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Research Article

Voltage Profile Improvement of Low Voltage Distribution System using D-STATCOM

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Abstract

This paper presents the design of a distribution static compensator (D-STATCOM) for voltage sag mitigation in an 11kV/440V Low Voltage Radial Distribution system in different loading conditions. The model is based on the voltage source converter (VSC) principle. A new PWM based control scheme has been implemented to control the electronic valves in VSC. The D-STATCOM injects current into the system to mitigate the voltage sags. In the present work the 6-pulse D-STATCOM configuration with IGBT has been designed using Matlab/Simulink. Accordingly, simulations are carried out to illustrate the use of D-STATCOM in mitigating voltage sag in the low voltage distribution system. Simulation results prove that the D-STATCOM is capable of mitigating voltage sag as well as reducing the power loss in the distribution system. Cost calculation has been made before and after installation of D-STATCOM.

Keywords: *Low Voltage Distribution system, voltage sag, D-STATCOM, cost calculation.*

1. Introduction

The majority of power consumption has been drawn in reactive loads such as fans and pumps etc. These loads draw lagging power factor currents in the distribution systems. These excessive reactive power demand increases feeder losses and reduces the active power flow capability of distribution system which also affects the voltage profile (R.C Dugan *et al*, 2006) (K.R. Padiyar *et al*, 2007).

Voltage sag is the most important power quality problems faced by many industries and utilities. It contributes more than 80% power quality (PQ) problems that exist in power systems. According to definition, voltage sag is a reduction in RMS value in AC voltage at power frequency, for duration of a half cycles to a few seconds (R.CDugan *et al*, 2006)(W.L. Chen *et al*,2003).

Voltage sags are not tolerated by sensitive equipment's used in modern industrial plants, such as process controllers, programmable logic controllers (PLC), adjustable speed drives (ASD), and robotics.(H.Agaki *et al*, 2007).It has been reported that high intensity discharge lamps used for industrial illumination get extinguished at voltage sags of 20% and industrial equipment like PLC and ASD are about 10% (Antonio Moreno-munoz *et al*,2007).

With recent developments in power semiconductor devices and power electronics, application of solid-state controller in power system is growing. This paper investigates the role of D-STATCOM at load end in a radial distribution system supplied by the 11kV/440V distribution transformer. The operation of the system with and without D-STATCOM devices is analyzed through simulation in MATLAB under different loading conditions.

2. Distribution Static Compensator (D-Statcom)

When used in low voltage distribution system, the static compensator (STATCOM) is identified as Distribution STATCOM (DSTATCOM). In general DSTATCOM is used to generate or absorb reactive power (H.seong *et al*, 1999).

The D-STATCOM is a three-phase shunt connected Flexible AC Transmission Systems (FACTS) device which uses power electronics to control power flow in the system. It is connected at the load points in the distribution systems. The major components of a DSTATCOM are shown in Figure 1 (B.singh *et al*, 2005). It consists of a dc voltage source, three-phase inverter (IGBT, thyristor) module, coupling transformer and a control strategy. The basic electronic block of the DSTATCOM is the voltage sourced inverter that converts an input dc voltage into a three phase output voltage at fundamental frequency (Alpesh Mahyavanshi *et al*, 2012). Referring to figure1, the controller of D-STATCOM measures the phase angle between inverter voltage and line voltage so that to operate inverter of D-STATCOM to either generate or absorb the desired VAR at the point of connection. Figure 2 shows the three basic operation modes of the

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D-STATCOM output current, I, which varies depending upon Vi. If Vi is equal to Vs, the reactive power is zero and the D-STATCOM does not generate or absorb reactive power. When Vi is greater than Vs, the D-STATCOM 'sees' an inductive reactance connected at its terminal. Hence, the system 'sees' the D-STATCOM as a capacitive reactance.

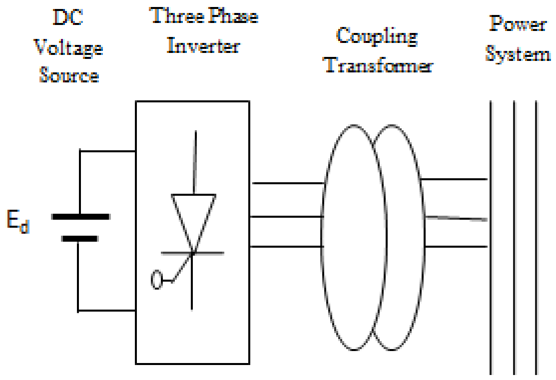

Fig.1 Basic configuration of D-STATCOM

The current, I, flows through the coupling inductor from the D-STATCOM to the ac system (kiran Kumar *et al*, 2012), and the device generates capacitive reactive power. If Vs is greater than Vi, the system 'sees' an inductive reactance connected at its terminal and the D-STATCOM 'sees' the system as a capacitive reactance. Then the current flows from the ac system to the DSTATCOM, resulting in the device absorbing inductive reactive power (Alpesh Mahyavanshi *et al*, 2012).

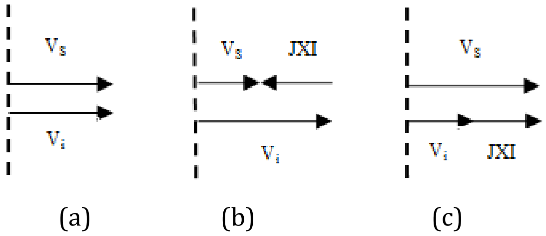

Fig.2 Operation of D-STATCOM (a) No load mode (V_s=V_i), (b) Capacitive mode (c) Inductive mode

3. Case study

For analysis purpose distribution system of Dharwad city, India has been considered. There are eight feeders in the cityt, out of which Madarmaddi is one of the feeder.

Madarmaddi feeder serves 44 11kV/440V Distribution transformers. Kattimani is one of the 44 distribution transformer which has radially connected 33 load points. The voltage level at load points under normal loading conditions is below the rated value. Hence this low voltage distribution network is been considered for analysis. The single line diagram of the network under case study is shown in figure 4(H.Awad *et al*, 2004).

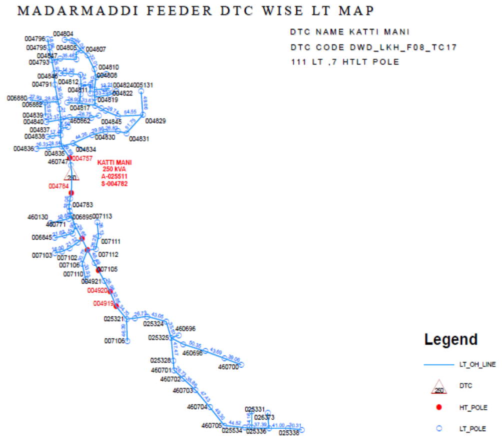

Fig.4 Single line diagram of 11kV/440V LV side Distribution network

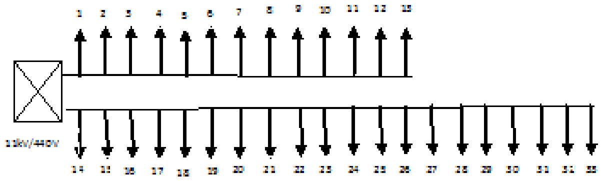

Fig.5 Simplified diagram of the network

As shown in figure 5 (J.sevensso *et al*, 1999), network has total 33 radially connected load points. Load 1 to load 13 are connected in series, which serves an area of total feeder length 0.23121 km and load 14 to load 33 are connected in series, which serves another area of total feeder length 0.506 km. System operates at 440V, 0.85pf.

Table 1 Distribution network parameters

Load connected	Maximum Load	Average Load	Minimum Load
P (kW)	417.598	313.198	208.799
Q (kVar)	220.0296	165.02	110.014

4. Experimental Result

Matlab/Simulink model of the system under consideration is shown in figure 6.

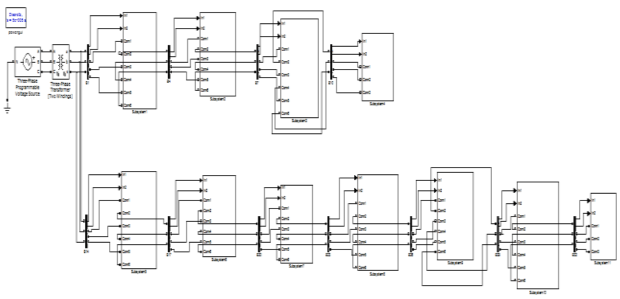

Fig.6 Matlab/Simulink model of the Distribution network

From mathematical procedure it is found that end point is the optimal allocation. Hence D-STATCOM is connected near load 33. Matlab/Simulink model of the D-STATCOM is shown in the figure 7.

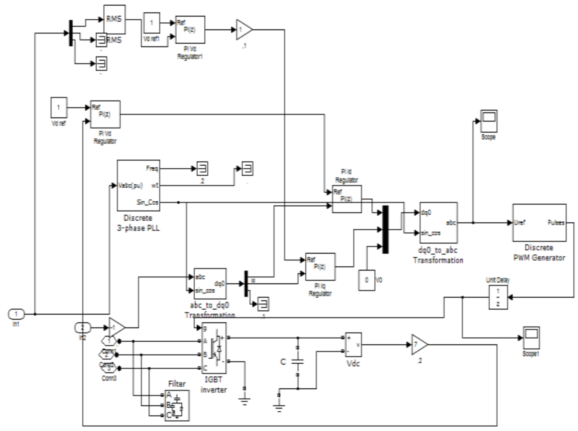

Fig.7 Matlab/Simulink model of the D-STATCOM

5. Simulation Results

The Voltage level at different loading conditions before insertion of D-STATCOM.

Table 2 Voltage level at Different loading condition without D-STATCOM

Load Points	Voltage Level at different Loading Conditions		
	Maximum Loading	Average Loading	Minimum Loading
1	0.96	0.96	0.98
2	0.95	0.96	0.97
3	0.94	0.95	0.97
4	0.93	0.95	0.96
5	0.92	0.94	0.96
6	0.92	0.94	0.96
7	0.91	0.93	0.95
8	0.91	0.93	0.95
9	0.90	0.93	0.95
10	0.90	0.92	0.95
11	0.90	0.92	0.95
12	0.90	0.92	0.95
13	0.90	0.92	0.95
14	0.96	0.97	0.98
15	0.95	0.96	0.97
16	0.93	0.96	0.94
17	0.92	0.94	0.96
18	0.91	0.93	0.95
19	0.90	0.92	0.95
20	0.77	0.82	0.88
21	0.76	0.81	0.88
22	0.76	0.80	0.87
23	0.75	0.80	0.87
24	0.74	0.79	0.87
25	0.74	0.79	0.86
26	0.73	0.79	0.86
27	0.73	0.78	0.86
28	0.73	0.78	0.86
29	0.72	0.78	0.86
30	0.72	0.78	0.85
31	0.72	0.77	0.85
32	0.72	0.77	0.85
33	0.72	0.77	0.85

A D-STATCOM of 10.26kVar is used for maximum and average loading conditions. When used for minimum loading conditions the voltage value exceeds the rated value of 1.1 pu. Hence for minimum loading condition D-STATCOM of 9.85kVAR is used for analysis.

Table 3 Voltage level after insertion of DSTATCOM at different loading conditions

Load Points	Voltage Level at different Loading Conditions with D-STATCOM		
	Maximum Loading	Average Loading	Minimum Loading
1	0.96	0.96	0.98
2	0.95	0.96	0.97
3	0.94	0.95	0.97
4	0.93	0.95	0.96
5	0.92	0.94	0.96
6	0.92	0.94	0.96
7	0.91	0.93	0.95
8	0.91	0.93	0.95
9	0.90	0.93	0.95
10	0.90	0.92	0.95
11	0.90	0.92	0.95
12	0.90	0.92	0.95
13	0.90	0.92	0.95
14	0.96	0.97	0.98
15	0.95	0.96	0.97
16	0.93	0.95	0.97
17	0.93	0.95	0.97
18	0.92	0.95	0.96
19	0.91	0.94	0.95
20	0.90	0.94	0.94
21	0.90	0.95	0.94
22	0.90	0.95	0.94
23	0.90	0.95	0.94
24	0.90	0.95	0.94
25	0.90	0.95	0.94
26	0.90	0.95	0.94
27	0.90	0.96	0.95
28	0.90	0.96	0.95
29	0.91	0.96	0.95
30	0.91	0.96	0.95
31	0.91	0.96	0.95
32	0.91	0.97	0.95
33	0.92	0.97	0.97

Table 4 Power loss calculation at different loading condition before and after insertion of D-STATCOM

Power Loss	Without D-STATCOM	With D-STATCOM
Maximum Loading	P=62.07 kW Q=46.27 kVar	P=49.95 kW Q=36.01kVar
Average Loading	P=44.23 kW Q=33.58kVar	P=32.35 kW Q=23.51kVar
Minimum Loading	P=25.85 kW Q=20.08kVar	P=14.17 kW Q=10.23kVar

6. Economic Consideration

From the load flow, the loss is evaluated as 62.07kW and 49.95kW respectively without and with D-STATCOM insertion in the system. The cost of this loss per annum works out to be Rs. 23,27,167 and Rs.18,72,450 respectively without and with D-STATCOM, considering the prevailing rate of 4.28 per kWh. The ---installation cost of D-STATCOM is Rs. 34,884. Hence the cost saved is Rs. 4,19,833.

Conclusion

Table 2 shows the increase in bus voltages with the insertion of D-STATCOM at load 33. It is also observed that there was loss reduction in the system. In the minimum loading condition the voltage level was at practically acceptable range. For analysis purpose the rating of D-STATCOM has been changed. By inserting the D-STATCOM, Rs. 4,19,833 can be saved per annum. Finally, simulation results for Dharwad distribution network are presented.

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