International Journal of Advance Research in Engineering, Science & Technology(IJAREST),
ISSN(O):2393-9877, ISSN(P): 2394-2444,
Volume 2, Issue 5, May – 2015, Impact Factor: 2.125

Voltage Profile Improve Using FACTS Devices and Comparison of SVC and TCSC

***Maulik C. Patel*[1], *Nilesh K. Patel*[2]**

[1]*P.G. Student, Electrical Engg. Department, S. P. C. E. Visnagar, India,maulikpatel1219@gmail.com*

[2]*Associate Professor, Electrical Engg. S. P. C. E., Ta-Visnagar, Gujarat, India nkpee.spce@gmail.com*

Abstract— *The many FACTS devices are use to correct voltage profile of bus and control the reactive power of line. In this paper three SVC, TCSC, and UPFC FACTS controller are use to control the reactive power of line which is connected to weak bus of the power system. The comparison of SVC, TCSC, and UPFC power flow result with Modified IEEE14 bus data using MATLAB base MATPOWER software.*

Keywords - *Modelling of SVC, TCSC,Voltage Profile, FACTS, MATPOWER package.*

I. INTRODUCTION

In restructure power system, transmission network are subjected to operate near to full capacity. This situation cause transmission network to be congested, so it's to become difficult to maintain constant voltage of bus during this time so the voltage instability in transmission system is due to increasing load demand. Flexible ac transmission (FACTS) Devices play important role to maintain constant voltage by absorbing or supplying reactive power to transmission network. We use the FACTS device in ac transmission line and control the reactive power flow of line to maintain the voltage in specified limit. The objective of work is to improve voltage profile and improve voltage stability margin using FACTS devices.

In recent years, the increase in peak load demand and power transfers between utilities has elevated concerns about system voltage security. Voltage collapse has been demanded responsible for several major disturbances [1] and significant research efforts are under way in an effort to further understand Voltage phenomena [2].

II.MODELLING OF FACTS DEVICES

There are different types of FACTS Model used for power system analysis. The model discuss below.

A. SVC

A possible structure of the SVC is given in Fig. 1. It is a shunt-connected device composed of several modules built of a fixed capacitance in parallel with a thyristor controlled reactor. Each of these modules corresponds to a variable susceptance. The equivalent susceptance B_{eq} is determined by the firing angle α of the thyristors which is defined as the delay angle measured from the peak of the capacitor voltage to the firing instant. The fundamental frequency equivalent neglecting the harmonics of the current results in [3]

$B_{eq} = B_L(\alpha) + B_C$ ………………………… (1)

Where

$B_L(\alpha) = -\frac{1}{\omega L}\left(1 - \frac{2\alpha}{\pi} - \frac{\sin(2\alpha)}{\pi}\right), \; B_C = \omega C$……….. (2)

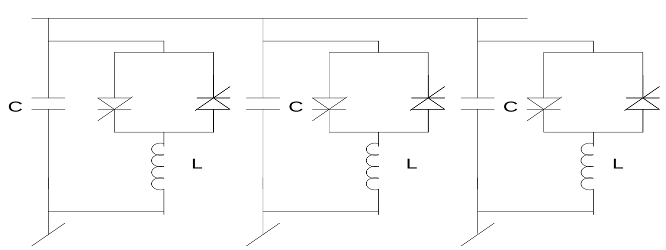

Fig 1. Structure of an SVC

The minimal and maximal values for the firing angle are 0° and 90°, respectively, resulting in a minimal value $\mathbf{B_{min}}$ and a maximal value $\mathbf{B_{max}}$ for the equivalent susceptance of each module. At the resonance angle where

$B_L(\alpha_{res}) = -B_C$……………………….. (3)

The equivalent susceptance is zero. But this resonance is not a problem here because this simply corresponds to a module which is not connected to the bus.

The total susceptance of the SVC is composed of the parallel equivalent susceptances of the modules, each controlled separately. Thus, the SVC can be modeled as a shunt-connected variable susceptance $\mathbf{B}_{SVC}$ (Fig. 2) with a lower bound $\underline{\mathbf{B}}_{SVC}$ and an upper bound $\overline{\mathbf{B}}_{svc}$ [4]. In the power flow equations this is accounted for by including the reactive power

$$Q_k = -V_k^2 B_{svc} \ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

into the reactive power balance at bus *k* subject to

$$\underline{B}_{svc} \leq B_{svc} \leq \overline{B}_{svc} \ldots\ldots\ldots\ldots\ldots\ldots (5)$$

This range normally includes positive as well as negative values.

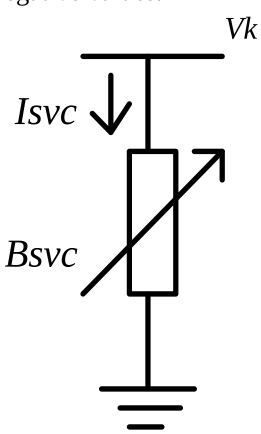

Fig 2. Model of SVC

B. TCSC

Similar to the SVC, the TCSC consists of several modules built of a fixed capacitance in parallel with a thyristor controlled inductor. But here, the modules are connected in series as shown in Fig. 3 [5].

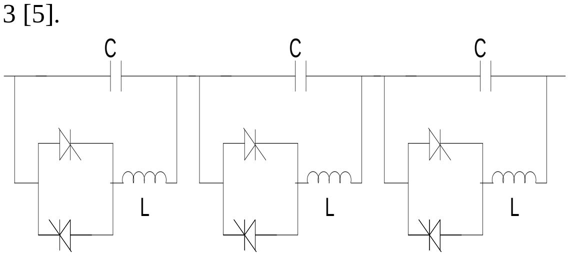

Fig 3.Structure of a TCSC

Therefore, the equivalent reactance $\mathbf{X}_{\mathbf{eq}}$ of each individual module is considered which is determined by the firing angle of the thyristors by

$$X_{eq}(\alpha) = \frac{1}{B_L(\alpha) + B_C} \ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

Where $\mathbf{B}_L(\alpha)$ and $\mathbf{B}_C$ are given in equation (2). A minimal value $\mathbf{X}_{\mathbf{min}}$ and a maximal value $\mathbf{X}_{\mathbf{max}}$ result for the equivalent reactance. Additionally, the minimal and maximal values for the firing angle are again 0° and 90° [6].

For the total reactance value of the TCSC, the equivalent reactance of the modules are added. As each module is controlled separately, the unavailable band around zero can be covered [7]. Thus, the TCSC is modeled as variable reactance $\mathbf{X}_{\mathbf{TCSC}}$ with a lower bound $\underline{\mathbf{X}}_{\mathbf{TCSC}}$ and an upper bound $\overline{\mathbf{X}}_{\mathbf{TCSC}}$ connected in series with a line.

The allowed degree of compensation of the line reactance gives rise to additional limitations. In accordance with [8], the compensation range is set to 20% inductive and 80% capacitive. Therefore, this simplification is justified and the TCSC is incorporated into the load flow calculations by setting the total line reactance to

$$X_{Total} = X + X_{TCSC} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (7)$$

and accounting for the limitations by

$$\max(\underline{X}_{TCSC}, -0.8 * X) \leq X_{TCSC} \leq \min(\overline{X}_{TCSC}, 0.2 * X).$$

III SIMULATIONS AND RESULTS

The modified IEEE 14 bus system with SVC and TCSC FACTS devices power flow result.

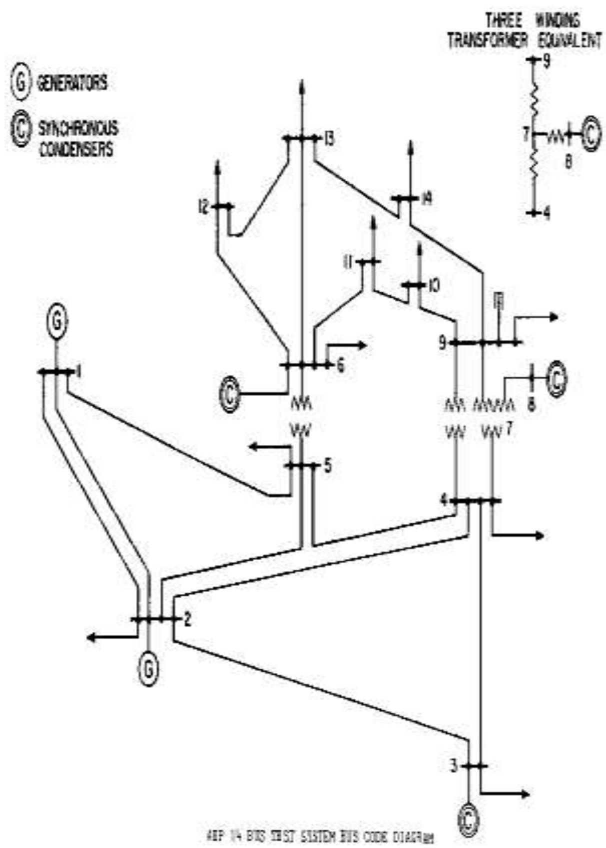

Fig. 9 IEEE 14 bus system [11]

Modified IEEE14 bus system have 2 generator, 3 condensers, 20 transmission line and 326 MW load.

Table 1 Power flow result of modified IEEE14 bus system without FACTS.

Bus NO.	Voltage		Generation		Load	
	Vm (p.u.)	Va (deg.)	P (MW)	Q (MW)	P (MW)	Q (MW)
1	1.060	0.000	312..33	-	-	-
				20.99		
2	1.045	-6.71	40.00	79.25	21.70	12.70
3	1.010	-15.68	0.00	37.76	94.20	19.00
4	0.996	-13.88	-	-	47.80	-3.90
5	1.001	-12.07	-	-	7.60	1.60
6	1.070	-21.62	0.00	53.58	11.20	7.50
7	1.027	-20.01	-	-	-	-
8	1.090	-20.01	0.00	38.98	-	-
9	0.997	-23.29	-	-	39.50	30.00
10	0.987	-24.19	-	-	36.00	15.80
11	1.023	-22.99	-	-	3.50	1.80
12	1.044	-22.86	-	-	6.10	1.60
13	1.025	-23.08	-	-	13.50	5.80
14	0.932	-26.24	-	-	44.90	25.00
	Total		352.3	188.5	326.0	116.9

Table 2 Bus voltages with and without SVC

Bus No.	Voltage (p.u.)	
	Without SVC	With SVC
1	1.060	1.060
2	1.045	1.045
3	1.010	1.010
4	0.996	1.004
5	1.001	1.007
6	1.070	1.070
7	1.027	1.053
8	1.090	1.090
9	0.997	1.049
10	0.987	1.031
11	1.023	1.046
12	1.044	1.062
13	1.025	1.060
14	0.932	1.089

After connecting SVC at bus 14 the voltage profile of bus no. 4, 9, 10 and 14 improved by SVC FACTS devices. Also the total losses of system are reduced.

Table 3 Active Power Flow with and without TCSC

Branch	Bus	P flow without TCSC (MW)	P flow with TCSC (MW)

1	1-2	209.49	187.36
2	1-5	102.84	124.72
3	2-3	84.25	80.73
4	2-4	76.49	69.24
5	2-5	59.34	49.53
6	3-4	13.25	16.60
7	4-5	71.86	81.55
8	4-7	53.34	52.97
9	4-9	30.11	29.91
10	5-6	75.66	76.25
11	6-11	20.48	20.85
12	6-12	12.00	12.04
13	6-13	31.97	32.15
14	7-8	0.00	0.00
15	7-9	53.34	52.97
16	9-10	20.03	19.67
17	9-14	23.91	23.70
18	10-11	16.44	16.80
19	12-13	5.72	5.76
20	13-14	23.26	23.48

The TCSC is series device which control the power flow of TCSC connected line. The Active power flow of branch 2 without TCSC is 102.84 MW. After connecting TCSC between bus 1 and bus 5 or branch 2 the Active power flow increased 124.72 MW.

Table 4 Total line losses with and without FACTS for modified IEEE14 bus system

	Total line losses	
	P (MW)	Q(MVAR)
Without FACTS	26.330	114.72
With SVC	26.054	111.19
With TCSC	26.082	106.85

IV CONCUSIONS

The voltage profile of weak bus is improved after incorporating of SVC.
The active power flow of line is increases and total losses of system is reduces after incorporating TCSC.
The FACTS devices are improve voltage Profile of the system.

V REFERENCES

[1] C. W. Taylor, Reactive Power Compensation and Voltage Stability: Removing Transmission Limitations. Carson Taylor Seminars, 1989.
[2] Proceedings**:** Bulk Power System Voltage Phenomena-Voltage Stability and Security, EPRI EL-6183, Project 2473-21, Electric Power Research Institute, January 1989.
[3] N. G. Hingorani and L. Gyugyi, *Understanding FACTS concepts and technology of flexible AC transmission systems*. New York: IEEE Press, 2000.
[4] H. Ambriz-Perez, E. Acha, and C. R. Fuerte-Esquivel, "Advanced SVC models for Newton-Raphson load flow and Newton optimal power flow studies," *Power Systems, IEEE Transactions on*, vol. 15, pp. 129-136, 2000.
[5] E. V. Larsen, K. Clark, S. A. Miske, Jr., and J. Urbanek, "Characteristics and rating considerations of thyristor controlled series compensation," *Power Delivery, IEEE Transactions on*, vol. 9, pp. 992-1000, 1994.
[6] T. Orfanogianni, "A flexible software environment for steady-state power flow optimization with series FACTS devices." Diss. ETH Zurich, 2000, pp. 135 S.
[7] E. V. Larsen, K. Clark, S. A. Miske, Jr., and J. Urbanek, "Characteristics and rating considerations of thyristor controlled series compensation," *Power Delivery, IEEE Transactions on*, vol. 9, pp. 992-1000, 1994.
[8] A. Oudalov, "Coordinated control of multiple FACTS devices in an electric power system." Diss. EPF Lausanne, 2003, pp. 190.
[9] M. Noroozian, 6. Andersson, ‘‘Power Flow Control by Use of Controllable Series Components“, IEEE Transactionson Power Delivery, vol. 8, no. 3, pages 1420-1429, July 1993.
[10] M. Noroozian, L. Angquist, M. Ghandhari, and G. Andersson, “Use of UPFC for Optimal Power Flow Control,” IEEE Transactions on Power Delivery, vol. 12, no. 4, pp. 1629-1634, October 1997.
[11] K.Narasimha Rao, J.Amarnath, A.Girivardhana Kumar, “Voltage Constrained Available Transfer Capability Enhancement with FACTS Devices” ARPN JOURNAL OF ENGG.& SCIENCE, VOL. 2,NO. 6,PP.1-9, DEC 2007.