Voltage Sag Mitigation Analysis Using DSTATCOM Under Different Faults in Distribution System

Dhanorkar Sujata , E. Himabindu

Abstract: **An important task in power system operation is to decide whether the system, at a given point of time, operates safely, critically and optimally .Voltage sag has been considered as one of the most harmful power quality problem as it may significantly affect industrial production. To overcome the problem related to power quality Custom power devices, a distribution static compensator is used in this work which is one of the power-conditioning technology devices used to correct end-user problems in response to voltage sag. The fast response of the Distribution Static Compensator (DSTATCOM) makes it the efficient solution for improving power quality in distribution systems.**

The main objective of this paper is to show that with DSTATCOM, it is possible to reduce the voltage fluctuations like sag and swell conditions in distribution systems.

Keywords: Voltage sag mitigation, custom power device, DSTATCOM, line faults, Simulink.

I. INTRODUCTION

Custom power is formally defined as the employment of power electronic or static controllers in distribution systems rated up to 33 kV for the purpose of supplying a level of reliability or power quality that is needed by electric power customers who are sensitive to power variations. Distribution Static Compensator (DSTATCOM) to protect the distribution System from the effects of voltage sags and swells. Voltage sag is frequently occurring power quality problem. Voltage Sag is defined as a short reduction in voltage magnitude for duration of time, and is the most important and commonly occurring power quality issue. According to the IEEE defined standard (IEEE Std. 1159, 1995), voltage sag is a decrease of rms voltage from 0.1pu to 0.9 pu(per unit), for a duration of half cycle to 1 minute. Voltage sag is mainly occurs because of faults on the system, transformer energizing or heavy load switching, etc. Most sags is represented by an instantaneous voltage drop caused by the cutting off of the power supply circuit due to a short circuit to the ground or high inrush current generation when starting a large motor like equipments. This voltage drop may cause a stop or reset of equipment, turn off lighting, speed change or stop of motor, and synchronization error of synchronous motors or generators.

The main causes of voltage sags are network faults and the starting of equipment which draw large currents. The different factors affecting sag characteristics are type of fault, Location of fault, X/R ratio of the lines, Point on wave of sag initiation and Single/Double circuit transmission.

Type of fault i.e. balanced or unbalanced, sag will be balanced or unbalanced in all three phases. The magnitude and phase angle of sag will also depend on the type of fault.

Along with the type, the location of faults in the system has a great impact on the magnitude as well as the phase-angle jump of the sag. With change in the X/R ratio of the line there is change in the X/R ratio of fault to source impedance which will affect the magnitude as well as phase-angle jump. The point on wave of sag initiation is the phase angle of the fundamental voltage wave at which the voltage sag starts. This angle corresponds to the angle at which the short circuit fault occurs. With change in point on wave of sag initiation it is expected that the phase-angle jump will change more as compared to the magnitude of sag.

In the power system it is common practice to have double circuit transmission to improve reliability. With changes in the transmission configuration basically there will be change in X/R ratio of impedances, which will affect the characteristic of sag.

A. Problem Definition

Voltage sag has been considered as one of the most harmful power quality problem as it may significantly affect industrial production. To overcome the problem related to power quality Custom power devices, a distribution static compensator is used .The main objective of the paper is to show that using DSTATCOM it is possible to reduce the voltage fluctuations like sag conditions in distribution systems. The DSTATCOM which can be used for improving power quality is modeled and simulated using proposed control strategy. DSTATCOM is applied to IEEE 30 Bus system at different line fault conditions.

B. DSTATCOM as A Solution

The DSTATCOM is basically one of the custom power devices. The main component of the DSTATCOM is a power VSC that is based on high power electronics technologies.

Required voltages and currents are measured and are compared with the commands. Then the controller gives a set

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of switching signals to drive the main semiconductor switches of the power converter accordingly. The basic scheme of the DSTATCOM is shown in Fig .1.

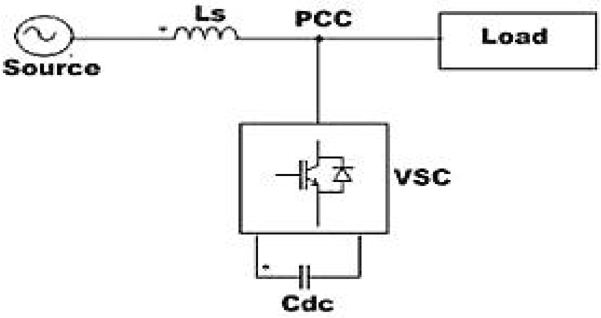

Fig. 1.The basic diagram of the DSTATCOM

The ac voltage control is achieved by firing angle control. The output voltage of the VSI is in phase with the bus (where the DSTATCOM is connected) voltage. In steady state, the dc side capacitance is maintained at a fixed voltage and there is no real power exchange, except for losses. There are two control objectives implemented in the DSTATCOM. One is the ac voltage regulation of the power system at the bus where the DSTATCOM is connected and the other is dc voltage control across the capacitor inside the DSTATCOM. The DSTATCOM is capable of generating continuously variable inductive or capacitive shunt compensation at a level up its maximum MVA rating. The DSTATCOM continuously checks the line waveform with respect to a reference ac signal and provide the correct amount of leading or lagging reactive current compensation to reduce voltage fluctuations.

The sending end source is assumed to be a strong system with high short circuit ratio and low impedance and source voltage is considered as a constant source irrespective of variations in load current is as shown in Fig .2.

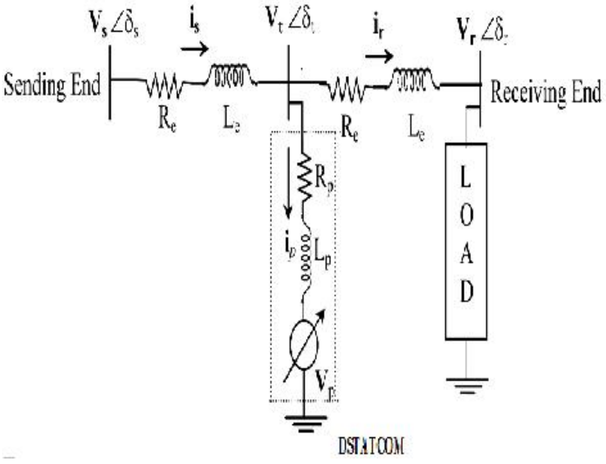

Fig.2. Equivalent Circuit of the Above System with DSTATCOM

II.PROPOSED DSTATCOM MODEL

DSTATCOM has been represented as three independently controllable single phase current sources injecting reactive current in the three phases at the point of coupling. The proposed DSTATCOM model has been shown in Fig.3. It consists of a two-level Voltage Source Converter (VSC), a dc energy storage device, a coupling transformer connected in shunt to the distribution network through a coupling transformer. The control scheme consists of three control switches which can be set on/off as per compensation requirement. The amount of reactive compensation provided by DSTATCOM can be adjusted to mitigate voltage sag at load buses. The three switches remain open during pre-fault condition and are closed upon occurrence of faults. This permits injection of independently controllable reactive currents under fault, to the three phases of DSTATCOM bus.

The VSC converts the dc voltage across the storage device into a set of three-phase ac output voltages which are in phase and coupled with the ac system. D-STATCOM allows effective control of active and reactive power exchanges between the D-STATCOM and the ac system by proper adjustment of the phase and magnitude.

Such configuration allows the device to absorb or generate controllable active and reactive power. The DSTATCOM is connected to the power networks where the voltage sag is a concern. All required voltages and currents are measured and are fed into the controller to be compared with the commands. The controller then performs feedback control and outputs a set of switching signals to drive the main semiconductor switches (IGBT's, which are used at the distribution level) of the power converter accordingly The maximum and minimum reactive power injection limit of DSTATCOM has been taken as +50 M VAR and -50 MVAR, respectively.

III. TESTING DSTATCOM MODEL

The performance of the DSTATCOM is analyzed with a variable load at bus 2 .First, there is no load connected at bus 2. Then the switch S1 is closed so that load1 is applied and after some duration the switch S2 is closed i.e load2 is applied ; both switches remain closed until the end of the simulation. During these events, the terminal voltage of bus 2 decreases showing the effect of sags.

Following are the specifications of IEEE 30 Bus system used which is as shown in Fig.4.

- No .of generator buses:6
- No. of load buses :24
- Real power demand :283.40 MW
- Reactive power demand :126.20 MVAR
- Faults Applied :L-G, L-L, L-L-G and L-L-L-G
- Duration of fault :50 ms
- Fault resistance :0.001 Ω

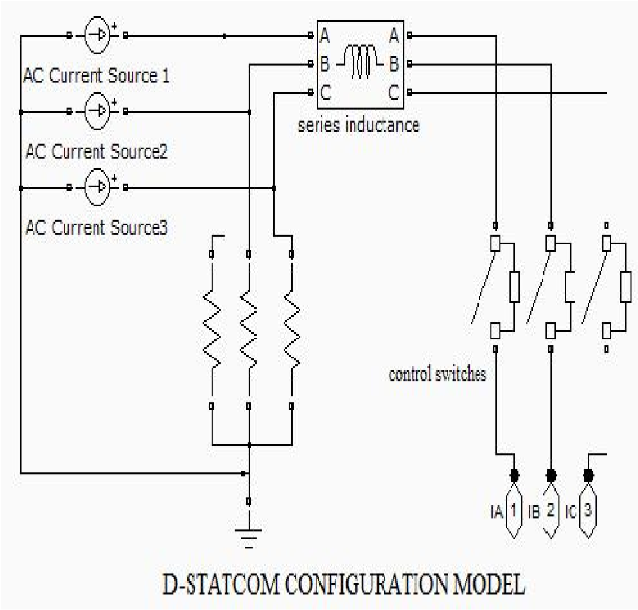

Fig. 3. Proposed DSTATCOM Configuration Model

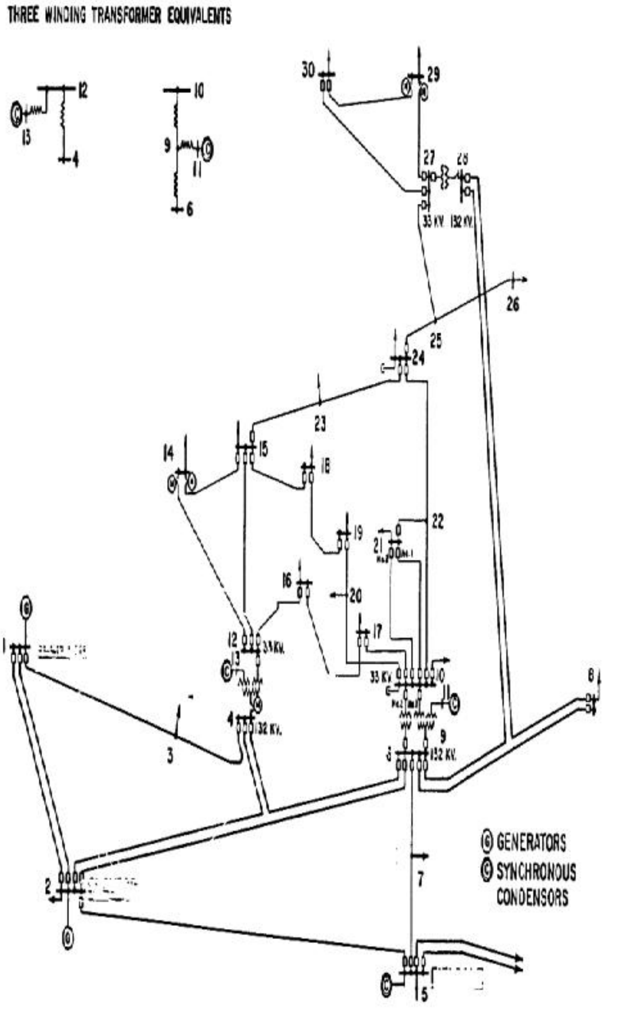

Fig. 4. IEEE 30 Bus System

IV. METHODOLOGY AND TEST SYSTEM RESULTS

The simulation model of the power system network understudy is developed using MATLAB/SIMULINK. As shown in Fig. 5, Fig. 6 and Fig. 7.

The three phase per unit (p.u.) voltages of all the buses of the network under different type of short-circuits viz. single line to ground (L-G), line to line (L-L), double line to ground (L-L-G) and three phase (L-L-L or L-L-L-G) faults are found using this model.

The testing result provides information about most insecure bus of the system based on highest deviation from the target. The bus with the highest deviation from the target data has been considered as the optimal location for the placement of DSTATCOM to mitigate the voltage sag problem.

Voltage profile of bus no. 17 and 10 with 3 phase faults at bus 13 with and without DSTATCOM for different faults i.e. Single Line to Ground (LG), Line to Line Fault (LL), Double Line to Ground (LL) and Triple Line to Ground Fault (LLG) are as shown in Fig.8 to Fig.15.

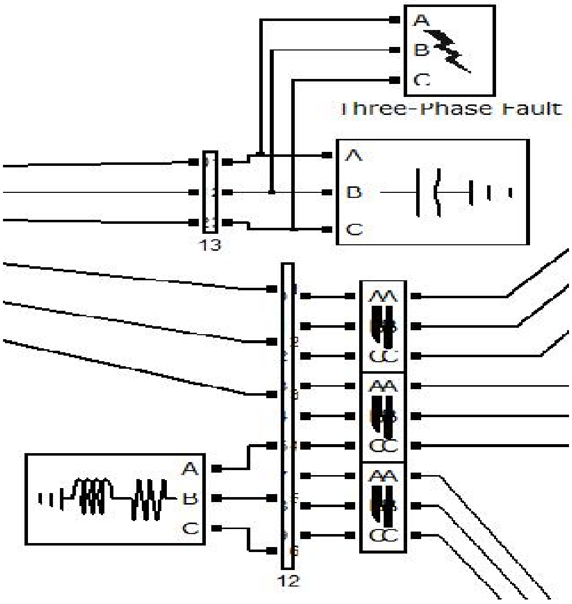

Fig. 5. 3 Φ Faults at Bus No.13

IV. CONCLUSION

Voltage sag and swells has emerged as a major concern in the area of power quality. The voltage sag problems in a distribution system using IEEE 30 bus system has been analyzed which can be used in a distribution system suffering from short-circuit level and stability constraints, the installation of a DSTATCOM controller may be a good choice since the fault currents are minimized .

The simulation results show that proposed approach of placement of DSTATCOM is quite effective in voltage sag mitigation under short-circuits in distribution system. This approach is quite simple and easy to adopt.

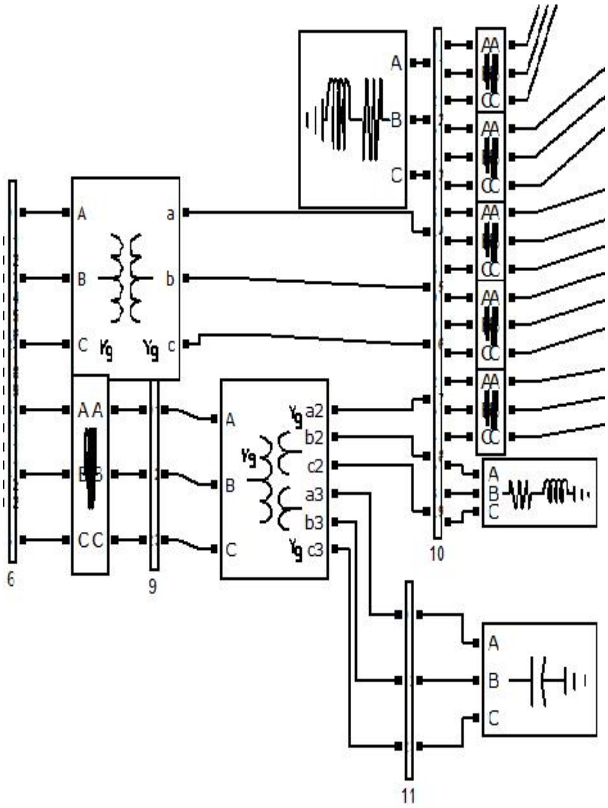

Fig.6. Simulink Model of Test System without DSTATCOM at Bus No. 10

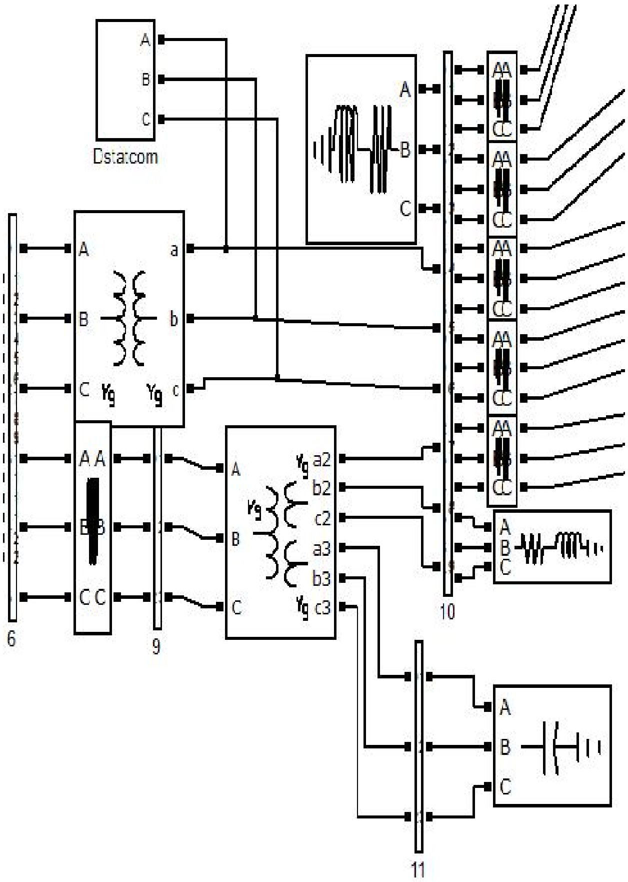

Fig.7. Simulink Model of IEEE 30 Bus Test System with Optimal Placement of DSTATCOM at Bus No. 10 for 3 Φ Faults at Bus No.13

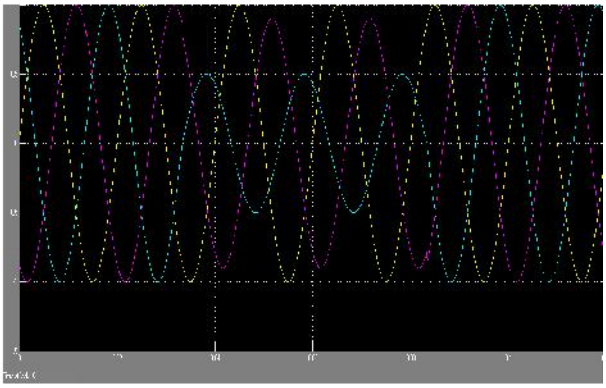

Fig. 8. Single Line to Ground (LG) Fault Voltage Profile of Bus No. 17 and 10 With LG Fault at Bus 13 without DSTATCOM at Bus 10

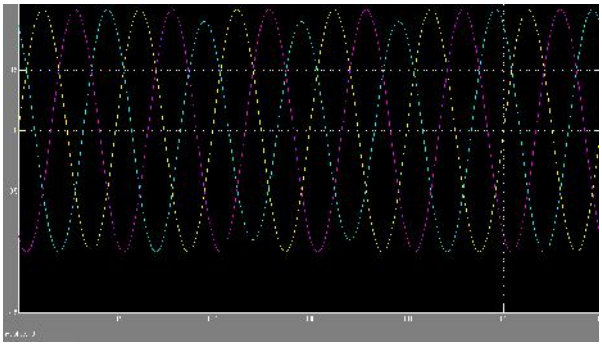

Fig.9. Single Line to Ground (LG) Fault Voltage Profile of Bus No. 17 and 10 with LG Fault at Bus 13 with DSTATCOM at Bus 10

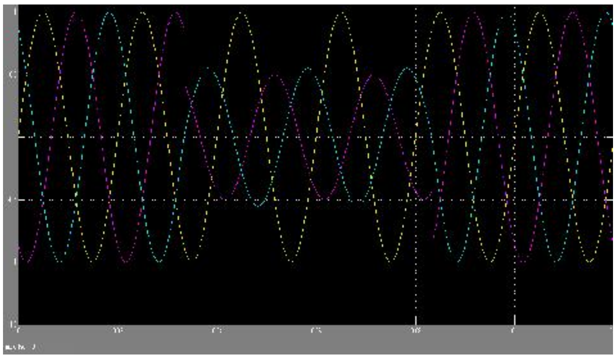

Fig. 10. Voltage Profile of Bus No. 17 and 10 with for Line to Line Fault (LL) at Bus 13 without DSTATCOM at Bus 10

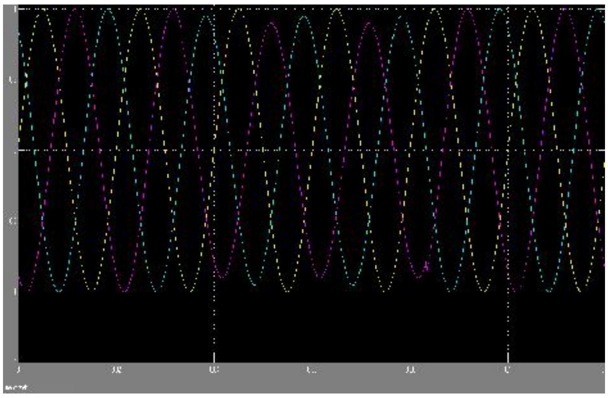

Fig. 11 .Voltage Profile of Bus No. 17 and 10 With for Line to Line Fault (LL) at Bus 13 with DSTATCOM at Bus 10

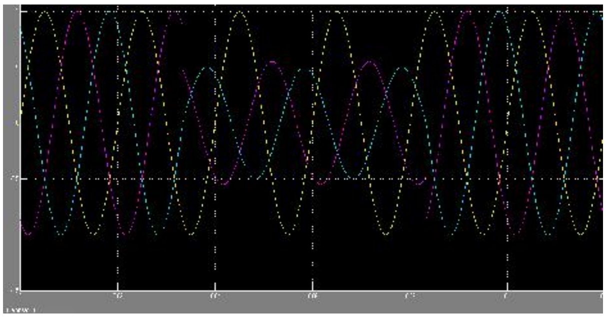

Fig.12. Voltage Profile of Bus No. 17 and 10 with for Double Line to Ground Fault (LLG) at Bus 13 without DSTATCOM at Bus 10

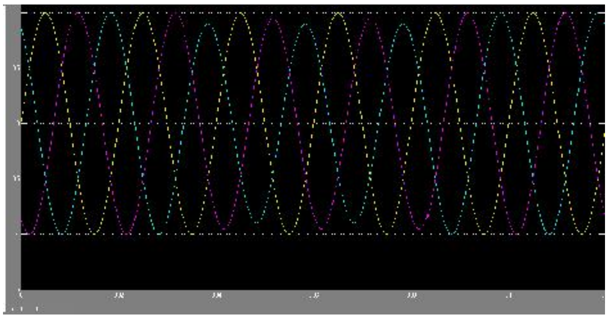

Fig. 13 Voltage Profile of Bus No. 17 and 10 with for Double Line to Ground Fault (LLG) at Bus 13 with DSTATCOM at Bus 10

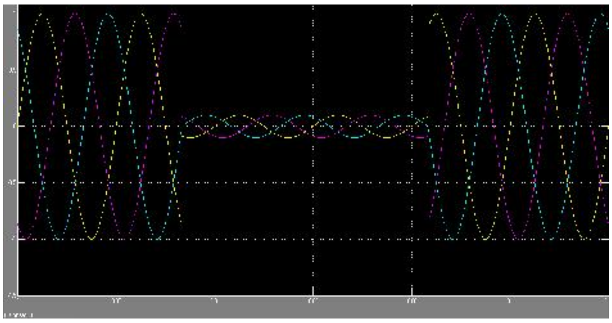

Fig.14 Voltage Profile of Bus No. 17 and 10 with For Triple Line to Ground Fault at Bus 13 without DSTATCOM at Bus 10

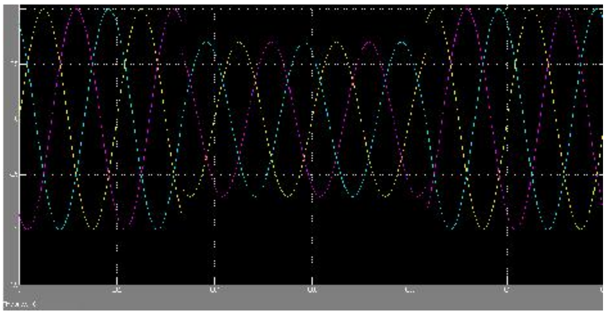

Fig.15 Voltage Profile of Bus No. 17 and 10 with For Triple Line To Ground Fault at Bus 13 With DSTATCOM at Bus 10

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