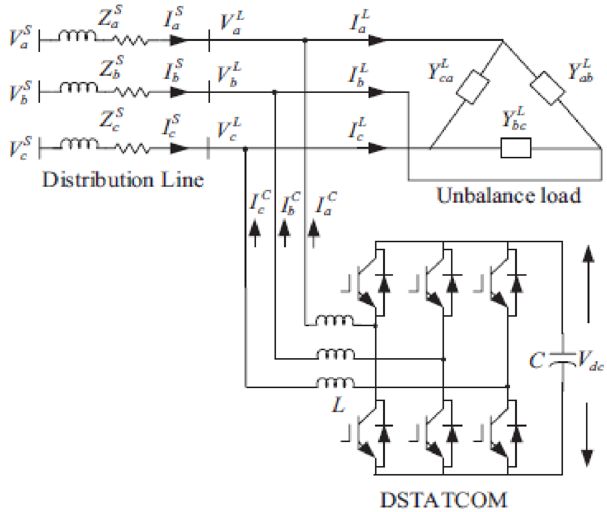

Fig. 4 A radial distribution system with an unbalance load and a DSTATCOM

III. Radial Distribution Test System

The test system comprises a 230kV, 50Hz transmission system, represented by a Thevenins equivalent, feeding into the primary side of a 3-wdg transformer connected in Y/Y/Y, 230/11/11 kV. A varying load is connected to the 11 kV, secondary side of the transformer. A two-level D-STATCOM is connected to the 11kV tertiary winding to provide instantaneous voltage support at the load point. A 750 μF capacitor on the dc side provides the D-STATCOM energy storage capabilities. Breaker 1 is used to control the period of operation of the D-STATCOM and breaker 2 is used to control the connection of load 1 to the system.

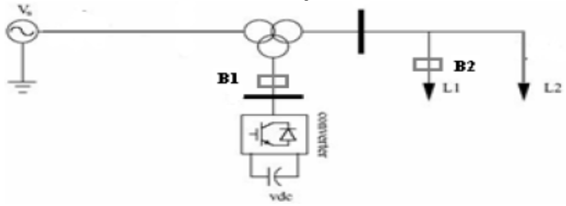

Fig. 5 Single Line Diagram of Test system

IV. Simulation Results & Discussion

4.1 Simulation Model for Test System without Insertion of D-STACTOM

To create distortion in the distribution system, different types of fault such as Three Phase to Ground (TPG), Double Line to Ground (DLG), Line to Line (LL), and Single Line to Ground (SLG) are injected.

Table 1 Results of voltage sags for different types of faults

R_f in Ω	SLG fault	DLG fault	TLG fault	LL fault
0.86	0.8679	0.7833	0.7515	0.8210
0.76	0.8485	0.7487	0.7106	0.7918
0.66	0.8259	0.7070	0.6600	0.7587

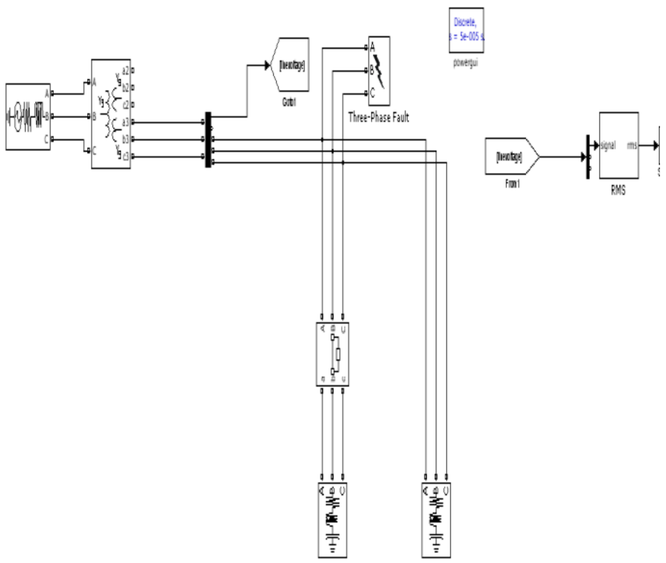

Fig. 6 Simulink Diagram for test system without D-STACTOM

Table 1 shows the overall results of voltage sags in p.u for different types of fault. From the table, it can be observed that when the value of fault resistance is increase, the voltage sags will also increased for different types of fault.

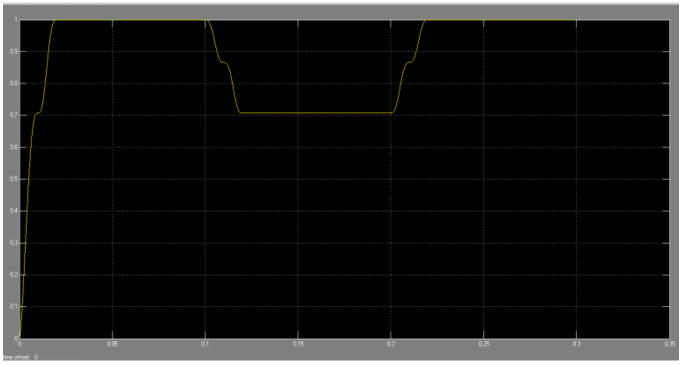

Fig .7 Voltage at load point is 0.6600 p.u in TPG fault

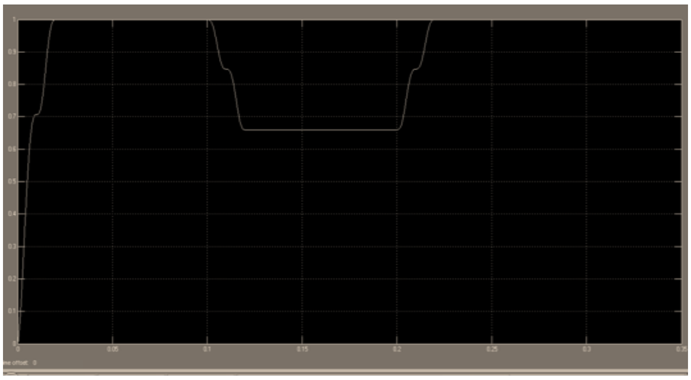

Fig. 8 Voltage at load point is0.7070 p.u in DLG fault

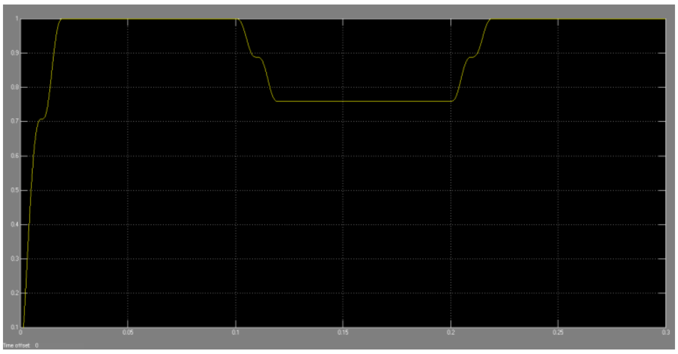

Fig. 9 Voltage at load point is 0.7587 p.u in LL fault

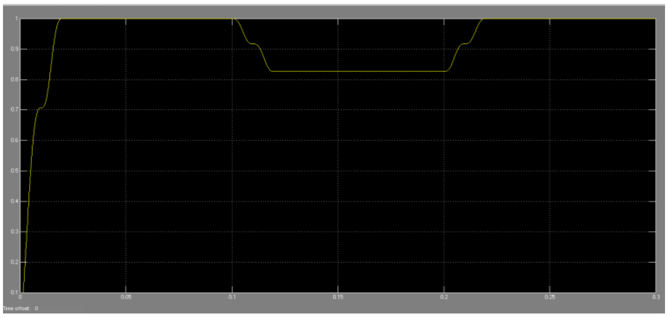

Fig. 10 voltage at load point is 0.8259 p.u in SLG fault

Figs. 7 to 10 show the simulation results of the test system for different types of fault without D-STATCOM. The fault occurs during when the fault resistance is 0.66 Ω

4.2 Simulation Model for the test system with insertion of D-STATCOM

To create distortion in the distribution system, different types of fault such as Three Phase to Ground (TPG), Double Line to Ground (DLG), Line to Line (LL), and Single Line to Ground (SLG) are injected.

Table 2 Results of voltage sags for different types of faults.

R_f in Ω	SLG fault	DLG fault	TLG fault	LL fault
0.86	0.9863	0.9858	0.9543	1.0152
0.76	0.9817	0.9806	0.9448	1.0143
0.66	0.9836	0.9801	0.9368	1.0169

Table 2 show the overall results of voltage sags in p.u with different types of fault. From the table, it can be observed that voltage sags improved with insertion of DSTATCOM. The value of voltage sags is between (0.9 to 1.02 p.u.)

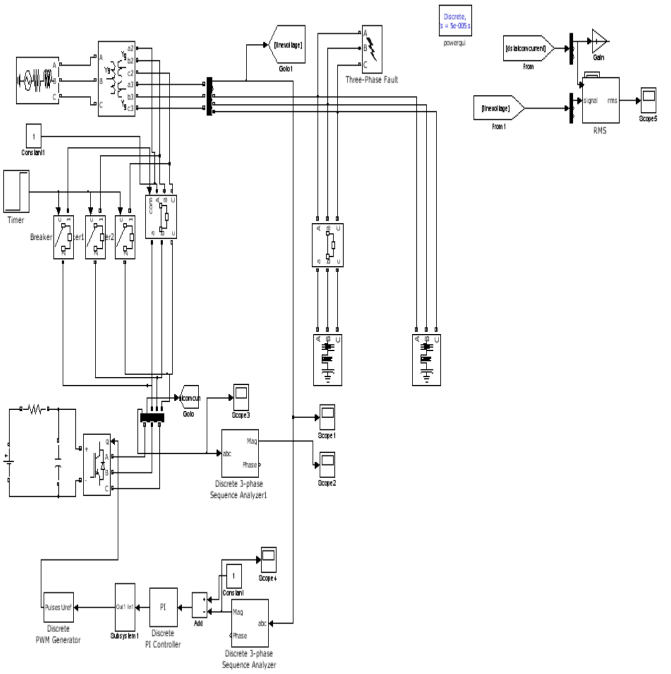

Fig. 11 Simulink Diagram for test system with D-STACTOM

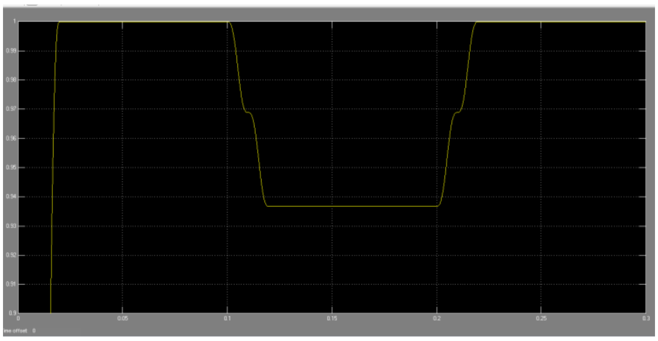

Fig. 12 Voltage at load point is 0.9367 p.u in TPG fault

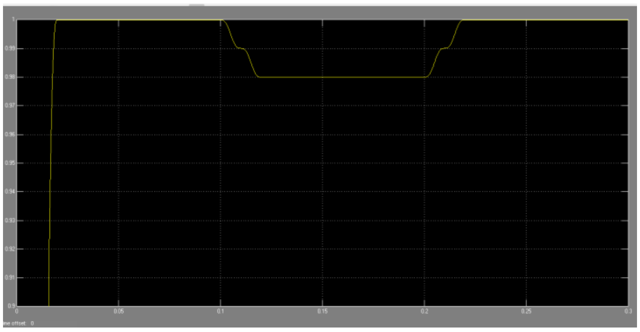

Fig. 13 Voltage at load point is 0.9888 p.u in DLG fault

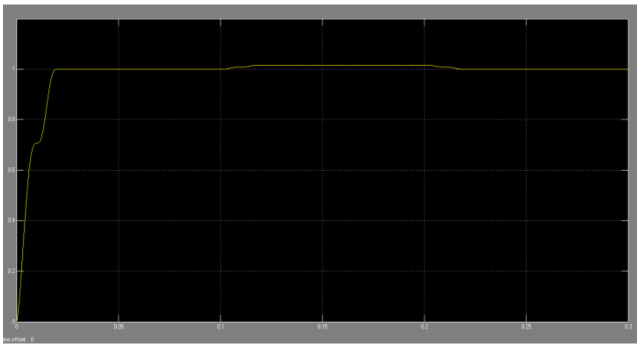

Fig. 14 voltage at load point is 1.0168 p.u in LL fault

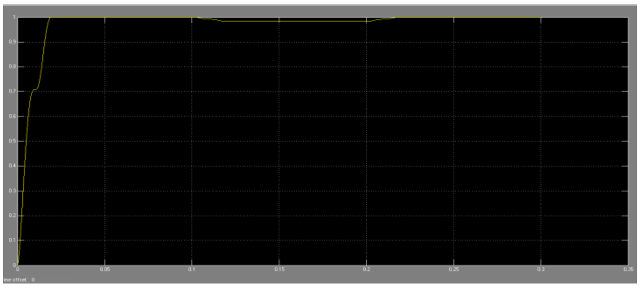

Fig. 15 voltage at load point is 0.9837 p.u in SLG fault

Figs. 12 to 15 show the simulation results of the test system for different types of fault with D-STATCOM. The fault occurs during when the fault resistance is 0.66 Ω.

Table 3 Results for different types fault before & after insert D-STACTOM when R_f=0.86

Types of Faults	Without D-STATCOM (p.u)	Without D-STATCOM (p.u)	% of improvement
SLG	0.8679	0.9863	11.84
DLG	0.7833	0.9858	20.25
TPG	0.7515	0.9543	20.28
LL	0.8210	1.0152	19.42

From Table 3 it can be seen that with D-STATOM the voltage sags has improved close to 1.0 p .u

4.3 Simulation Model for the test system with insertion of D-STATCOM with LCL Passive Filter

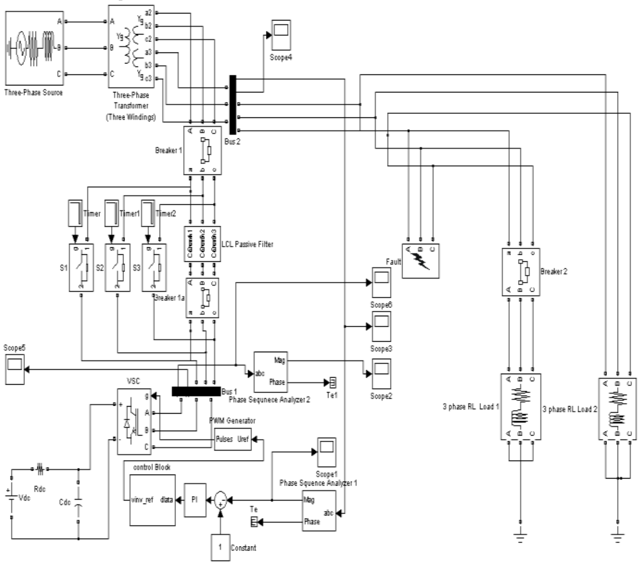

Fig. 16 Simulink Diagram for test system with insertion D-STACTOM with LCL Passive Filter

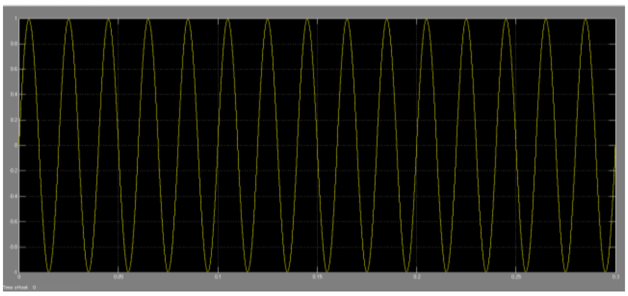

Fig. 17 waveform of output current with LCL Passive Filter

Fig. 17 shows the waveforms of output current. It is sinusoidal with LCL Passive filter was connected to the DSTATCOM. Figure 8.12 shows the spectrum of output current.

V. CONCLUSION

The simulation results show that the voltage sags can be mitigate by inserting D-STACTOM to the 11kV Radial distribution test system. By adding LCL passive filter to D-STACTOM, the Total Harmonic Distortions reduced and power factor can also increases close to unity. Thus, it can be concluded that by adding D-STACTOM with LCL passive filter the power quality is improved**.**

REFERENCES

[1] N. G. Hingorani, "Power electronics in electrical utilities: role of power electronics in future power systems," *Proceedings of the IEEE* Vol. 76 No.4, pp.481-482, Apr. 1988

[2] N. G. Hingorani and L. Gyugyi, "Understanding FACTS-concepts and technology of flexible AC transmission systems," *IEEE press, First Indian Edition*, 2001.

[3] A.E. Hammad, Comparing the Voltage ource capability of Present and future Var Compensation Techniques in Transmission System, IEEE Trans, on Power Delivery. volume 1. No.1 Jan 1995.

[4] G.Yalienkaya, M.H.J Bollen, P.A. Crossley, "Characterization of Voltage Sags in Industrial Distribution System", IEEE transactions on industry applications, volume 34, No. 4, July/August, PP.682-688, 1999

[5] Haque, M.H., "Compensation Of Distribution Systems Voltage sags by DVR and D STATCOM", Power Tech Proceedings, 2001IEEE Porto, Volume 1, PP.10-13, September 2001.

[6] Anaya-Lara O, Acha E., "Modeling and Analysis Of Custom Power Systems by SCAD/EMTDC", IEEE Transactions on Power Delivery, Volume 17, Issue: 2002, Pages: 266-272.

[7] Bollen, M.H.J.,"Voltage sags in Three Phase Systems", Power Engineering Review , IEEE, Volume 21, Issue :9, September 2001, PP: 11-15.

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