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Voltage stability and Power flow improvement using STATCOM and TCSC

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Abstract: FACTS controllers are increasingly used to improve transmission capability of transmission lines with galloping energy consumption; the demand of transmission line is increasing. It is imperative to use existing transmission system to its full capacity. FACTS controllers play an important role in enhancement in power flow capacity and improvement of voltage stability. This paper investigates the application of STATCOM and TCSC for Voltage stability & power flow enhancement. The case has been tested on IEEE-14 bus system.

Keywords: Power flow enhancement, Voltage stability improvement, STATCOM, TCSC.

I. INTRODUCTION

With improvement in economic development of a country, the per capita energy consumption increases. Electric energy being a most common form of energy being used translates into overall higher energy demand on the power network. This galloping energy demand has not kept pace with development of transmission sector. It's development is further affected by environmental restrictions, right-of-way issues, economic consideration etc.

Hence, constructing a new transmission line more expensive than utilizing existing transmission line optimally. Generally, all transmission line operates for below thermal limit and hence there is simple scope for the line to carry more power. This is facilitated by a class of power electronic device called FACTS or Flexible AC transmission system. This paper studies the effect of using two such FACTS device viz. STATCOM (static synchronous compensator) and TCSC (Thyristor controlled series capacitor) for Voltage stability & Power Flow Enhancement.

In the following sections, section-2 discusses literature review, section-3 gives mathematical modeling of FACTS devices used and section-4 gives simulation results. The conclusion is given in section-5.

II. LITERATURE REVIEW

Hingorani & Gyugi[1] had proposed the concept of FACTS devices in early eightees. They had shown the improvement of power system performance by using power electronic devices called FACTS devices. SVC and TCSC were first generation FACTS devices using thyristors while STATCOM, UPFC etc. are second generation FACTS devices using GTO, IGBT, IGCT etc. Singh and Srivastava [2] had demonstrated improvement in load ability of power system using FACTS devices. They had demonstrated the proposal of IEEE-14 and IEEE-30 bus system. Kessel and Glavitsch[3] had estimated voltage stability and line load ability of FACTS devices. They showed that FACTS devices could improve line load ability as well as stability of the system.

Anwar and Tanmoy[4] had used STATCOM and SVC for improvement of voltage stability. They concluded that STATCOM was better than SVC in reactive power injection. His proposal was demonstrated on IEEE-14 bus system.

Sharvana and Gholamreza[5] compared the performance of STATCOM and SVC for voltage stability improvement. They concluded that during contingency situation when bus voltage dips than STATCOM can still provide reactive power support but reactive power output of SVC reduces.
Siddiqui and Deb[6] had used SVC and STATCOM among other fact devices to improve load ability of transmission lines there by reducing congestion. They had demonstrated the voltage stability improvement by STATCOM and SVC on IEEE-14 bus system.

N. Taleb et al[7] had studied voltage collapse phenomenon using SVC and STATCOM .They found that reactive power output of SVC reduces with reduction in bus voltage at the line contingency. Hence STATCOM was better suited for voltage stability improvement.

III. MODELING OF FACTS DEVICES

3.1 Modeling of STATCOM

STATCOM is a shunt connected reactive power compensator whose inductive and capacitive output current can be controlled independent of system AC voltage. It generates or absorbs independently controllable real and reactive power at its output terminal when fed from a energy storage device at the input.

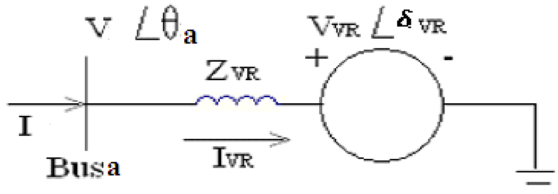

Fig 3.1 STATCOM equivalent circuit

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Assuming following voltage source representation–
$E_{VR} = V_{VR}(\text{COS}\ \delta_{VR} + j\ \sin\delta_{VR})$ .... (1)
Also, $S_{VR}= V_{VR}I^*_{VR}=V_{VR}Y^*_{VR}(V^*_{VR}- V^*_a)$...(2) following active and reactive power equations can be obtained after some complex operation.

$P_{VR}=V_{VR}^2 G_{VR}+V_{VR}V_a[G_{VR}\text{Cos}(\delta_{VR}-\theta_a)+B_{VR}\text{Sin}(\delta_{VR}-\theta_a)]$ (3)
$Q_{VR}=-V^2_{VR}B_{VR}+V_{VR}V_a[G_{VR}\text{Sin}(\delta_{VR}-\theta_a)-B_{VR}\text{Cos}(\delta_{VR}-\theta_a)]$...... (4)
$P_a=V^2_A G_{VR}+V_aV_{VR}[G_{VR}\text{COS}(\theta_a-\delta_{VR})+B_{VR}\text{Sin}(\theta_a-\delta_{VR})]$......... (5)
$Q_a = -V^2_a B_{VR}+ V_aV_{VR}[G_{VR}\text{Sin}(\theta_a- \delta_{VR})- B_{VR}\text{Cos}(\theta_a-\delta_{VR})]$....... (6)

Linearized model is given by following equations using above equations –

$$\begin{bmatrix}\Delta Pa\\ \Delta Qa\\ \Delta Pvr\\ \Delta Qvr\end{bmatrix} = \begin{bmatrix} \frac{\partial Pa}{\partial\theta a} & \frac{\partial Pa}{\partial Va}Va & \frac{\partial Pa}{\partial\delta vr} & \frac{\partial Pa}{\partial Vvr}Vvr \\ \frac{\partial Qa}{\partial\theta a} & \frac{\partial Qa}{\partial Va}Va & \frac{\partial Qa}{\partial\delta vr} & \frac{\partial Qa}{\partial Vvr}Vvr \\ \frac{\partial PVR}{\partial\theta a} & \frac{\partial Pvr}{\partial Va}Va & \frac{\partial Pvr}{\partial\delta vr} & \frac{\partial Pvr}{\partial Vvr}Vvr \\ \frac{\partial QVR}{\partial\theta a} & \frac{\partial Qvr}{\partial Va}Va & \frac{\partial Qvr}{\partial\delta vr} & \frac{\partial Qvr}{\partial Vvr}Vvr \end{bmatrix} \begin{bmatrix}\Delta Qa\\ \frac{\Delta Va}{Va}\\ \Delta\delta vr\\ \frac{\Delta Vvr}{Vvr}\end{bmatrix}$$
....(7)

3.2 Modelling of TCSC

TCSC can be considered as a variable series reactance whose magnitude can be adjusted to control the power flow in a branch .The amount of reactance X_{TCSC} can be found by Newton's method.

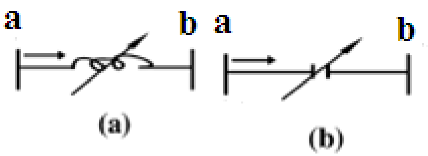

Fig 3.2 TCSC equivalent circuit

Fig 3.2 TCSC equivalent circuit in inductive and capacitive region. Inductive susceptance is given by

$B_{aa}=B_{bb}= \frac{-1}{X_{TCSC}}$ (8)
$B_{ab} = B_{ba}= \frac{1}{X_{TCSC}}$. (9)

For capacitive susceptance, signs are reversed. Active and reactive power equations at bus a are given by-
$P_a =V_aV_bB_{ab}\,\text{Sin}(\theta_a- \theta_b)$ (10)
$Q_a = -V^2_aB_{aa}-V_aV_bB_{ab}\cos(\theta_a- \theta_b)$ (11)
Linearizing above equation for active power P_{ab}^{reg} flowing from bus a to bus b-

$$\begin{bmatrix}\Delta Pa\\ \Delta Pb\\ \Delta Qa\\ \Delta Qb\\ \Delta P_{ab}^{XTCSC}\end{bmatrix} = \begin{bmatrix} \frac{\partial Pa}{\partial\theta a} & \frac{\partial Pa}{\partial\theta b} & \frac{\partial Pa}{\partial Va}V_a & \frac{\partial Pa}{\partial Vb}V_b & \frac{\partial Pa}{\partial X_{TCSC}}X_{TCSC} \\ \frac{\partial Pb}{\partial\theta a} & \frac{\partial Pb}{\partial\theta b} & \frac{\partial Pb}{\partial Vb}V_a & \frac{\partial Pb}{\partial Vb}V_b & \frac{\partial Pb}{\partial X_{TCSC}}X_{TCSC} \\ \frac{\partial Qa}{\partial\theta a} & \frac{\partial Qa}{\partial\theta b} & \frac{\partial Qa}{\partial Va}V_a & \frac{\partial Qa}{\partial Vb}V_b & \frac{\partial Qa}{\partial X_{TCSC}}X_{TCSC} \\ \frac{\partial Qb}{\partial\theta a} & \frac{\partial Qb}{\partial\theta b} & \frac{\partial Qb}{\partial Vb}V_a & \frac{\partial Qb}{\partial Vb}V_b & \frac{\partial Qb}{\partial X_{TCSC}}X_{TCSC} \\ \frac{\Delta P_{ab}^{XTCSC}}{\partial\theta a} & \frac{\Delta P_{ab}^{XTCSC}}{\partial\theta b} & \frac{\Delta P_{ab}^{XTCSC}}{\partial Va} & \frac{\Delta P_{ab}^{XTCSC}}{\partial Vb} & \frac{\Delta P_{ab}^{XTCSC}}{\partial X_{TCSC}}X_{TCSC} \end{bmatrix} \begin{bmatrix}\Delta Qa\\ \Delta Qb\\ \frac{\Delta Va}{Va}\\ \frac{\Delta Vb}{Vb}\\ \frac{\Delta X_{TCSC}}{X_{TCSC}}\end{bmatrix}$$
..(12)

ΔP_{ab}^{XTCSC} is given by
$\Delta P_{ab}^{XTCSC} = P_{ab}^{reg} - P_{ab}^{XTCSC.cal}$. ....(13)
This is active power mismatch for series reactance .Also,
$\Delta X_{TCSC} = X^i_{TCSC} - X^{i-1}_{TCSC}$ ...... (14)

The state variable X_{TCSC} is updated at the end of each iterative step
$X^i_{TCSC} = X^{i-1}_{TCSC} + [\frac{\Delta X_{TCSC}}{X_{TCSC}}]^i X^{i-1}_{TCSC}$. ....(15)

IV. RESULT AND DISCUSSIONS

Newton raphson load flow carried out on IEEE-14 bus system. STATCOM controls the bus voltage to the specified value ,in table -1 the base case voltage in bus 14 is 0.9417 which is lowest value , after connecting STATCOM to that bus the bus voltage improves to 1.0 having reactive power supplied by STATCOM is -0.2445 at source voltage magnitude and phase angel is 1.024 and -0.3175 respectively. By increasing the load by 20%, the reactive power and voltage (both magnitude and phase angle) is -0.3053 and 1.029, -0.3883 respectively to make the bus voltage magnitude to 1.0 .By decreasing the load by 20% , the reactive power and voltage(both magnitude and phase angle) is -0.1887 and 1.0185, -0.2485 respectively to make the bus voltage magnitude to 1.0. From this discussion the STATCOM voltage magnitude is more than the bus voltage so it works on the capacitive mode and supplies reactive power to the system. About other bus, the data is given in table-1.

In table -2 the lowest base case active power (pu) is 0.0944 the branch 9-14 by connecting TCSC in this branch the active power improved to 0.12 and reactance value is -0.2771.Then increasing 20% load, the reactance value is -0.1071 to make the active power 0.12.Then decreasing 20% load the maximum active power can be improved is 0.099 at this reactance limit, the reactance value is -0.2956. In all the cases TCSC operates in capacitive mode. For the test of TCSC in inductive mode ,the active power in branch 2-3 is decreased from 0.7443(base case value) to 0.6,at that time TCSC reactance is 0.1195, the reactance value shows that TCSC works in inductive mode. Like this for other branch the data is given in table-2.

V. CONCLUSION

STATCOM and TCSC were implemented in IEEE-14 bus system using Newton-Raphson load flow algorithm.

By using the STATCOM model, the voltage magnitude at the bus is improved on base case load, 20% increasing load and 20% decreasing load.

By using TCSC, the active power flow is improved in the branch on base case load, 20% increasing load and 20% decreasing load.

REFRENCES

[1] N.G.Hingorani, L.guyngi, "UNDERSTANDING FACTS: Concept and Technology of Flexible AC Transmission Systems" IEEE Press, 2000.
[2] J.G.Singh, S.N.Singh,S.C. Srivastava "Placement of fact controllers for enhancing power system loadibility",proceeding of IEEE Power India conference,2006,p810-17.
[3] P.Kessel, H.Glavitsch, "Estimating the voltage stability and loadibility of power systems", IEEE trans. On power delivery 1986, vol1, pp1586-1599.
[4] Anwar S. Siddiqui, Tanmoy deb, "voltage stability improvement using STATCOM and SVC" INT. J. of computer application, VOL.88, no.14, feb 2014.
[5] Sharvana Masunuri,gholamraza "Comparison of STATCOM,SVC,TCSC and SSSC performance in steady state

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voltage stability improvement", North American Power Symposium,26-28sept,pp1-7,2010.

[6] Anwar S. Siddiqui, Tanmoy deb, "Congestion management using facts devices", I. J.Of system assurance Engg& management springer,Dec 2013.

[7] N.Taleb, M. Ehsan "Effect of SVC and TCSC Control straygies on static voltage collapse phenomenon", IEEE proceeding, south east conf. MAY 2004, pp.161-168.

APPENDIX-I

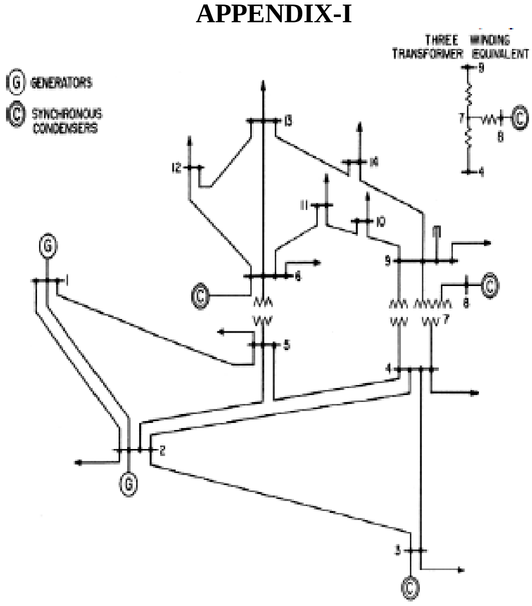

Figure-1 IEEE -14 bus system

TABLE-1

Bus No	Base Case voltage (pu)	With STATCOM (on base case load)			20%increased load (With STATCOM)			20% decreased load (With STATCOM)		
		Voltage (pu)	Reactive power(pu)	Source Voltage magnitude & angle (pu)	Voltage (pu)	Reactive power (pu)	Source Voltage magnitude & angle(pu)	Voltage (pu)	Reactive power (pu)	Source Voltage magnitude & angle(pu)
4	0.9898	1.0	-0. 3276	1.0318 - 0.1830	1.0	-0.4980	1.0475 - 0.2254	1.0	-0.1772	1.0174 - 0.1416
5	0.9974	1.0	-0.1241	1.0123 - 0.1548	1.0	-0.2746	1.0267 - 0.1911	1.0	0.0065	0.9993 - 0.1192
7	0.9780	1.0	-0.2684	1.0262 - 0.2416	1.0	-0.3534	1.0342 - 0.2956	1.0	-0.1905	1.0187 - 0.1887
9	0.9595	1.0	-0. 3497	1.0338 - 0.2759	1.0	-0.4447	1.0426 - 0.3369	1.0	-0. 2608	1.0254 - 0.2162
10	0.9563	1.0	-0. 2747	1.0268 - 0.2860	1.0	-0.3461	1.0335 - 0.3497	1.0	-0. 2074	1.0203 - 0.2238
11	0.9679	1.0	-0.1762	1.0173 - 0.2836	1.0	-0.2210	1.0216 - 0.3473	1.0	-0.1339	1.0132 - 0.2216
12	0.9703	1.0	-0.1238	1.0122 - 0.2954	1.0	-0.1513	1.0149 - 0.3616	1.0	-0.0971	1.0096 - 0.2310
13	0.9642	1.0	-0. 2768	1.0270 - 0.2971	1.0	-0.3405	1.0330 - 0.3636	1.0	-0. 2156	1.0211 - 0.2324
14	0.9417	1.0	-0. 2455	1.0240 - 0.3175	1.0	-0.3053	1.0297 - 0.3883	1.0	-0.1887	1.0185 - 0.2485

TABLE-2

Branch (From- To)	Base Case active power (pu)	With TCSC (on base case load)		20%increased load (With TCSC)		20% decreased load (With TCSC)	
		Active power (pu)	TCSC Reactance (pu)	Active power (pu)	TCSC Reactance (pu)	Active power (pu)	TCSC Reactance (pu)
4 -9	0.1608	0.25	-0.2771	0.25	-0.1847	0.20	-0.2741
5-6	0.4403	0.55	-0.1552	0.55	-0.0121	0.55	-0.2937
6-13	0.1777	0.25	-0.1614	0.25	-0.0861	0.25	-0.2425
7-9	0.2829	0.45	-0.2213	0.45	-0.1511	0.45	-0.2909
9-14	0.0944	0.12	-0.2771	0.12	-0.1071	0.099	-0.2956
2-3	0.7433	0.6	0.1195	-	-	-	-