International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878 (Online), Volume-8 Issue-2, July 2019

Optimal Placement of Distributed Transformer with STATCOM to Enhance the Efficiency of the Distribution Networks

Rudresh. B. Magadum, D.B.Kulkarni

Abstract*: Due to increase in the population and modernization every year there is exponential growth in the power demand followed by lack of adequate amount of power generation and out dated electrical infrastructure makes weak distribution network to handle the increased power demand. This leads to poor voltage throughout the network, more power loss, load shedding, failure of protection scheme and other power quality related issues. In this paper, optimal placement of DTC with UPFC is carried out to improve the overall efficiency of the network. The analysis is carried out on twenty four bus system using MiPower software. The obtained results are satisfactory in terms of power loss minimization and improvement of the voltage stability.

Index Terms*: Distributed networks, Distributed transformer, power loss, optimal placement, voltage stability, Unified power flow controller.

Nomenclature:

DTC	Distributed Transformer
FACTS	Flexible AC Transmission Systems
FKBC	Fuzzy Knowledge based controller
k,m,n	Nodes
N	Number of branches
UPFC	Unified Power Flow Controller
δm, δn	Voltage angle magnitudes at nodes m and n
Vm, Vn	Voltage magnitudes at bus m and n
P_{Loss}	Total power loss in the network
Gk	Conductance of k^{th} node connects between nodes m and n.
SVC	Static Var Compensator
UPQC	Unified Power Quality Conditioner
TCSC	Thyristor Controlled static Compensator
I_n	Current flowing in the branch n
R_n	Resistance of the n^{th} branch
V_{min}	Minimum voltage in p.u.
NR	Newton Raphson
V_{max}	Maximum voltage in p.u.
STATCOM	Static Synchronous Compensator
p.f	Power factor
RDS	Radial Distribution Systems
LFA	Load flow analysis
SSSC	Static Synchronous Series Compensator

Revised Manuscript Received on 30 July 2019.
***** Correspondence Author
Rudresh. B. Magadum*, Department of Electrical and Electronics Engineering, KLS Gogte Institute of Technology, Belagavi-590008, Karnataka, India.
Dr. D.B.Kulkarni, Department of Electrical and Electronics Engineering, KLS Gogte Institute of Technology, Belagavi-590008, Karnataka, India.

I. INTRODUCTION

Distribution network is connected to end user to supply the required electricity for their needs. It is integrated with variety of loads like residential, commercial and industrial. Out of all, more than 90% of the load is in inductive in nature [1]. They draw the more reactive power for their smooth operation and this will creates more pressure on the network for reactive power and also makes poor voltage profile and poor p.f in the network, causes to more power loss in the network in terms of $I_n^2R_n$ [4][10]. If network is failed to fulfill required reactive power supply, then load will draws the more reactive power creating heating effect in the network, increasing the probability of permanent damage to the equipments. For secure, efficient and stable operation of the network, many researchers are working in different direction to address many such issues [11]-[12].

The distribution transformer is used mainly to step down the voltage level depending on the requirement [13]. The auto tap changing transformer mainly used in the distribution network to maintain the good voltage profile in the network. Optimal placement of DTC plays key role in power loss reduction with improving the voltage stability in the network [10].

The FACTS devices are fast operating power electronics devices mainly used in stable and efficient operation of the network [2]. FACTs devices mainly used to enhance the power transfer capability of the existing transmission lines by switching ON/OFF of the capacitor and inductor in the network. The FACTs devices are mainly used for voltage control and power flow control or both depending on the network requirement. The main FACTS devices are SVC, UPFC, TCSC, STATCOM, SSSC, UPQC etc [3, 6, 9]. Out of all STATCOM is used for improving the voltage profile with DTC. The optimal placement of DTC, STATCOM and combinations of both are tested on twenty four bus distribution network. The rest of this paper, results and methodology are discussed in section II and section III concludes the paper.

II. RESULTS AND DISCUSSIONS

The main objectives of DTC and STATCOM placement are maximization of the voltage profile with power loss reduction. The power loss in the network is given by,

$$\mathrm{Min}\{P_{Loss}\} = \mathrm{Min}\{\sum_{k=1}^{N}(Vm^2 + Vn^2 - 2Vm * Vn * \cos(\delta m - \delta n))\} \quad (1)$$

Algorithm for DTC and STATCOM placement

Step-1: For Given test system run the LFA and compute the bus voltages and total power loss in the distribution network.

Step-2: Place the STATCOM at each bus and run the LFA, each time tabulate the results. From the obtained results, choose the optimal location of multiple STATCOM, depending on effective power loss reduction with acceptable voltage improvement.

Step-3: Similarly, in the presence of STATCOM, choose the optimal location of DTC.

Step-4: Choose the best combination of DTC and STATCOM to enhance the overall efficiency of the network by improving the voltage profile.

Fig.1 shows the single line diagram of 24 bus system. The LFA analysis is carried out using MiPower software. It is power system analysis package and it can be used for different types of analysis like shot circuit analysis, economic load dispatch, long term load forecasting, relay coordination, harmonic analysis, transient analysis, ground grid design, EMTP analysis etc. In base case the system is converged at four iterations.

Table.1 shows the bus voltages at each bus after connecting STATCOM at particular bus. Even total losses also computed and tabulated in the same table to decide the STATCOM placement. From the obtained results bus number 24 is optimal location for placement of single STATCOM. Similarly Table.2 shows the LFA after connecting two STATCOM at different combination of placement locations. Bus 12 and 20 are the best locations for two STATCOM placement interms of losses reduction with improving the voltage profile. Fig.2 shows the voltage comparison after connecting STATCOM with base case.

Table.1 Comparison of Voltages after integration STATCOM

Bus No.	Base case	One STATCOM location				
		Bus-2	**Bus-6**	**Bus-9**	**Bus-15**	**Bus-24**
1	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
2	0.9949	0.9950	0.9950	0.9950	0.9950	0.9950
3	0.9923	0.9924	0.9924	0.9924	0.9924	0.9924
4	0.9908	0.9909	0.9909	0.9909	0.9909	0.9909
5	0.988	0.9881	0.9881	0.9882	0.9882	0.9882
6	0.9858	0.9859	0.986	0.986	0.986	0.986
7	0.9847	0.9848	0.9849	0.9849	0.9849	0.9849
8	0.9827	0.9828	0.9829	0.9829	0.9829	0.9829
9	0.9823	0.9824	0.9825	0.9825	0.9825	0.9825
10	0.9814	0.9815	0.9816	0.9817	0.9817	0.9817
11	0.9814	0.9815	0.9816	0.9816	0.9817	0.9817
12	0.9806	0.9806	0.9807	0.9808	0.9808	0.9808
13	0.9802	0.9803	0.9804	0.9804	0.9805	0.9805
14	0.9799	0.98	0.9801	0.9802	0.9802	0.9802
15	0.9797	0.9798	0.9799	0.98	0.98	0.98
16	0.9796	0.9796	0.9797	0.9798	0.9799	0.9799
17	0.9792	0.9793	0.9794	0.9794	0.9795	0.9795
18	0.9789	0.979	0.9791	0.9791	0.9792	0.9793
19	0.9787	0.9787	0.9788	0.9789	0.979	0.9791
20	0.9782	0.9783	0.9784	0.9785	0.9785	0.9787
21	0.9779	0.978	0.9781	0.9782	0.9782	0.9785
22	0.9779	0.978	0.9781	0.9782	0.9782	0.9785
23	0.9779	0.978	0.9781	0.9781	0.9782	0.9785
24	0.9779	0.978	0.9781	0.9781	0.9782	0.9785
Loss	**602.2**	**598.2**	**590.5**	**587.5**	**585.8**	**584.7**

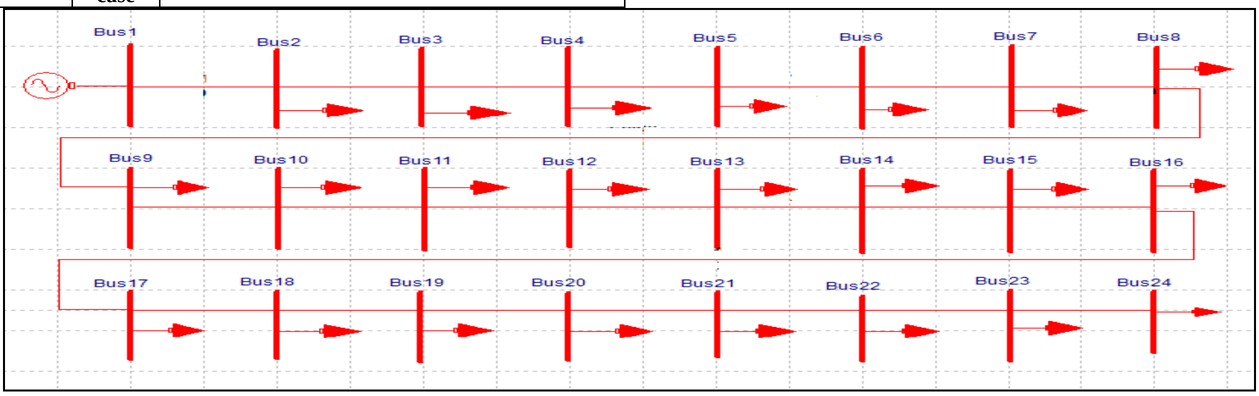

Fig.1 Single line diagram of 24 bus radial distribution

Retrieval Number: B3153078219/19©BEIESP
DOI: 10.35940/ijrte.B3153.078219
Journal Website: www.ijrte.org

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

Table.2 Voltage comparison after placement of two

Bus No.	Base case	Two STATCOM locations							
		2,24	3,20	4,20	5,15	6,16	7,19	9,16	12,20
1	1.000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
2	0.9949	0.9950	0.9950	0.9950	0.9950	0.9950	0.9950	0.9950	0.9950
3	0.9923	0.9925	0.9925	0.9925	0.9925	0.9925	0.9925	0.9925	0.9925
4	0.9908	0.9910	0.9910	0.9910	0.9910	0.9910	0.9910	0.9910	0.9910
5	0.988	0.9882	0.9882	0.9882	0.9883	0.9883	0.9883	0.9883	0.9883
6	0.9858	0.986	0.9861	0.9861	0.9861	0.9862	0.9862	0.9862	0.9862
7	0.9847	0.985	0.985	0.985	0.9851	0.9851	0.9851	0.9851	0.9851
8	0.9827	0.983	0.983	0.983	0.9831	0.9831	0.9831	0.9831	0.9831
9	0.9823	0.9826	0.9826	0.9826	0.9827	0.9827	0.9827	0.9828	0.9828
10	0.9814	0.9818	0.9818	0.9818	0.9818	0.9819	0.9819	0.9819	0.9819
11	0.9814	0.9817	0.9817	0.9818	0.9818	0.9818	0.9818	0.9819	0.9819
12	0.9806	0.9809	0.9809	0.9809	0.981	0.981	0.981	0.9811	0.9811
13	0.9802	0.9806	0.9806	0.9806	0.9806	0.9807	0.9807	0.9807	0.9808
14	0.9799	0.9803	0.9803	0.9803	0.9804	0.9804	0.9804	0.9805	0.9805
15	0.9797	0.9801	0.9801	0.9801	0.9802	0.9802	0.9802	0.9803	0.9803
16	0.9796	0.98	0.98	0.98	0.98	0.9801	0.9801	0.9801	0.9802
17	0.9792	0.9796	0.9796	0.9796	0.9797	0.9797	0.9797	0.9797	0.9798
18	0.9789	0.9793	0.9793	0.9794	0.9793	0.9794	0.9794	0.9794	0.9795
19	0.9787	0.9791	0.9791	0.9792	0.9791	0.9792	0.9793	0.9792	0.9793
20	0.9782	0.9788	0.9788	0.9788	0.9787	0.9787	0.9788	0.9788	0.979
21	0.9779	0.9785	0.9785	0.9785	0.9784	0.9784	0.9785	0.9785	0.9787
22	0.9779	0.9785	0.9785	0.9785	0.9784	0.9784	0.9785	0.9785	0.9787
23	0.9779	0.9785	0.9784	0.9784	0.9783	0.9784	0.9785	0.9784	0.9786
24	0.9779	0.9785	0.9784	0.9784	0.9783	0.9784	0.9785	0.9784	0.9786
Power Loss in KW	**602.2**	**580.9**	**578.5**	**577.3**	**576.1**	**574.3**	**572.8**	**571.6**	**569.7**

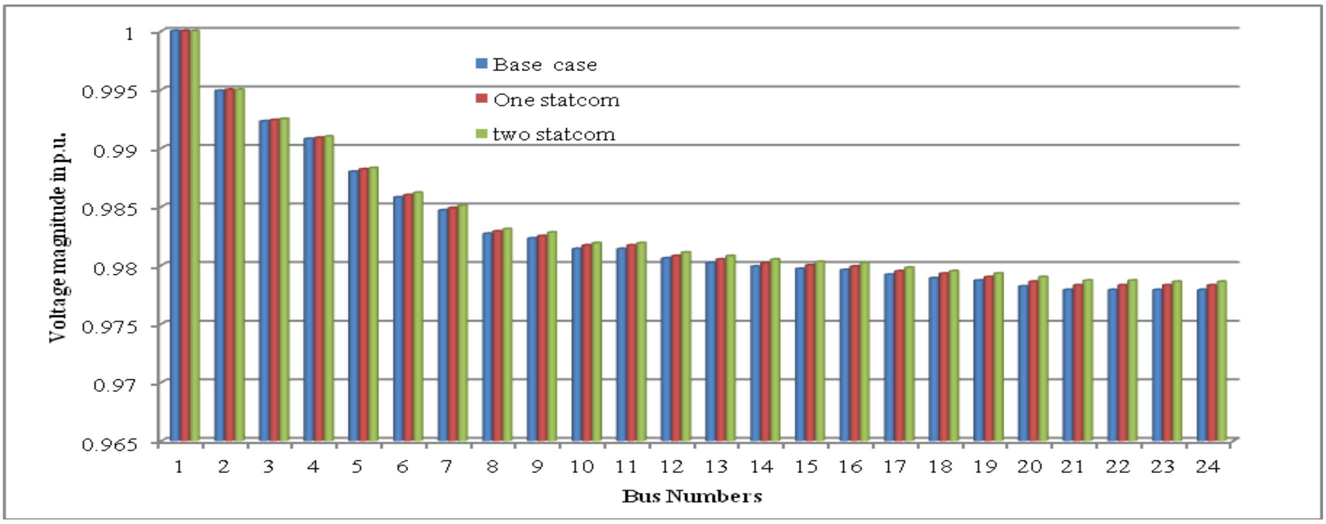

Fig.2 Voltage comparison base case with two STATCOM placement at different bus location combinations

Table.3 Comparison of voltage after integration of DTC at different branches

Bus No.	Base case	DTC placement between two buses			
		L 3,4	L 5,6	L 7,8	L 4,15
1	1.0000	1.0000	1.0000	1.0000	1.0000
2	0.9949	0.9949	0.9949	0.9949	0.9949
3	0.9923	0.9918	0.9919	0.9919	0.9919

4	0.9908	1.0137	0.9903	0.9903	0.9904
5	0.988	1.011	0.9875	0.9875	0.9875
6	0.9858	1.0089	1.009	0.9853	0.9854
7	0.9847	1.0078	1.008	0.9843	0.9843
8	0.9827	1.0058	1.006	1.0062	0.9823
9	0.9823	1.0054	1.0056	1.0058	0.9819
10	0.9814	1.0046	1.0047	1.005	0.9810
11	0.9814	1.0046	1.0047	1.0049	0.9810
12	0.9806	1.0037	1.0039	1.0041	0.9801
13	0.9802	1.0034	1.0035	1.0038	0.9798
14	0.9799	1.0031	1.0033	1.0035	0.9795
15	0.9797	1.0029	1.0031	1.0033	1.004
16	0.9796	1.0027	1.0029	1.0031	1.0039
17	0.9792	1.0025	1.0027	1.0029	1.0036
18	0.9789	1.0023	1.0024	1.0027	1.0034
19	0.9787	1.0021	1.0023	1.0025	1.0033
20	0.9782	1.0018	1.002	1.0022	1.003
21	0.9779	1.0016	1.0018	1.002	1.0028
22	0.9779	1.0016	1.0018	1.002	1.0028
23	0.9779	1.0016	1.0018	1.002	1.0027
24	0.9779	1.0016	1.0018	1.002	1.0027
Power Loss in KW	**602.2**	**591.1**	**597.2**	**599.8**	**599.1**

Table.3 shows the voltages in p.u. at each bus after integrating the DTC at various branches of the network. For the connection of DTC one extra bus is required. The connection of DTC is carried out by connecting existing line between 3 & 25 and DTC is connected between 25& 4. The optimal placement of tap changing transformer makes the enhancement of the voltage depending on the requirement. This will helps to 5-20% of total power loss reduction in the network.

From the Table.3 it can be observed that, the line between bus 3 and 4 is the best location for placement of DTC. After connecting DTC the power loss reduced to 602.2KW to 591.1KW without violating the any voltage limits. Fig.3 shows that voltage comparison base case with DTC placement in the branch L3, 4.

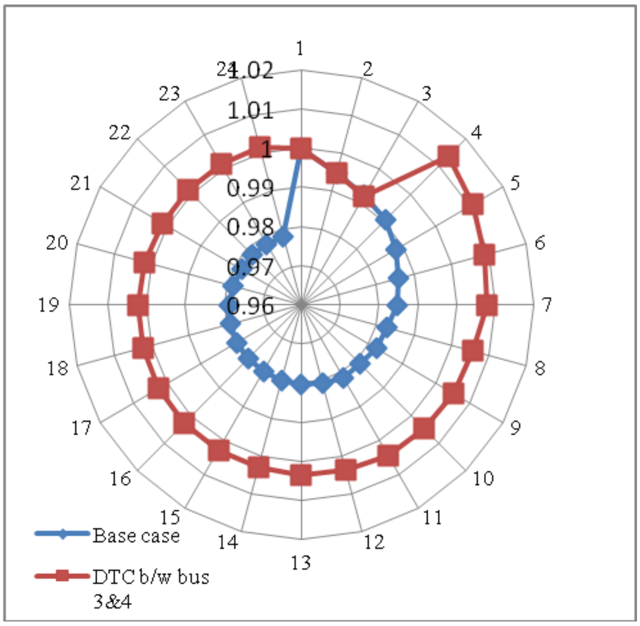

Fig.3 Voltage comparison of base case with DTC at L3,4

Table.4 shows the voltage value comparison after connecting DTC and STATCOM at various locations in the network considering the power loss minimization and improvement in the voltage profile. The DTC at L3,4 and STATCOM at bus 18 gives the best results among the other combinations, hence it can be chosen for placement of DTC and STATCOM.

Table.4 Voltage comparison base case with DTC and STATCOM connection

Bus No.	Base case	DTC L3,4 STATCOM at bus 18	Bus No.	Base case	DTC L3,4 STATCOM at bus 18
1	1	1	13	0.9802	1.0038
2	0.9949	0.995	14	0.9799	1.0036
3	0.9923	0.992	15	0.9797	1.0034
4	0.9908	1.014	16	0.9796	1.0032
5	0.988	1.0113	17	0.9792	1.003
6	0.9858	1.0092	18	0.9789	1.0028
7	0.9847	1.0081	19	0.9787	1.0027
8	0.9827	1.0062	20	0.9782	1.0024
9	0.9823	1.0058	21	0.9779	1.0022
10	0.9814	1.005	22	0.9779	1.0022
11	0.9814	1.005	23	0.9779	1.0021
12	0.9806	1.0042	24	0.9779	1.0021
Power loss in KW				**602.2**	**572.9**

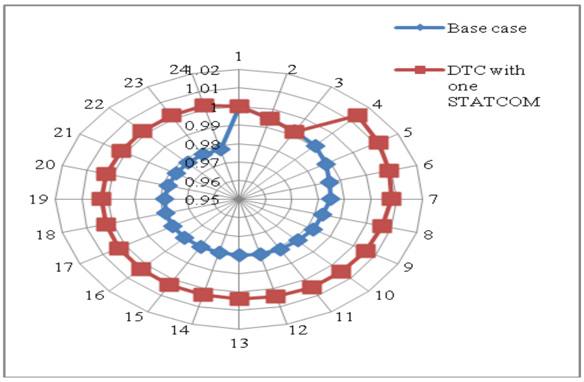

Fig.4 Voltage comparison base case with DTC with STATCOM

Fig.4 shows the voltage comparison of base case DTC with STATCOM. It can be observed that acceptable level voltage profile improvement without violating the acceptable voltage limits. Table.5 shows voltage and power loss comparison and it can be observed that DTC is at L3,4 and two STATCOMS at bus 14 and 22 will makes the power loss reduction from 602.2 KW to 543.1KW.

Fig 5 shows the single line diagram of twenty four bus system in presence of DTC between bus 3 and 4.For the connection of DTC is necessary to consider one extra bus as shown in the Fig.5 and also two STATCOM are connected at bus 14 and 22. Fig.6 shows the power loss comparison at different test cases and it is observed in all test cases significant power loss reduction is observed. The connection of two STATCOM and one DTC will make nearly 10% power loss reduction. Hence it can be used as optimal location of DTC and STATCOM for power loss minimization with enhancement of voltage profile.Fig.7 shows the voltage comparison base case with DTC and STATCOM with DTC combination.

Table.5 Voltage comparison base case with DTC and two STATCOM placement

Bus No.	Base case	DTC at L3,4 and STATCOM connected at buses			
		9,18	11,20	14,22	18,24
1	1.0000	1.0000	1.0000	1.0000	1.0000
2	0.9949	0.995	0.9951	0.9951	0.995
3	0.9923	0.9921	0.9922	0.9922	0.9921
4	0.9908	1.0142	1.0145	1.0145	1.0142
5	0.988	1.0116	1.0119	1.0119	1.0116
6	0.9858	1.0095	1.0098	1.0098	1.0095
7	0.9847	1.0085	1.0088	1.0088	1.0085
8	0.9827	1.0066	1.0069	1.0069	1.0066
9	0.9823	1.0062	1.0066	1.0066	1.0062
10	0.9814	1.0054	1.0058	1.0058	1.0054
11	0.9814	1.0054	1.0058	1.0058	1.0054
12	0.9806	1.0046	1.005	1.005	1.0046
13	0.9802	1.0042	1.0047	1.0047	1.0043
14	0.9799	1.004	1.0044	1.0045	1.0041
15	0.9797	1.0038	1.0042	1.0043	1.0039
16	0.9796	1.0036	1.0041	1.0042	1.0037
17	0.9792	1.0034	1.0039	1.0039	1.0035
18	0.9789	1.0032	1.0037	1.0038	1.0034
19	0.9787	1.0031	1.0036	1.0036	1.0032
20	0.9782	1.0028	1.0034	1.0034	1.003
21	0.9779	1.0026	1.0032	1.0033	1.0029
22	0.9779	1.0026	1.0032	1.0033	1.0029
23	0.9779	1.0025	1.0031	1.0033	1.0029
24	0.9779	1.0025	1.0031	1.0033	1.0029
Power loss	602.2	557.9	543.9	543.1	556

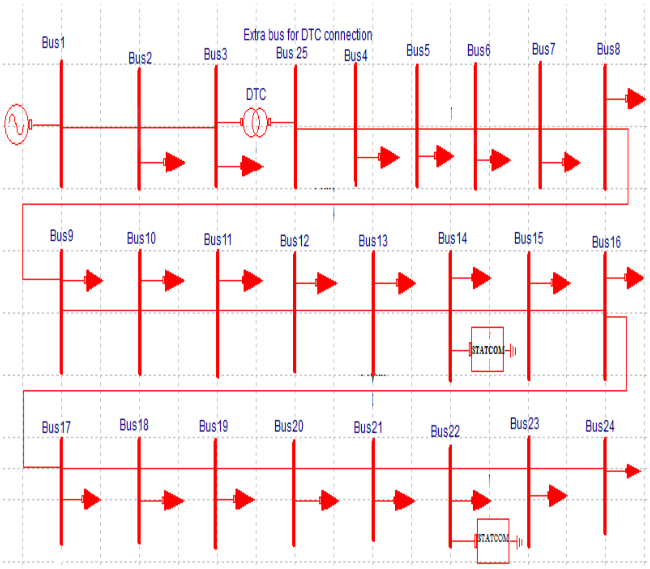

Fig.5 Single line diagram of twenty four bus DTC with two STATCOM

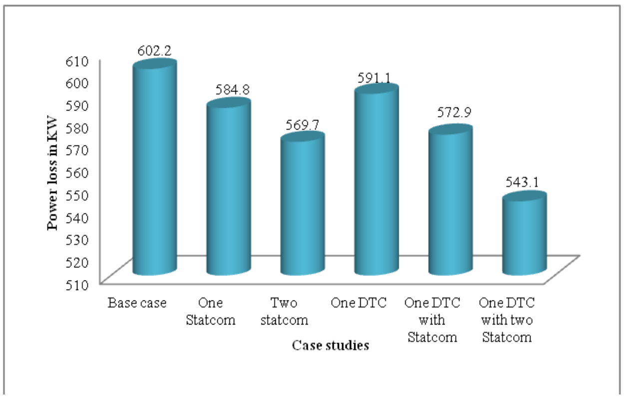

Fig.6 Power loss comparison considering different case studies

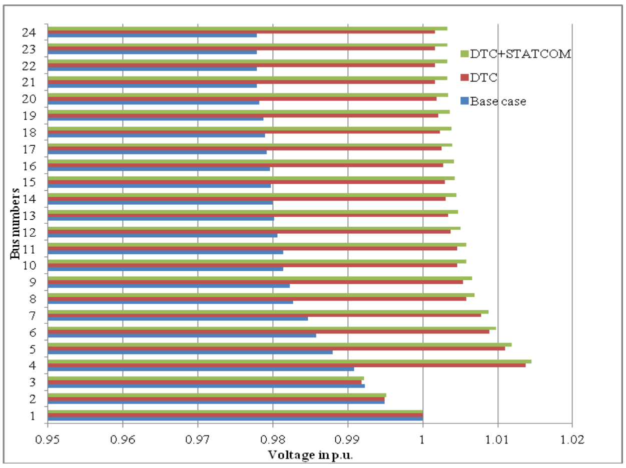

Fig.7 Voltage comparison base case with DTC and STATCOM-DTC combination

Retrieval Number: B3153078219/19©BEIESP
DOI: 10.35940/ijrte.B3153.078219
Journal Website: www.ijrte.org

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

III. CONCLUSION

In distribution network, voltage profile and power loss are two important factors for stable and efficient operation of the network. In this paper, DTC and STATCOM placement is used to improve the overall efficiency of the network with good voltage profile. The different combination of DTC and STATCOM are tested on twenty four bus radial distribution network. The obtained results are satisfactory to improve the performance of the distribution network.

REFERENCES

1. Rudresh B Magadum, Sateesh N Dodamani and Dr.D.B.Kulkarni, "Optimal Placement of Unified Power Flow Controller (UPFC) using Fuzzy Logic", IEEE international conference, ICEES 2019.
2. K.R.Padiyar, "FACTS controllers in transmission and distribution", New age international publishers, Edition 2007.
3. Tina Orfanogianni and Rainer Bacher, "Steady-State Optimization in Power Systems With Series FACTS Devices", IEEE transactions on power systems, Vol. 18, No. 1, February 2003, pp 19-26.
4. Rudresh B Magadum, D.B.Kulkarni, "Optimal Placement and Sizing of Multiple Distributed Generators using Fuzzy Logic", IEEE international conference ICEES-2019.
5. Zhang, X., Rehtanz, Ch., Pal, B.: Flexible AC Transmission System: Modelling and Control. Berlin: Springer, 2006. 383 p. ISBN 3-540-30606-4.
6. P. Kundur, Power System Stability and Control, McGraw-Hill, Inc., New York, 1994
7. Rudresh B Magadum, Dr.D.B.Kulkarni, "Power Loss Reduction by Optimal Location of DG using Fuzzy Logic", IEEE conference ICSTM-2015, pp.338-343.
8. H. Rastegar. "Improvement of voltage stability and reduce power system losses by optimal GA-based allocation of multi-type FACTS devices", 2008 11th International Conference on Optimization of Electrical and Electronic Equipment, 05/2008.
9. L. F. W. de Souza, E. H. Watanabe, J . E. R. Alves, and L. A. S. Pilotto, "Thyristor and Gate Controlled Series Capacitors Comparison of Components Rating", IEEE, 2003, pp: 2542-2547.
10. Rudresh B Magadum, D.B.Kulkarni, "Improvement of Voltage Profile by using Line Reconfiguration and Distribution Transformer Placement", IEEE international conference ICEET-2016, pp-330-340.
11. Rudresh B Magadum, D.B.Kulkarni, "Minimization of Power Loss with Enhancement of the Voltage Profile using Optimal Placement of Distribution Transformer and Distributed Generator", IEEE international conference ICCSP-2019, pp-392-395.
12. Rudresh B Magadum, D.B.Kulkarni, "Optimal Location and Sizing of Multiple DG for Efficient Operation of Power System" IEEE international conference ICEES-2018, pp-88-92.
13. Rudresh B Magadum, D.B.Kulkarni, "Optimal Placement of Capacitor to Enhance the Efficiency of the Distribution Network", International Journal of Innovative Technology and Exploring Engineering, Volume-8 Issue-9, July 2019, pp 2877-2881.
14. T arya Vishnu Ram, K.M Haneesh, "Voltage stability analysis using L-index under various transformer tap changer settings", IEEE international conference on ICCPCT-2016.
15. T.Nireekshana, G.Kesava Rao,S.Siva naga Raju, "Incorporation of unified power flow controller model for optimal placement using particle swarm optimization technique", IEEE 3rd international conference on Electronics computer Technology.
16. MiPower user manual Power research Development and Consultants Bangalore.

AUTHORS PROFILE

Mr.Rudresh.B.Magadum was born in Sankeshwar, Karnataka, India Jul 09, 1987. He obtained his B.E and M.Tech from VTU Belagavi in 2010 and 2012 respectively. Presently he is pursuing Ph.D at KLS Gogte institute of technology, Belagavi. His area of interests includes distributed generation, micro grid, smart grid, power quality and HVDC.

Dr. D.B. Kulkarni was born in Belagavi, Karnataka, India on Feb 10, 1966. He obtained his B.E and M.E degrees from Walchand college of Engineering, Sangli, Maharashtra, India in 1986 and 1993 respectively & Ph.D in the area of Power quality from VTU, Belagavi in 2012.Currently working as professor in Electrical and Electronics Engineering department, KLS Gogte Institute of Technology, Belagavi. His areas of interest include Power quality, FACTS, HVDC transmission and Power systems.