

Selection of Suitable FACTS Device for Indian Utility System to Reduce the Losses

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Abstract: This study presents a method to select the suitable FACTS device to reduce the power losses in the power system network. The FACTS devices are used to minimize real power loss and improve the voltage stability in the system. Based on the weak bus in the system, the suitable location of these FACTS device was identified. The effectiveness of the proposed work is analyzed using Indian utility system Neyveli Thermal Power Station (NTPS). The proposed method effectively reduces the real power loss and improves the voltage stability of the system.

Key words: Real power loss, NTPS, FACTS, STATCOM, TCSC

INTRODUCTION

The voltage stability is the major concern in the power system stability. If the bus voltage magnitudes are not maintained in within the acceptable voltage limits, it will leads to leads to voltage collapse and power system blackouts. In addition, need to minimize the real power losses in the system. This can be achieved by including Flexible AC Transmission Systems (FACTS) devices at the suitable locations. Optimal Power Flow (OPF) model has been developed and analyzed with Thyristor Controlled Series Compensator (TCSC) for practical power networks using Newton's optimization technique and the minimization of total system real power and controlling the power flow of specified transmission lines is discussed by Abdel-Moamen and Padhy (2003). This model has considered the optimal settings generators, transformers and TCSC devices. Acha *et al.* (2006) investigates the enhancement of voltage stability using FACTS devices. It is based on TCSC comparison with (Static Synchronous Compensator) STATCOM compensation to increase the steady state voltage stability margin of power capability. A genetic algorithm based method presented by Arhit *et al.* (2007) to use TCSC in power systems in order to increase system load ability and to decrease the total loss. Optimizations are done on two parameters: the location of TCSC and their values. A sensitivity analysis is used and the most sensitive lines are chosen to be compensated by TCSC.

Biansoongnern *et al.* (2006) presents an optimal placement of (Static Var Compensator) SVC and TCSC to determine SVC and TCSC locations and control parameters for minimization of transmission loss. An optimal location method utilizes the sensitivity of total real power transmission loss with respect to the control

parameters of devices and multiplies with new equation. Optimal control parameter utilizes the interior point method for the minimizing real power loss. Location of FACTS devices based on contingency studies is proposed by Boonpirom and Paitoonwattanakij (2005). Using modal analysis, a probabilistic index is defined which can be used to rank of system buses based on their effect on system voltage stability enhancement under all possible contingencies. Hingorani and Gyugyi (2001) presents a comparison of FACTS devices for static voltage stability study. Various performance measures including PV curves, voltage profiles and power losses are compared under normal and contingency conditions. Placement and sizing techniques of series FACTS devices and (Unified Power Flow Controller) UPFC are proposed for loading margin enhancement.

A comparison of FACTS controllers such as SVC, STATCOM, TCSC and the Static Synchronous Series Compensator (SSSC) on power system steady state voltage stability. The choice of the location and sizing of these devices is also presented by Kazemi *et al.* (2006). Ja'fari and Afsharnia (2007) presents the optimal power flow solution and enhancement of system performance without sacrificing the security of the system via optimal location and optimal sizing of TCSC when the system is operating under normal and network contingency conditions. This study presents a secured optimal power flow solution by integrating TCSC with the optimization model developed under normal and contingency cases. The optimization model developed in this study is solved by using linear programming method. New indices called Thermal Capacity Index (TCI) and Contingency Capacity Index (CCI) are proposed for placing the TCSC at appropriate location under normal and network contingency conditions, respectively.

In the above literature, it is found that the voltage stability and real power loss minimization is one of the major issue in the power system. The proposed work can able to mitigate the above mentioned problem. The main objective of this study is to reduce the real power loss and improve the bus voltage magnitude within the acceptable limits to improve the stability and security of the system by including STATCOM or TCSC at suitable locations of the system.

MATERIALS AND METHODS

Modeling of static synchronous compensator (STATCOM):

The STATCOM is a voltage-source converter based shunt compensation device which converts a DC input voltage into an AC output voltage in order to compensate the active and reactive needs of the system. The STATCOM has better characteristics and its maximum reactive power output will not be affected by the system voltage magnitude. STATCOM can provide the dynamic reactive power support at the bus where it is connected. Figure 1 shows the basic structure of a STATCOM TCSC (Musunuri and Dehnavi, 2010; Sundar and Ravikumar, 2012).

Modeling of thyristor controlled series compensator (TCSC):

A TCSC is a thyristor controlled series compensator which consists of a series capacitor bank shunted by a thyristor-controlled reactor in order to provide a smoothly variable series capacitive reactance. The basic idea behind the TCSC is to decrease or increase the overall lines effective series reactance of the line.

Consider the TCSC is connected in series with line connected between bus '1' and 'm'. Here X_{lm} represents reactance of the line and X_{TCSC} represents the effective reactance of the TCSC. Figure 2 shows the basic structure of a TCSC (Musunuri and Dehnavi, 2010; Sundar and Ravikumar, 2012).

Case studies: A Neyveli Thermal Power Station (NTPS) 23 bus test system is used to analysis the proposed method for real power loss minimization and the test system as shown in Fig. 3. The test system consists of four generators buses, nineteen load buses and twenty two lines. The behaviour of the test system without and with

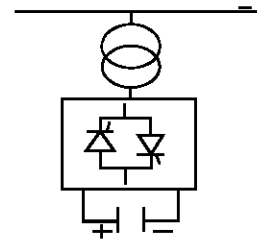


Fig. 1: Basic structure of STATCOM

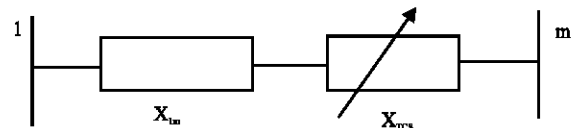


Fig. 2: Basic structure of TCSC

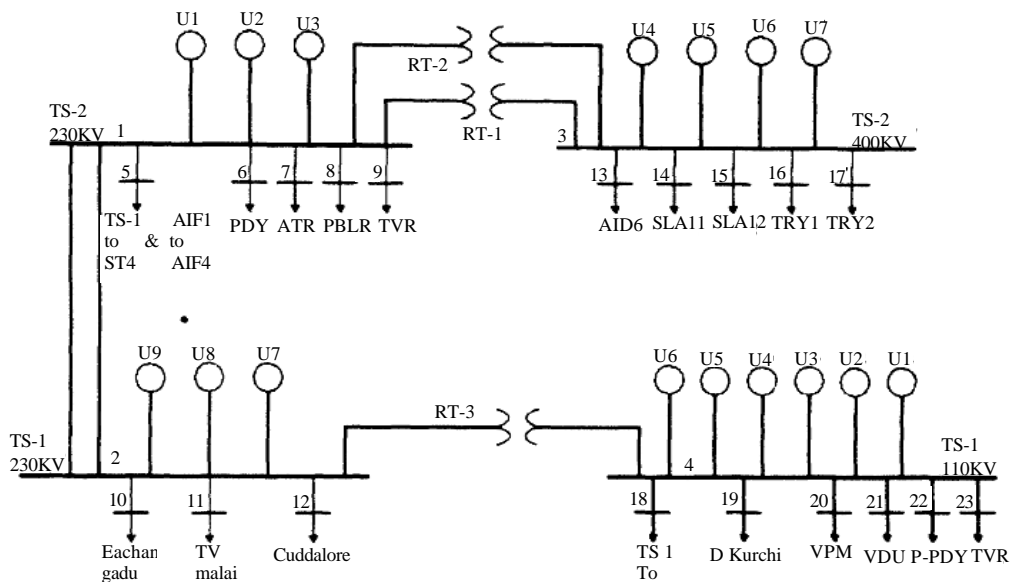


Fig. 3: Indian Utility, NTPS 23 bus system

FACTS devices is studied. The location of FACTS device is identified based on the weak bus in the system.

RESULTS AND DISCUSSION

The proposed work is analyzed using Newton Raphson load flow method. The test system is analysed in the following three cases such as. Without FACTS devices, with STATCOM, with TCSC. The results are compared and analysed to validate the proposed research.

Without FACTS devices: The NTPS 23 bus system is analysed using NR load flow method without any FACTS device for base case condition. The bus voltage magnitudes of all the buses without FACTS device is shown in Table 1. The bus voltage must be maintained within the permissible limit (0.94-1.06 pu) to ensure the voltage stability of the system. In this case, the bus voltage magnitude at bus 19 is 0.889 pu and violating the voltage stability limits. In addition, the total real power loss in the system is 0.2417 pu as shown in Table 2.

Figure 4 shows the voltage profile of the system without FACTS device. From Fig. 4, it is observed that bus voltage magnitude at bus 19 is violating their voltage stability limits. However, the objective of the proposed research is to maintain within the acceptable limits. Hence, the bus 19 is the suitable location for the STATCOM and line 18 is the suitable location for the TCSC.

With STATCOM: Now, the test system is analysed using NR load flow method including the STATCOM. Based on the base case load flow analysis, the bus 19 is identified as weakest bus among all other buses in the system, since bus 19 violate the bus voltage limits. The bus voltage magnitude of all the buses with STATCOM is shown in Table 1. In this case, the bus voltage magnitude at bus 19 is 1.0 pu and within the acceptable voltage limits. In addition, the total real power loss in the system is 0.2259 pu as shown in Table 2.

With TCSC: Again, the test system is analysed using NR load flow method including the TCSC. Based on the base case load flow analysis, the line 18 is identified as suitable location for TCSC which connect the weakest bus in the system, since bus 19 violate the bus voltage limits. The bus voltage magnitude of all the buses with TCSC is shown in Table 1. In this case, the bus voltage magnitude at bus 19 is 0.946 pu and within the acceptable voltage limits. In addition, the total real power loss in the system is 0.2046 pu as shown in Table 2.

Table 1 shows the voltage magnitude without and with FACTS devices. From Table 2, it is observed that the

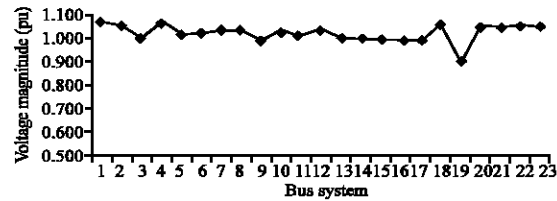


Fig. 4: Voltage profile of the system without FACTS

Table 1: Voltage magnitude without and with facts
Voltage magnitude (pu)

Without FACTS	With STATCOM at bus 19	With TCSC at line 18
1.060	1.060	1.060
1.045	1.045	1.045
1.000	1.000	1.000
1.060	1.060	1.060
1.010	1.010	1.010
1.016	1.016	1.016
1.028	1.028	1.028
1.024	1.024	1.024
0.987	0.987	0.987
1.028	1.028	1.028
1.004	1.004	1.004
1.028	1.028	1.028
0.996	0.996	0.996
0.991	0.991	0.991
0.989	0.989	0.989
0.983	0.983	0.983
0.983	0.983	0.983
1.047	1.047	1.047
0.889	1.000	0.946
1.043	1.043	1.043
1.042	1.042	1.042
1.048	1.048	1.048
1.037	1.037	1.037

Table 2: Real power loss without and with facts
Real power loss (pu)

Buses	Without FACTS	With STATCOM at bus 19	With TCSC at line 18
1-5	0.0776	0.0776	0.0776
1-6	0.0188	0.0188	0.0188
1-7	0.0057	0.0057	0.0057
1-8	0.0080	0.0080	0.0080
1-9	0.0220	0.0220	0.0220
1-2	0.0113	0.0114	0.0115
2-10	0.0029	0.0029	0.0029
2-11	0.0089	0.0089	0.0089
2-12	0.0038	0.0038	0.0038
2-4	0.0012	0.0013	0.0014
3-1	0.0204	0.0204	0.0204
3-13	0.0003	0.0003	0.0003
3-14	0.0013	0.0013	0.0013
3-15	0.0017	0.0017	0.0017
3-16	0.0055	0.0055	0.0055
3-17	0.0055	0.0055	0.0055
4-18	0.0034	0.0034	0.0034
4-19	0.0375	0.0215	0.0000
4-20	0.0015	0.0015	0.0015
4-21	0.0018	0.0018	0.0018
4-22	0.0009	0.0009	0.0009
4-23	0.0017	0.0017	0.0017
Total real power loss	0.2417	0.2259	0.2046

FACTS device such as STATCOM and TCSC can improve the voltage magnitude of the bus at which it is

Table 3: Comparison of real power generation, load and losses in the system without and with facts

Total generation/load/loss (pu)	Real power loss (pu)		
	Without FACTS	With STATCOM at bus 19	With TCSC at line 18
Total real power generation	14.8017	14.7859	14.7646
Total reactive power generation	9.8120	9.7315	9.7761
Total real power load	14.5600	14.5600	14.5600
Total reactive power load	8.0870	8.0870	8.0870
Total real power loss	0.2417	0.2259	0.2046
Total reactive power loss	1.7250	1.6445	1.6891

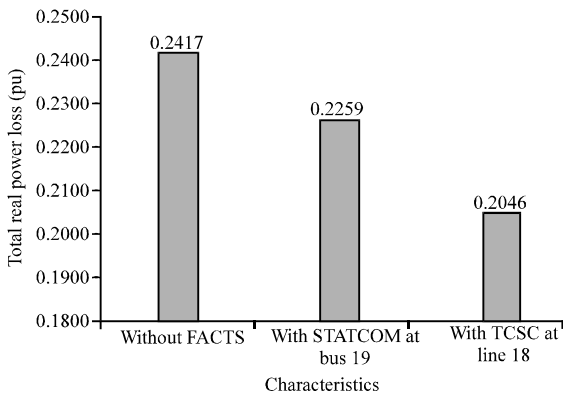


Fig. 5: Comparison of total real power losses in the system

connected. Both STATCOM and TCSC can able to maintain the voltage magnitude within the acceptable limits.

Table 2 and 3 shows the real power losses in the system without and with FACTS devices. From Table 3, it is observed that the FACTS device such as STATCOM and TCSC can reduce the total real power losses in the system. The STATCOM can reduce the total real power losses in the system from 0.2417- 0.2259 pu. The TCSC can reduce the total real power losses in the system from 0.2417-0.2046 pu. By comparing STATCOM and TCSC for real power loss minimization, the TCSC will be the best suitable device for loss minimization.

Figure 5 shows the total real power loss comparison of the system without and with FACTS device. From Fig. 5, it is observed that by locating TCSC at line 18 will greatly reduces the total real power losses of the system from 0.2417-0.2046 pu.

CONCLUSION

The real power loss minimization is analyzed in this paper without and with STATCOM or TCSC. The suitable location of these FACTS devices is identified based on the weak bus in the system. While locating FACTS device

in the system, bus voltage is improved and total real power loss in the system reduced. Hence, FACTS device will improve the stability and security of the system.

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