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POWER QUALITY IMPROVEMENT IN POWER DISTRIBUTION SYSTEM BY USING D – STATCOM

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***Abstract**:* One of the key areas of study in the power system is power quality. The utilities deal with a variety of power quality issues, such as voltage sag, flicker, electrical noise, harmonic distortion, and other disruptions. Utilizing equipment that can address power quality issues is crucial. One of the FACTS devices used in power systems as a power electronic shunt device that absorbs and supplies reactive power to address power quality issues in power distribution systems is D-STATCOM (distribution static compensator). The most efficient way for determining the ideal location of DSTATCOM in the test system is to simulate the IEEE 15 bus test system while using the sensitivity index. The PI controller creates the D-STATCOM controller, which is used to reduce voltage under various conditions such as: load increasing decreasing, line outage and single line to ground fault (SLG) using MATLAB Simulink.

Index Terms - **D-STATCOM, FACTS, MATLAB, Simulink, power quality, PWM,** Voltage sag**,** Sensitivity index**.**

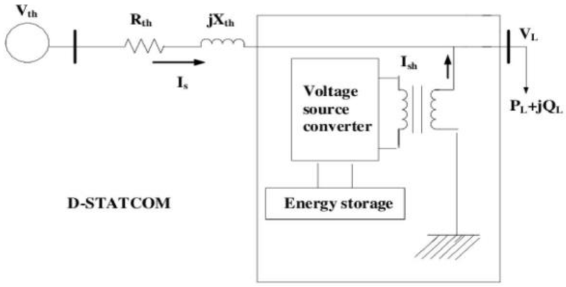
I. INTRODUCTION

You can divide the causes of bad power quality into two categories: (1) actual loads, equipment, and components; and (2) transmission and distribution system subsystems. Power line disturbances like impulses, notches, voltage sags and swells, voltage and current imbalances, brief interruptions, and harmonic distortions are typically to blame for poor quality. The classification of power quality by the International Electro-Technical Commission (IEC) includes loss-of-balance as a source of disruption. This feature is listed as a source of electric power quality degradation in the IEEE standard. Reactive power and harmonics are the other two main causes of bad power quality. The main cause of harmonics is the solidstate regulation of ac power utilizing high speed switches, whilst other non-linear loads are responsible for the excessive consumption of reactive power from the supply. And determine the maximum achievable closed loop performance parameters. To implement the proposed voltage regulator at DC grid to maintain voltage and power consumption. It has disastrous effects such prolonged production halts, device malfunctions, and limited equipment life [1]. According to wave shape, IEEE standards divided power quality issues into seven problems:

- Transients
- Interruptions
- Sag(dips)/under voltages
- Swell/over voltage
- Waveform distortion
- Voltage fluctuation
- Frequency variations

D-STATCOM CONFIGURATION AND OPERATION

The D-STATCOM is a power electronics-based three-phase device with shunt connections. It is connected to the distribution systems close to the load. Figure 1 depicts the main parts of a DSTATCOM. A three-phase inverter (IGBT, thyristor) module, an ac filter, and a control scheme make up the device

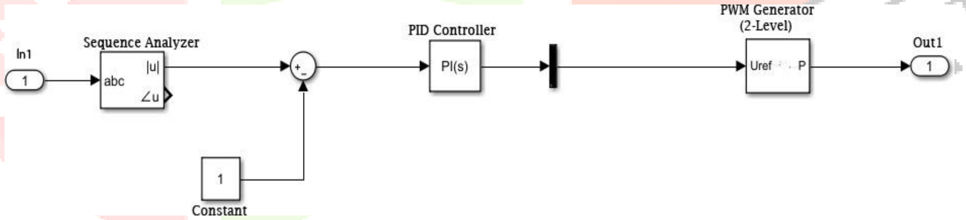


VOLTAGE SOURCE CONVERTER (VSC):

A power electronic device known as a voltage-source converter may produce sinusoidal voltages with any necessary magnitude, frequency, and phase angle. power source Although they can also be used to reduce voltage dips, converters are frequently utilized in adjustable-speed drives. The voltage is either entirely replaced by the VSC or the 'missing voltage' is injected. The discrepancy between the nominal voltage and the actual voltage is known as the "missing voltage." The converter often relies on a form of energy storage to provide it with a DC voltage. The converter's solid-state electronics are then switched to produce the required output voltage. The VSC is typically employed to address additional power quality issues, such as flicker and harmonics [6], in addition to mitigating voltage dips. The Simulink model of the D-STATCOM Controller is depicted in Figure.

CONTROLLER:

The control strategy's goal is to keep the voltage magnitude constant at the location of a sensitive load's connection throughout system disruptions. There are no measurements of reactive power necessary because the control system just measures the r.m.s voltage at the load location. The sinusoidal PWM approach, which offers simplicity and good response, is the foundation of the VSC switching strategy. Custom power is a low-power application as a result, and PWM methods provide a more flexible alternative to Fundamental Frequency Switching (FFS) methods, which are preferred in FACTS applications. Furthermore, the efficiency of the converter can be increased while minimizing switching losses by using high switching frequencies. The



measured value of the terminal voltage's rms value plus the error signal acquired from the reference voltage make up the controller input. A PI controller processes this error and outputs the angle

The sinusoidal voltage control signal (V inverter) phase- modulated by means of the angle

$VA = Sin(\omega t + \delta)$

$VB = Sin\,(\omega t + \delta - 2\pi/3)$

$VC = Sin\,(\omega t + \delta + 2\pi/3)$

THE TEST SYSTEM

The simulation applied on IEEE 15 bus test system, it, s line data and load data described in table

IEEE 15 Bus Line Data				IEEE 15 Bus Load Data		
from	To	R(Ω)	X(Ω)	Bus	PL(kw)	QL(kvar)
1	2	1.35309	1.32349	2	44.1	44.99
2	3	1.17024	1.14464	3	70	71.41
3	4	0.84111	0.82271	4	140	142.82
4	5	1.53248	1.0276	5	44.1	44.99
2	9	2.01317	1.3579	6	140	142.82
9	10	1.68671	1.1377	7	70	71.41
2	6	2.55727	1.7249	8	140	142.82
6	7	1.0882	0.734	9	70	71.41
6	8	1.25143	0.8441	10	44.1	44.99
3	11	1.79553	1.2111	11	70	71.41
11	12	2.44845	1.6516	12	44.1	77.99
12	13	2.01317	1.3579	13	140	142.82
4	14	2.23081	1.5047	14	140	142.82
4	15	1.19702	0.8074	15	70	71.41

Table 5.1 IEEE 15 bus test system line data and load data

The test system shown in the figure -5.1, contain 11 KV, 50 Hz distribution system, 15 bus, Total generation: P= 1.26 MW, Q= 1.28 MVAR, D-STATCOM is connected to the bus no 6, three phase fault block connected at the line (1-2).

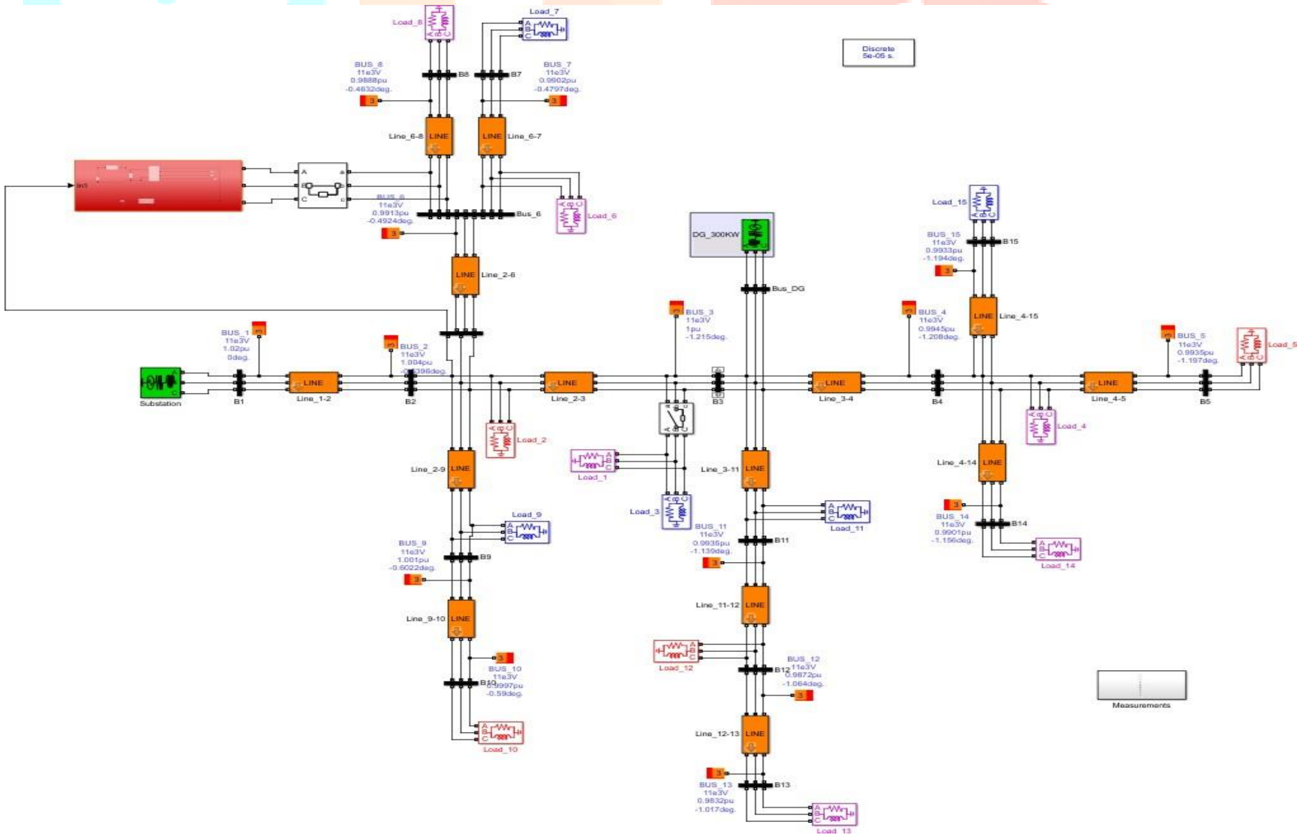


Figure 5.2: single line diagram for the system with D-STATCOM

The D-STATCOM controller and components shown in figure

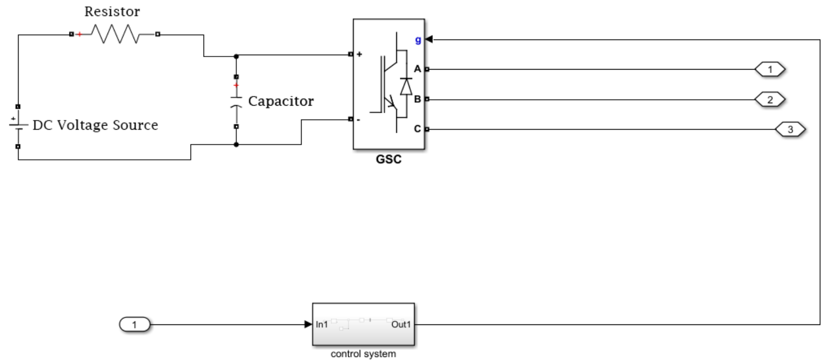


Figure 5.2 Model Simulink of D-STATCOM PI controller

OPTIMAL LOCATION OF D-STATCOM:

The stability index of each bus is calculated to determine the best location for D-STATCOM [13–15]. The bus chosen as a candidate is the one with the highest stability index value. In Fig.6, a single line diagram of a two-bus distribution system is shown. Sending and receiving end voltages are shown as Vm and Vn, respectively. Branch current is shown as Im, and branch resistance and reactance are shown as Rm and Xm, respectively.

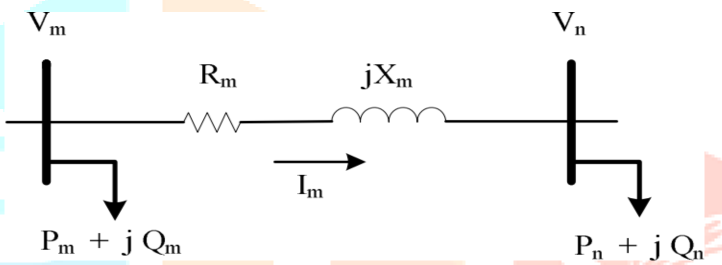


Figure 5.2 Single line diagram of 2-bus distribution system

After deriving the expression, stability index defined as $SI = \frac{4R_m(P_n^2+Q_n^2)}{V_n^2 P_n}$

The value should be <1for stability. The bus with highest value of SI is most unstable and is selected as candidate bus.

The calculation of stability index (S.I) for all busses of IEEE 15 bus test system using equation 1described in table 2

Table 2: Stability index (S.I) for all buses of IEEE 15 bus test

Bus No	Stability Index (S.I)
2	0.0039
3	0.0055
4	0.0079
5	0.0046
6	0.0239
7	0.0052
8	0.0120
9	0.0094
10	0.0050
11	0.0085
12	0.0074
13	0.0195
14	0.0213
15	0.0057

IV. RESULTS AND DISCUSSION

system description	11 kv, 50 Hz	PI controller	Kp 0.5, Ki 500
Carrier frequency	1000 Hz	Sample time	50 μsec
Energy storage system	18.9 Kv		

CASE 1.A (Additional load with different values at all buses without using D-statcom).

Table 2.The min and max bus voltage without using D-statcom

Case	Without D-statcom		With D-statcom	
	Min voltage	Max voltage	Min voltage	Max voltage
Additional load 20% at all buses	0.8962	0.8962	0.9635	1.006
Additional load 30% at all buses	0.8678	0.9128	0.9596	1.005
Additional load 40% at all buses	0.841	0.8882	0.9519	0.9997
Additional load 50% at all buses	0.8157	0.865	0.9443	0.9947

CASE 2.A.(load rejection at bus 11,12 and 13without D-statcom)

Case	Without D-statcom	
	Min voltage	Max voltage
For load rejection at buses 11,12 and 13 after 0.5 sec	1.04	1.068

The voltage at bus 11,12 and 13 falls down to zero after load rejection from 0.5 sec of the simulation starting. The voltage profile for 15 bus test system is shown in figure 6.1

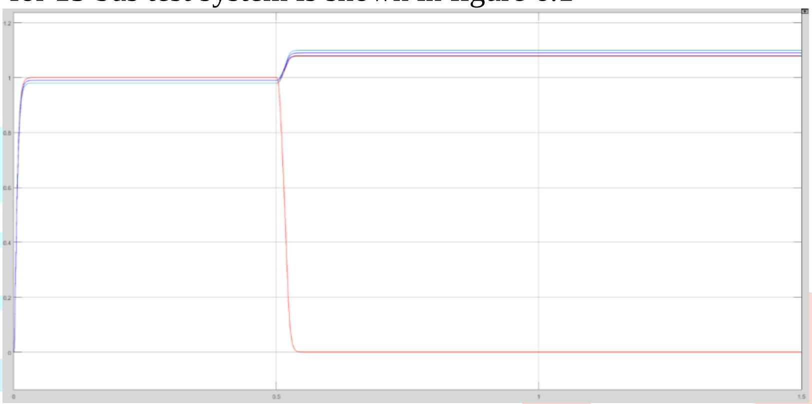


Figure 6.1 Voltage profile for 15 bus test system after load rejection without D-statcom

Case.2.B (load rejection at busses 11,12 and 13 with D-statcom connected at bus 6).

Case	With D-statcom	
	Min voltage	Max voltage
For load rejection at buses 11,12 and 13 after 0.5 sec	0.9926	1.024

The voltage at buses 11,12 and 13 falls down to zero after load rejection from 0.5 sec of the simulation starting. The voltage profile

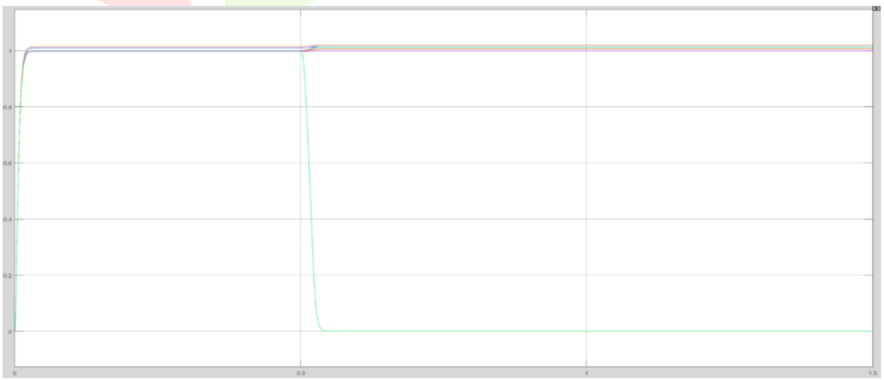


Figure 6.2 voltage profile for 15 bus test system after load rejection with D-statcom

Case 3.A (single line to ground fault occurs at line 1-2 from 0.5 sec to 1 sec without D-statcom).

Case	Without D-statcom	
	Min voltage	Max voltage
During Single line to ground fault occurs from 0.5 sec to 1 sec	0.6575	0.6727

The voltage profile for 15 bus test system is shown in figure 7.1

Case 3.B.(single line to ground fault occurs at line 1-2 from 0.5 sec to 1 sec with D-statcom connected bus 6).

Case	With D-statcom	
	Min voltage	Max voltage
During Single line to ground fault occurs from 0.5 sec to 1 sec	0.9131	1.015

The voltage profile for 15 bus test system is shown in figure 7.2

Figure 7.2 voltage profile for 15 bus test system during fault with D-statcom

Case 4.A. (without D-statcom, additional load 20% is applied and disconnect the generator DG at bus 3 after 0.5 sec)

Case	Without D-statcom	
	Min voltage	Max voltage
After additional load 20% and disconnect the generator DG at bus 3 after 0.5 sec from the simulation time	0.7069	0.7546

The voltage profile for 15 bus system is shown in figure 8.1

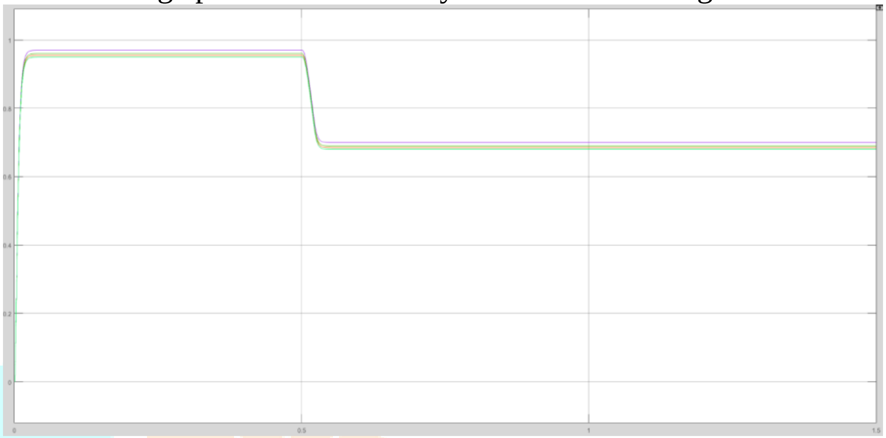


Figure 8.1 voltage profile for 15 bus test system with additional load 20% is applied and disconnect the generator at bus 3 simulation archived without D statcom

Case 4.B(with D-statcom connected bus 6, additional load 20% is applied and disconnect the generator DG at bus 3 after 0.5 sec)

Case	With D-statcom	
	Min voltage	Max voltage
After additional load 20% and disconnect the generator DG at bus 3 after 0.5 sec from the simultation time	0.9475	0.9965

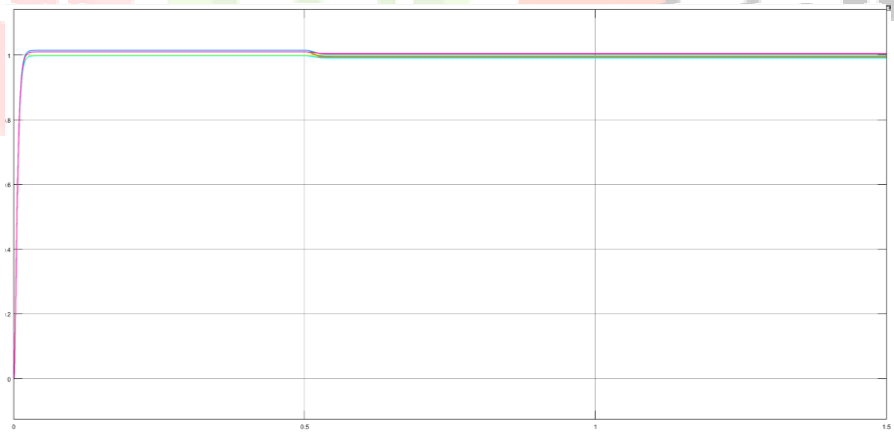


Figure 10. voltage profile for 15 bus test system with additional load 20% and disconnect the generator at bus 3. Simulation archived with D-statcom

Case5.(A comparision between D-statcom location at bus 6 and bus 14 when single line to ground fault is applied at line 1-2 from 0.5 sec to 1 sec)

Case	With D-statcom	
	Min voltage	Max voltage
D-statcom connected at bus 6 and single line to ground fault is applied at Line 1-2 from 0.5 sec to 1 sec	0.9131	1.015
D-statcom connected at bus 14 and single line to ground fault is applied at Line 1-2 from 0.5 sec to 1 sec	0.8709	1.013

The next figure 9,10 describe the result of the simulation when D statcom is connected at bus 6 and bus 14 respectively.

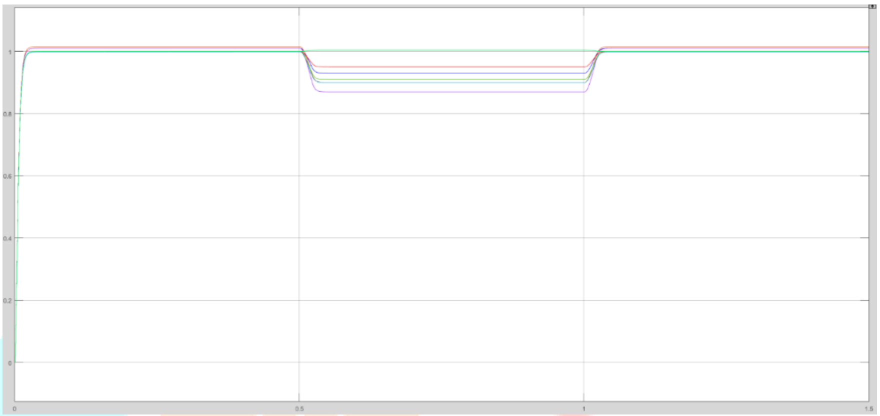


Figure 9. Voltage profile for 15 bus test system when D-statcom is connected at bus 6 single line to ground fault is applied at line 1-2 from 0.5 sec to 1 sec

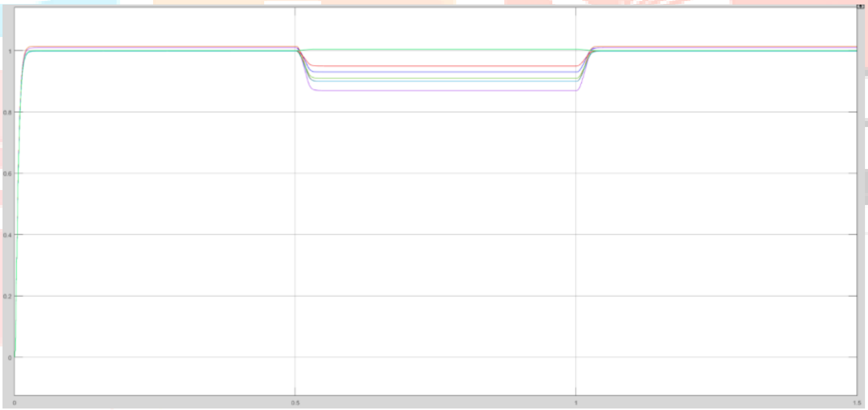


Figure 10. Voltage profile for 15 bus test system when D-statcom is connected at bus 14 and single line to ground fault is applied at line 1-2 from 0.5 sec to 1 sec

Case 6.A. (An additional nonlinear load is applied at bus 5 without D-statcom)

Case	Without D-statcom	
	Min voltage	Max voltage
The test system steady state voltage at 1 sec After applying nonlinear load at bus 5 from 0.5 sec of the simulation	0.594	0.6957
Duration from transient at 0.5 sec after applying nonlinear load to the steady state	0.5 sec	

The voltage profile for 15 bus test system is shown in figure 11.1

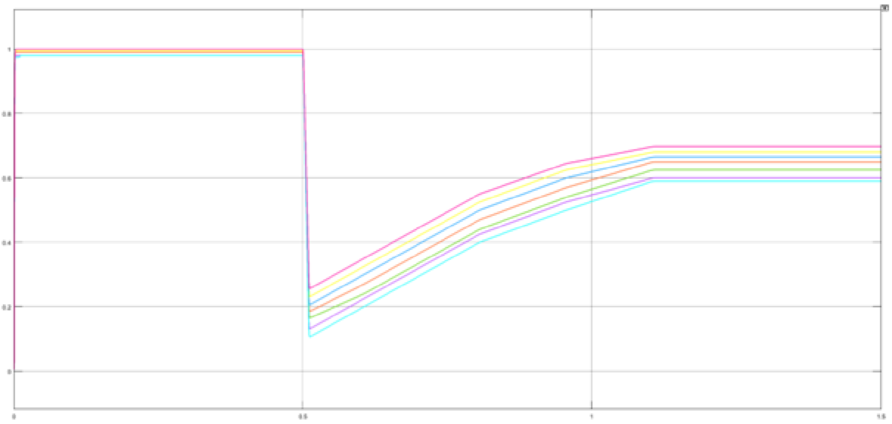


Figure 11.1 voltage profile for 15 bus test system after additional nonlinear load at 0.5 sec and without D-statcom

Case 6.B An additional nonlinear load is applied at bus 5 with D statcom)

case	With D-statcom	
	Min voltage	Max voltage
The test system steady state voltage at 1 sec after applying nonlinear load at bus 5 from 0.5 sec of the simulation	0.858	1.058
Duration from transient at 0.5 sec after applying nonlinear load to the steady state	0.183 msec	

The voltage profile for 15 bus test system is shown in figure 11.2

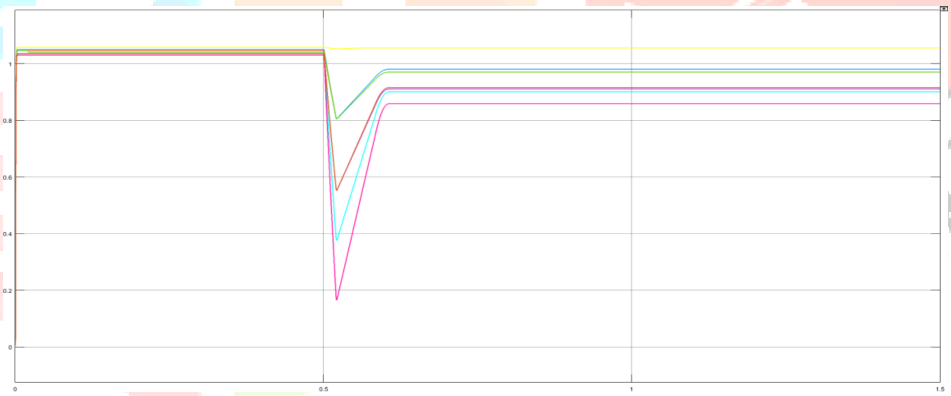


Figure11.2 voltage profile for 15 bus test system after additional nonlinear load with D-statcom

IV. RESULTS AND DISCUSSION

The most successful strategy for placing D-statcom is the sensitivity index. The gadget is found to be most effectively situated on bus number 6. The test system's simulation results show that one of the main benefits of employing D-statcom is the distribution systems' quick voltage recovery. Additionally, moving the D-statcom to a different bus, such as bus number 14, which is listed as a second option in the table list and has the same condition (a single line to ground fault at lines (1-2), does not produce better results than placing the device on bus number 6. The effectiveness of a proposed system is mostly dependent on the percentage of voltage sag or voltage swell, fault type, location of the fault, and Dc storage system rating, according to the analysis of the test system.

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