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Mitigation of Faults in the Distribution System by Distributed Static Compensator (DSTATCOM)

P. RAMESH[1], C. SURYA CHANDRA REDDY[2], D. PRASAD[3], D. PRAMEELA[4], A.ANUSHA[5]
[1]Research Scholor, Department of E.EE, S V U College of Engineering, S V University, Tirupati, A.P., India.
[2] IV B.Tech Student, Department of E.E.E., Sree Vidyanikethan Engineering College, Tirupati, A.P., India.
[3] IV B.Tech Student, Department of E.E.E., Sree Vidyanikethan Engineering College, Tirupati, A.P., India.
[4] IV B.Tech Student, Department of E.E.E., Sree Vidyanikethan Engineering College, Tirupati, A.P., India.
[5] IV B.Tech Student, Department of E.E.E., Sree Vidyanikethan Engineering College, Tirupati, A.P., India.

Abstract:
This paper proposes a flexible D-STATCOM (Distribution Static Compensator) and its new controller system, that be able to mitigate all types of faults (LG, DLG, LL, 3-PHASE and 3-PHASE TO GROUND), and improve the distribution system performance. This paper validates the performance of D-STATCOM system to mitigate the power quality problems such as voltage flickers, voltage sags/swells harmonics and improve the distribution system performance under all types of system related disturbances and system unbalanced faults (LG, LL, DLG), balanced faults (3-phase fault and 3-phase to ground fault). 12-pulse D-STATCOM configuration with IGBT is designed and the graphic models of the D-STATCOM is developed using the MATLAB/SIMULINK.

Keywords: Distribution System, D-STATCOM, Voltage Sags, Faults.

I.INTRODUCTION

The modern power distribution network is constantly being faced with an ever-growing load demand. Distribution networks experience distinct change from a low to high load level every day. Electric load growth and higher regional power transfers in a largely interconnected network becoming more complex and less secure power system operation. Power generation and transmission facilities are unable to meet these new demands. Many loads at various distribution ends like domestic utilities, computers, process industries, adjustable speed drives, printers, and microprocessor based equipment etc. have become intolerant to voltage fluctuations, harmonic content and interruptions. Electrical power losses in distribution systems correspond to about 70% of total losses in electric power systems. One of the most severe problems faced by distribution networks operators is voltage drop along distribution feeders, which is caused by real and reactive power flow. Voltage control is a difficult task because voltages are strongly influenced by random load fluctuations. Voltage profile can be improved and power losses can be considerably reduced by installing Custom Power Devices or Controllers at suitable location. These controllers which are also named Distribution Flexible AC Transmission System (D-FACTS) [1] are a new generation of power electronics-based equipment aimed at enhancing the reliability and quality of power flows in low-voltage distribution networks. Custom power is formally defined as the employment of power electronic or static controllers in distribution systems rated up to 38 kV for the purpose of supplying a level of reliability or PQ that is needed by electric power customers who are sensitive to power variations. Custom power devices or controllers [2] include static switches, inverters, converters, injection transformers, master-control modules and energy-storage modules that have the ability to perform current-interruption and voltage-regulation functions within a distribution system.

The STATCOM is applied in distribution system is called D-STACOM (Distribution STACOM) and its configuration is the same, or with small modifications, oriented to a possible future amplification of its possibilities in the distribution network at low and medium voltage implementing the function so that we can describe as flicker damping, harmonic, filtering and short interruption compensation. D-STATCOM exhibits high speed control of reactive power to provide voltage stabilization, flicker suppression, and other types of system control. The D-STATCOM utilizes a design consisting of a GTO- or IGBT-based voltage sourced converter connected to the power system via a multi-stage converter transformer. This paper proposes a flexible D-STATCOM system designed to mitigate the voltage sags caused by LG, LL, DLG, 3-Phase and 3-Phase to ground faults. And improve the power quality of the distribution system. Reactive power compensation is an important issue in the control of distribution systems. The main reason for reactive power compensation in a system is the voltage regulation increased system stability, better utilization of machines connected to the system, reducing losses associated with the system and to prevent voltage collapse as well as voltage sag. Reactive current increases the distribution system losses, reduces the system power factor, shrink the active power capability and can cause large-amplitude variations in the load-side voltage [3,4]. Various methods have been applied to mitigate voltage sags. The conventional methods use capacitor banks, new parallel feeders, and uninterruptible power supplies (UPS).The D-STATCOM has emerged as a promising device to provide not only for voltage sag mitigation but also for a host of other power quality solutions such as voltage stabilization, flicker suppression, power factor correction [5]. By a similar argument, the D-STATCOM is also suitable for reducing the impact of voltage transients The DSTATCOM configuration consists of a typical 12-pulse inverter arrangement, a dc energy storage device; a coupling transformer connected in shunt with ac system, and associated control circuits. The configurations that are more sophisticated use multi pulse and/or multilevel configurations. The VSC converts the dc voltage across the storage device into a set of three-phase ac output voltages. These voltages are in phase and coupled with the ac system of network through the reactance of the coupling transformer [6].

A control method based on RMS voltage measurement has been presented in [7] and [8] where they have been presented a PWM-based control scheme that requires RMS voltage measurements and no reactive power measurements are required. In addition, in this given method, Clark and Park transformations are not required. However, they have been investigated voltage sag/swell mitigation due to just load variation while no balanced and unbalanced faults have been investigated. In this paper, a new control method for mitigating the load voltage sags caused by all types of fault is proposed. In [9] and [10], a Lookup Table is used to detect the proportional gain of PI controller, which is based only on Trial and Error. While in this paper, the proportional gain of the PI controller is fixed at a same value, for all types of faults, by tuning the transformer reactance in a suitable amount. Then the robustness and reliability of the proposed method is more than the mentioned methods. In this method, the dc side topology of the D-STATCOM is modified for mitigating voltage distortions and the effects of system faults on the sensitive loads are investigated and the control of voltage sags are analysed and simulated.

II.THE PROPOSED D-STATCOM STRUCTURE

The basic electronic block of the DSTATCOM is the voltage source inverter that converts an input dc voltage into a three-phase output voltage at fundamental frequency.

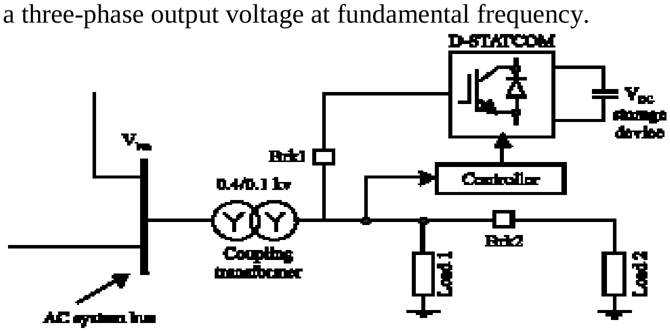

Fig.1 Block diagram of D-STATCOM

These voltages are in phase and coupled with the ac system through the reactance of the coupling transformer. Suitable adjustment of the phase and magnitude of the D-STATCOM output voltages allow effective control of active and reactive power exchanges between the D-STATCOM and the ac system. Fig. 2 shows a typical 12-pulse inverter arrangement utilizing two transformers with their primaries connected in series. The first transformer is in Y-Y connection and the second transformer is in Y-Δ connection. Each inverter operates as a 6-pulse inverter, with the Y-Δ inverter being delayed by 30 degrees with respect to the Y-Y inverter. The IGBTs of the proposed 12-pulse FD-STATCOM are connected anti parallel with diodes for commutation purposes and charging of the DC capacitor [11]. This is to give a 30 degrees phase shift between the pulses and to reduce harmonics generated from the FD-STATCOM.

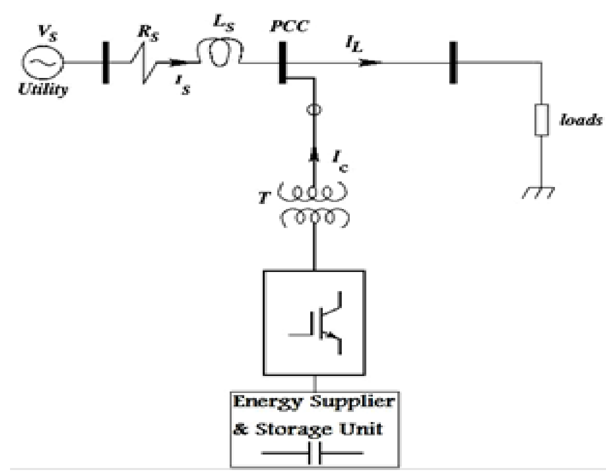

Fig 2: D-STATCOM structure

The coupling transformer injects the three phase voltages to the distributed line which is equal to the line voltage and phase angle.

III. CONTROL STRATEGY

The block diagram of the control scheme designed for the FD-STATCOM is shown in Fig. 3. It is based only on measurements of the voltage VRMS at the load point.

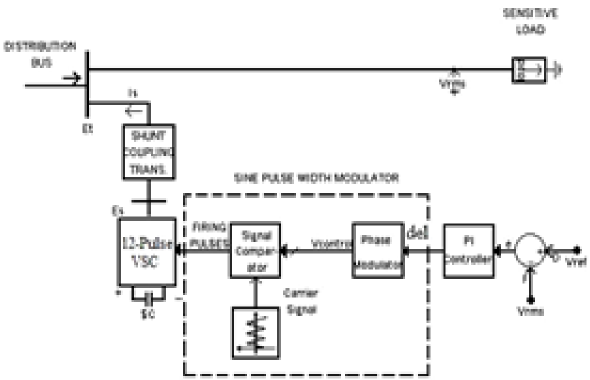

Fig.3. Control scheme designed for the

D-STATCOM

The voltage error signal is obtained by comparing the measured V_{RMS} voltage with a reference voltage, V_{RMSRef}. A PI controller processes the difference between these two signals in order to obtain the phase angle δ that is required to drive the error to zero. The angle δ is used in the PWM generator as the phase angle of the sinusoidal control signal. The switching frequency used in the sinusoidal PWM generator is 1450 Hz and the modulation index is 1 [12]. The modulating angle δ is applied to the PWM generators in phase A. The angles of phases B and C are shifted 120 and 240 degrees, respectively.

IV. PROPOSED CONTROL METHOD

In this paper, in order to mitigate voltage sags caused by LG, LL, DLG, 3-Phase and 3-Phase to ground faults and improve the power quality improvement of the distribution system. Considering this fact that all types of fault may occur in distribution system, controller system must be able to mitigate any types of voltage sags. The control of a D-STATCOM is developed to mitigate such problems and enhance power quality and improve distribution system reliability. D-STATCOM is connected to the Y-Y and Y- Δ transformers for creating the 30 degrees phase shift. Harmonics mitigation will takes place by creating the 30 degrees phase shift.

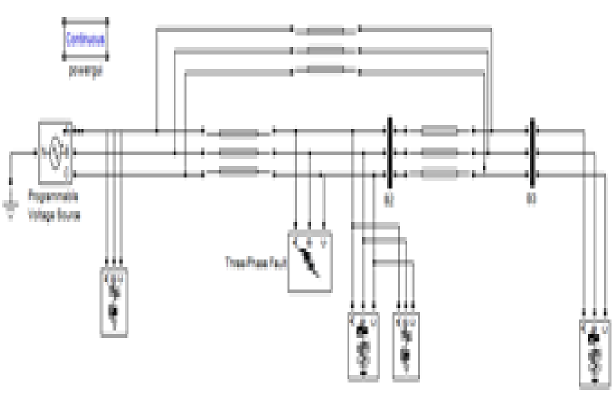

Fig 4: SIMULINK diagram WITHOUT D-STATCOM

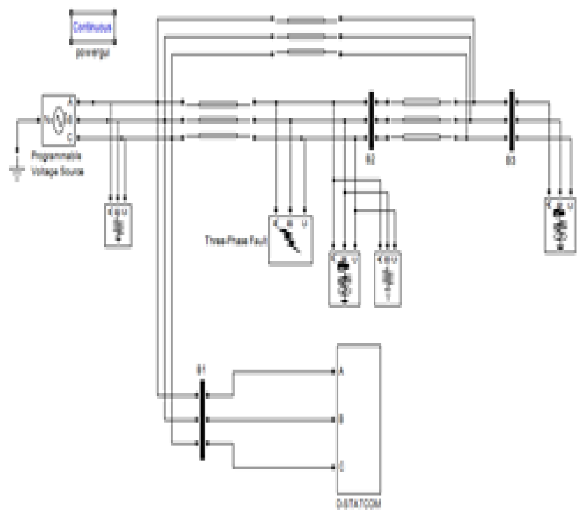

Fig 5: SIMULINK diagram WITH D-STATCOM

parameters	Values
Source 1	25kv
Source2	25KV
Source3	25KV
Load 1	300KW
Load2	200KW
Length BW B1 to B2	25Km
Length BW B2 to B3	20Km

Table 1: Specifications of test system

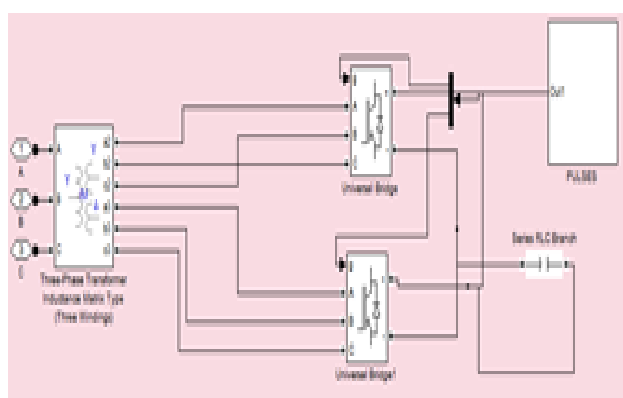

Fig 6: Simulink model for D-STATCOM

V.SIMULATION RESULTS

Fig .4 and Fig.5 are the test system implemented in MATLAB/SIMULINK to carryout simulations for the D-STATCOM. The test system is a distribution system having a voltage of 25 KV and different loads are connected to that supply. The fault occurred in the test system between 0.1 to

0.15 seconds. The simulations are carried out for both cases where the D-STATCOM is connected to or disconnected from the system. The simulations of the D-STATCOM in fault condition are done using LG, LL, DLG, 3-phase and 3-phase to ground faults.
In this paper, the D-STATCOM uses the proposed control method to mitigate the load voltage sags due to all types of faults; the simulations are done for all types of faults introduced in the 25 KV distribution systems as follows.

A.SIMULATION RESULTS LINE TO GROUND FAULT

Fig 7 shows the voltage and current at the buse2, and fault is injected in the system between 0.1 and 0.15, whenever voltage value is less than the reference value, on that time the D-STATCOM injects voltage into the system and making the voltage profile be unity.

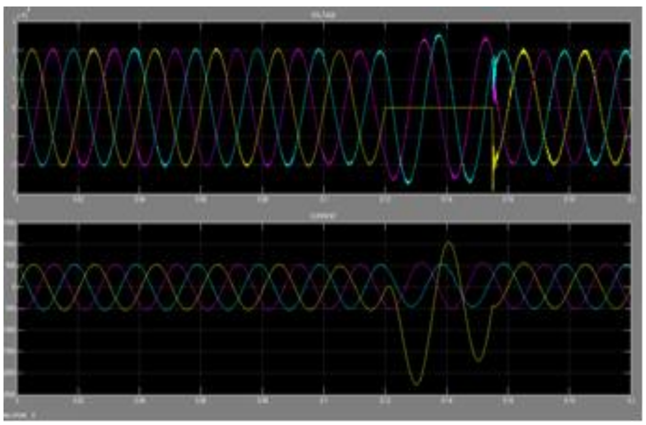

Fig 7: voltage and current at bus2 without D-STATCOM

Fig 8 shows the voltage and current at the bus2 with D-STATCOM, the voltage is continuous and current is also continuous without any deviation.

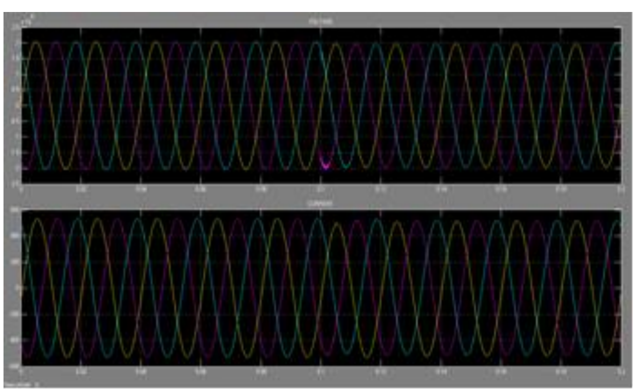

Fig 8: voltage and current at bus2 with **DSTATCOM**

B.SIMULATION RESULTS DOUBLE LINE FAULT

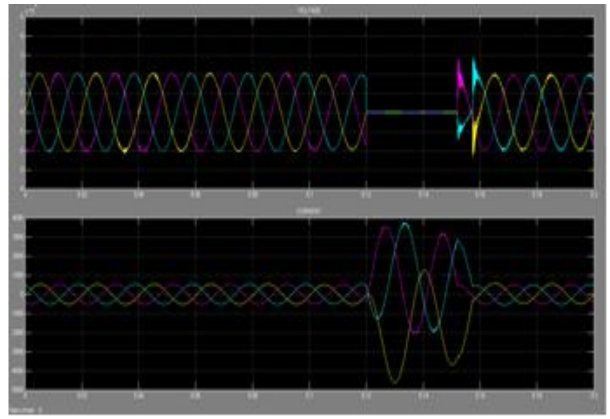

Fig 9: voltage and current at bus2 without D-STATCOM

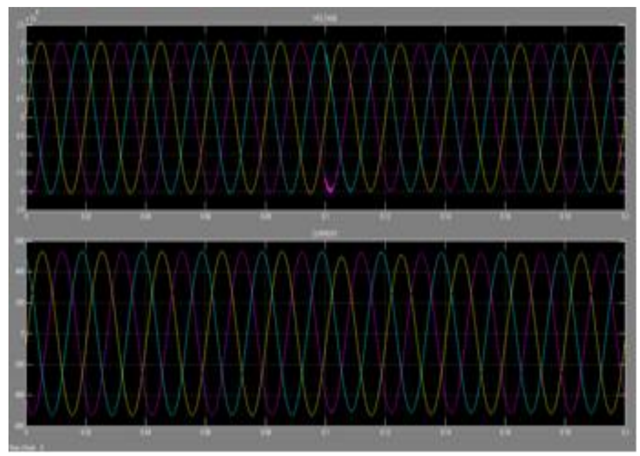

Fig 10: voltage and current at bus2 with D-STATCOM

C.SIMULATION RESULTS FOR DOUBLE LINE TO GROUND FAULT

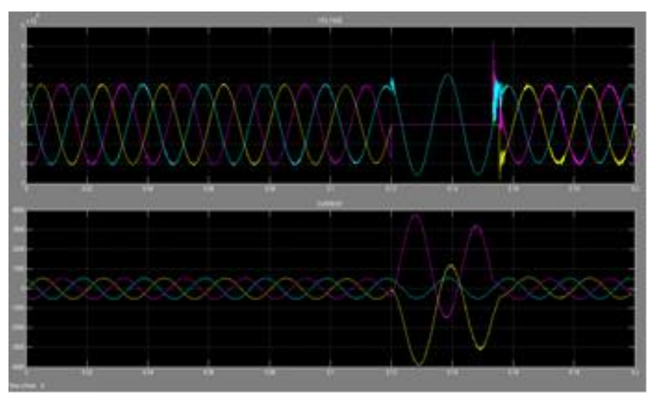

Fig 11: voltage and current at bus2 without D-STATCOM

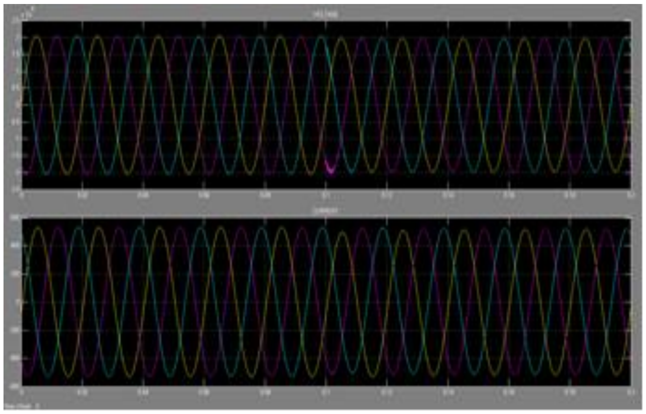

Fig 12: voltage and current at bus2 with D-STATCOM

D.SIMULATION RESULTS FOR 3-PHASE FAULT

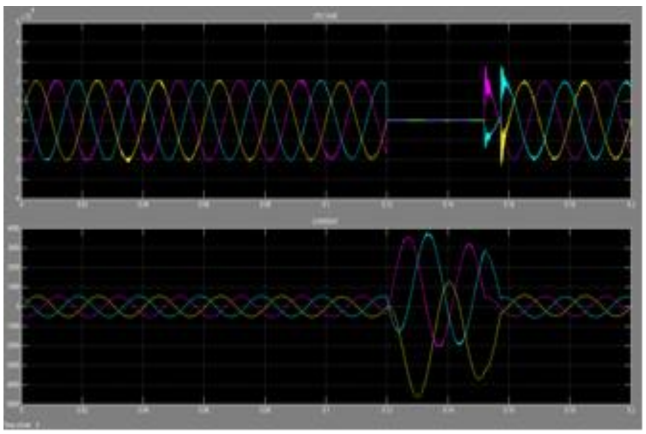

Fig 13: voltage and current at bus2 without D-STATCOM

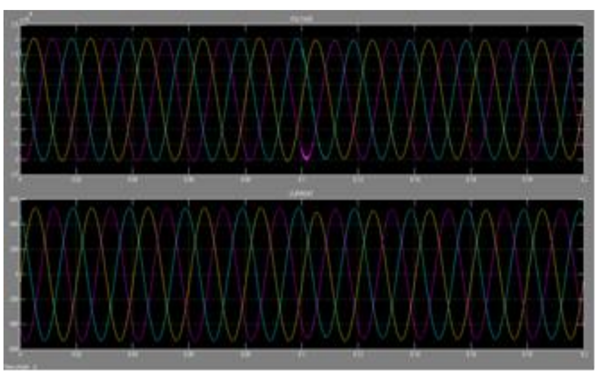

Fig 14: voltage and current at bus2 with D-STATCOM

E.SIMULATION RESULTS FOR 3-PHASE TO GROUND FAULT

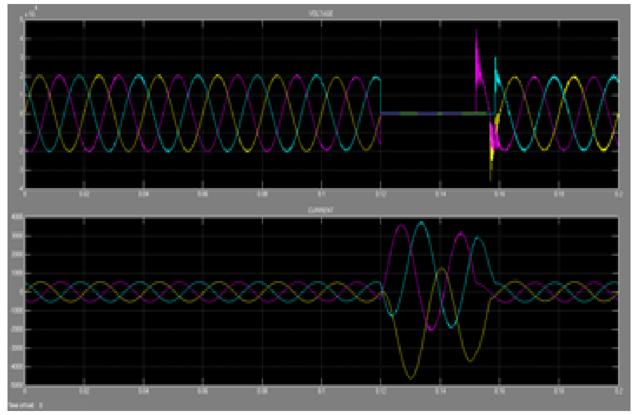

Fig 15: voltage and current at bus2 without D-STATCOM

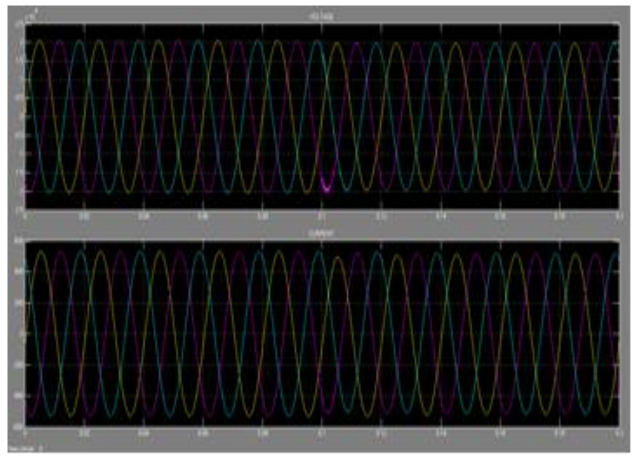

Fig 16: voltage and current at bus2 with D-STATCOM

VI. CONCLUSIONS

In this paper, the D-STATCOM and its control system proposed that could mitigate the voltage sags (such as LG, LL, DLG, 3-Phase and 3-Phase to Ground faults) and improved the power quality of the distribution system such as voltage flickers and power factor correction. The D-STATCOM is connected to the Y-Y and Y-Δ, the harmonics generated by a power electronic component is mitigated by providing the 30 degrees phase shift. The operation of the D-STATCOM and its control system are developed in MATLAB/SIMULINK for mitigating the voltage sags and improving the power quality of the distribution system.

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BIOGRAPHIES

P.Ramesh was born in Andhra Pradesh, India, 1982. He received the B.E degree in Electrical and Electronics Engineering from University of Madras, India, in 2003, and the M.Tech. degree in Power electronics and drives from Bharath University, Chennai, India, 2005.From 2005 to 2010 he worked as a faculty in the field of Electrical and Electronics Engineering Since August, 2010, he has been working toward the Ph.D. degree in the field of Flexible AC Transmission Systems, Sri Venkateswara University College of Engineering, Sri Venkateswara University, India.s