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Optimal Placement of DSTATCOM in Radial Distribution System - A Case Study

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Abstract: DSTATCOM is used to supply reactive power demand at the load end while maintaining the voltage level in acceptable range. This paper demonstrates an effective method to identify the suitable bus for DSTATCOM placement. The main objective is to improve voltage profile and minimize power loss in radial distribution network. The DSTATCOM is modelled to determine its rating by assuming voltage magnitude as 1p.u. at weaker bus. Also, this placement of DSTATCOM at optimal location is based on voltage stability index criteria. The effectiveness of this proposed method is tested on university 11kV feeder by performing load flow analysis before and after reactive power compensation using MATLAB. The obtained results are compared without and with DSTATCOM for all the load models. The voltage profile and power loss reduction are observed.

Keywords: DSTATCOM; Load flow analysis (LFA); Stability index (SI); Optimal location; FACTS, Feeder, SLD.

I. INTRODUCTION

In Pakistan major distribution system problem is having low power factor and voltage profile due to loading up to its thermal values. This problem is prominent in urban areas due to excessive loading. The power loss arises due to the excessive use of inductive loads i.e. induction motors, air conditioning plants, fans and pumps etc. in the industrial and domestic areas. These loads draw lagging currents and give rise to the problem of difference in demand and supply of reactive power.

Loads generally tend to vary a lot in accordance with different seasons as their demand fluctuates. Because of different loading conditions, the transformers connected at different areas of university are according to their maximum power demand which in turns becomes the cause of low power factor as for most of the time a lot of the portion of transformer stays idle. Many research works are carried out for optimal location of fact devices system parameters.

In this paper, an effective method [1] is proposed and implemented on 11kV feeder of University of Engineering and Technology, Taxila under different loading conditions. The method involves the calculation stability index (SI) of each bus of the power system. The calculation involves the utilization of the results obtained from the load flow analysis (LFA) performed using MATLAB. DSTATCOM is placed at the bus which has the maximum value of SI and LFA is performed again on the power system by implementing the compensating values for 90%, 60% and 30% of the total maximum load. The rating of DSTATCOM is determined by assuming the voltage at candidate bus as 1p.u. The cost of DSTATCOM and other related benefits have not been considered while solving location and sizing problems. This method is suitable for placement of single DSTATCOM in given system.

II. METHODOLOGY

A. Load Flow Analysis

The steady load flow analysis consists of following:

i. Preparing a model of power systems and network.
ii. Producing equations of load flows.
iii. Solving equations of load flow using numerical methods.

In this paper, MATLAB is used to perform load flow analysis using Newton Raphson (N.R) method because this method is highly accurate and is independent of number of buses.

B. Stability Index

Optimal placement of DSTATCOM is determined by finding stability index for each bus. That bus with the highest value of stability index is chosen as the entrant bus. Distribution system of two buses is shown in following figure where V_b and V_r are the voltages at sending and receiving ends and I_l is the branch current and X_l and R_l are branch reactance and resistance respectively. Simple diagram of sending and receiving bus is shown in fig 1.

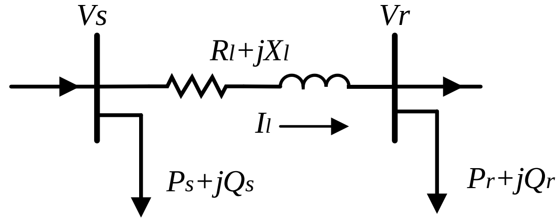

Fig. 1. Single line diagram of sending and receiving bus

The equation for stability index is given as follows in equation 1;

$$SI = \frac{4R_l(P_r^2+Q_r^2)}{V_s^2 P_r} \quad (1)$$

C. Mathematical Modelling of DSTATCOM

After DSTATCOM installation, the voltage profile of candidate bus and all the other buses will change to a new value. To perform steady state modelling [1], it is shown in fig. 2 after installation at candidate bus. V_s' and V_r' are voltages of sending and receiving bus respectively while I_{DS} is the DSTSTCOM injected current

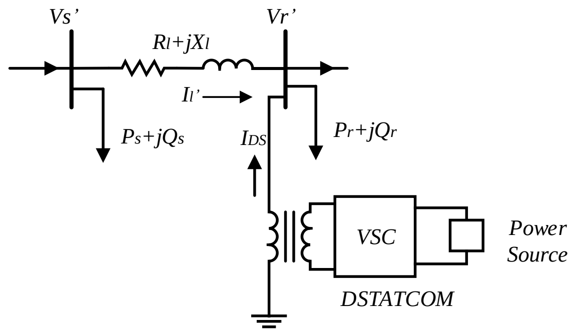

Fig. 2 DSTATCOM integration on power system

D. Proposed Algorithm

Algorithm to find the optimal location of DSTATCOM is given in fig. 3;

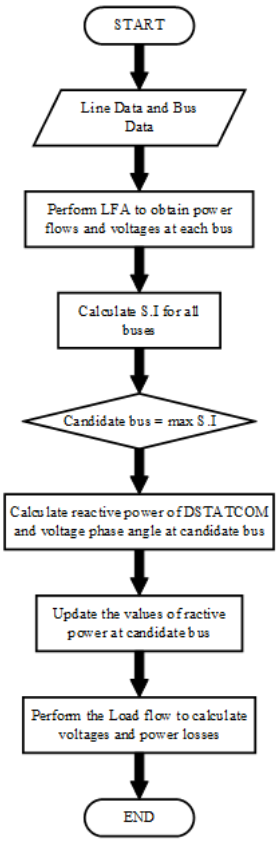

Fig. 3. Flow chart of Algorithm

III. RESULTS & COMPARISONS

The validity of this proposed method is tested at University of Engineering and Technology, Taxila 11kV feeder. Results in term of voltage profile, active and reactive power loss are obtained. The single line diagram of 11kV, 4.5MVA radial distribution feeder is shown in following figure 3:

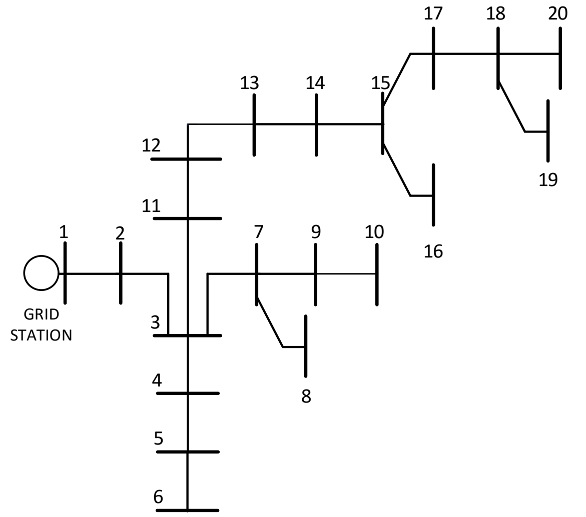

Fig. 3 Simplified SLD of university 11kV feeder

Load flow is performed using MATLAB and stability index for each bus is calculated under different loading schemes. The stability index for each loading is shown in following table 1:

Table 1 Stability Index of Each Load Bus

STABILITY INDEX			
Bus No.	**30% Loading**	**60% Loading**	**90% Loading**
2	**0.00416579**	**0.00823470**	**0.01361980**
4	0.00030359	0.00061870	0.00096810
5	0.00004164	0.00008489	0.00013280
6	0.00005365	0.00010940	0.00017110
8	0.00001259	0.00002597	0.00004090
9	0.00002150	0.00004436	0.00006990
10	0.00015802	0.00032216	0.00050400
11	0.00004123	0.00008403	0.00013150
12	0.00001602	0.00003266	0.00005110
13	0.00002065	0.00008623	0.00006720
14	0.00016392	0.00033603	0.00052570
16	0.00015805	0.00032250	0.00050490

17	0.00016062	0.00032777	0.00051350
18	0.00004268	0.00008376	0.00013240
19	0.00007219	0.00014742	0.00011500
20	0.00059723	0.00121969	0.00191160

The bus 2 is having a highest value for stability index, so this one is regarded as a candidate bus for all loadings. Load flow is performed after providing the required reactive power supplied by DSTATCOM in MATLAB. The results are compiled and shown in figures 4,5 and 6 for the significant improvement in voltage at all buses. Bus and line data of system under test is represented in appendix A and B respectively.

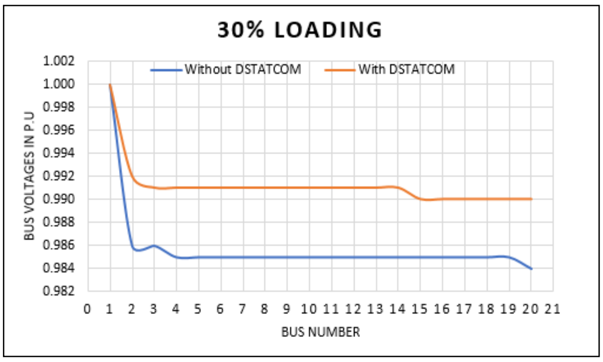

Fig. 4 Voltage comparison at all buses with and without DSTACOM at 30% loading scheme

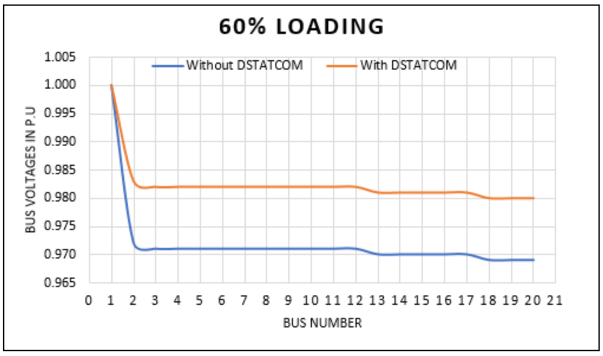

Fig. 5 Voltage comparison at all buses with and without DSTACOM at 60% loading scheme

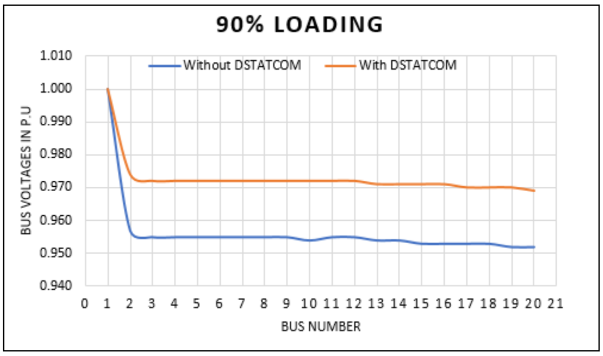

Fig. 6 Voltage comparison at all buses with and without DSTACOM at 90% loading scheme

Comparison has been done with and without DSTATCOM under different loadings on 11kV feeder. Table 2,3 and 4 show the total active and reactive load connected to the system at different loading conditions. After installation of DSTATCOM for 90% of loading active power loss are reduced by 44.83 %, while reactive power loss are reduced to 44.94% and the minimum bus voltage at 20th bus also increaases from 0.952 p.u. to 0.969 p.u. Similar improvements have been observed for 60% and 30% loading conditions.

Table 2 Results Comparison Without and With DSTATCOM at 30% Loading

30 % LOADING		
Description	**Without DSTATCOM**	**With DSTATCOM**
Total kW Load	941	941
Total kVAR Load	961	961
Minimum voltage (p.u.)	0.984 (20th bus)	0.990 (20th bus)
Proposed location of DSTATCOM	-	2nd bus
Proposed Size of DSTATCOM	-	0.651 MVAR
Total kW Loss	12	7
Total kVAR Loss	16	9
Iterations of N.R Method Performed	2	2

Table 3 Results Comparison Without and With DSTATCOM at 60% Loading

60 % LOADING		
Description	**Without DSTATCOM**	**With DSTATCOM**
Total kW Load	1861	1861
Total kVAR Load	1901	1901
Minimum voltage (p.u.)	0.969 (20th bus)	0.980 (20th bus)
Proposed location of DSTATCOM	-	2nd bus
Proposed Size of DSTATCOM	-	1.287 MVAR
Total kW Loss	49	27

Total kVAR Loss	66	37
Iterations of N.R Method Performed	2	2

Table 4 Results Comparison Without and With DSTATCOM at 90% Loading

90 % LOADING		
Description	**Without DSTATCOM**	**With DSTATCOM**
Total kW Load	2882	2822
Total kVAR Load	2887	2887
Minimum voltage (p.u.)	0.952 (20th bus)	0.969 (20th bus)
Proposed location of DSTATCOM	-	2nd bus
Proposed Size of DSTATCOM	-	1.952 MVAR
Total kW Loss	116	64
Total kVAR Loss	158	87
Iterations of N.R Method Performed	2	2

IV. CONCLUSION

This paper demonstrates an efficient way to place DSTATCOM in a radial distribution system. The case study of the University 11kV feeder considered different loading scenarios to address seasonal variations in load. Stability index for each bus is calculated and DSTATCOM is placed on the bus with the highest stability index value. The load flow analysis is performed using the compensation value of the reactive power and the result are plotted. An improvement in voltage distribution and power factor is observed.

- Voltage profile improved on 30% loading by an approximate margin of 0.006p.u. or 0.6% and power loss is reduced by a margin of 5kW. Voltage profile improved on 60% loading by an approximate margin of 0.011p.u. or 1.1% and power loss is reduced by a margin of 22kW.
- Voltage profile improved on 90% loading by an approximate margin of 0.017p.u. or 1.7% and power loss is reduced by a margin of 52kW.

Hence, DSTATCOM can play a dynamic role in voltage profile improvement. It proposes an effectual solution to reduce losses can in turn make a profit for the utility.

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