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Voltage Profile Improvement in Power System Using Series and Shunt Type FACTS Controller

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Abstract: ***In recent years, much attention has been attracted to the problems of voltage quality for the electrical power systems. Because of continuous increase of power demands and large scale system interaction as well as the consideration of both the economic benefit and the environment protection, modern power system are operated more and more close to the their maximum operating conditions. As a consequence, some transmission lines are heavily loaded and the system stability becomes a power transfer-limiting factor. In these days, voltage of the system can be control in many ways and the latest technology by using power electronic device that we call as FACTS-devices. Flexible Ac Transmission System (FACTS) devices are the option to mitigate voltage instability by reactive power flow and voltage control criteria. It has lot of configuration like series, shunt etc. TCSC is series type and STATCOM is shunt type controller. In this paper both the devices are compared for voltage stability enhancement.***

Keywords: Voltage Stability, FACTS, TCSC, STATCOM, Voltage Control, CPF analysis.

1. Introduction

Power Generation and Transmission is a complex process, requiring the working of many components of the power system in tandem to maximize the output. One of the main components to form a major part is the reactive power in the system. It is required to maintain the voltage to deliver the active power through the lines. Loads like motor loads and other loads require reactive power for their operation. To improve the performance of ac power systems, we need to manage this reactive power in an efficient way and this is known as reactive power compensation which is efficiently controlled by FACTS controller.

Flexible AC Transmission Systems (FACTS) can provide benefits in increasing system transmission capacity and power flow control flexibility and speed. FACTS are basically power electronics equipment which is very useful for increasing transmission capacity in the power system and have capacity to control several parameters in transmission network. These types of devices can enhance the stability of power system network and can support voltage with better controllability of their parameters such as impedance, current, phase angle and voltage. They have ability to operate fast and effective manner to control the voltage magnitude and phase angle at chosen buses. FACTS devices include Thyristor Controlled Series Reactor (TCSC), Static Var Compensator (SVC), Unified Power Flow Controller (UPFC), and Static Compensator (STATCOM).

There are several types to connect the FACTS devices such as in series, shunt, or a combination of both series and shunt. Basically static VAR compensator (SVC) and static synchronous compensator (STATCOM) are shunt connected fact devices where as Thyristor Controlled Series Compensator (TCSC), Static Synchronous Series Compensator (SSSC) are series connected fact devices. FACTS controller improves the real power handling capacity of a line at a more economic cost than building other transmission line of the same as well as of higher capability. This paper focuses on STATCOM and TCSC FACTS controller. [1,2]

2. Voltage Stability

Voltage stability is the ability of a power system to maintain steady acceptable voltages at all buses in the system under normal operating conditions and after being subjected to a disturbance. Voltage instability is mainly occurs due to reactive power imbalance. The load ability of a bus in the power system depends on the reactive power support that the bus can receive from the system. A power system enters a state of voltage instability when a disturbance, increase in load demand power or change in system condition causes a progressive and uncontrollable decline in voltage. When the system approaches the maximum loading point or to the point of voltage collapse both real and reactive power losses increases rapidly. Therefore the reactive power supports has to be local and must be adequate to satisfy the requirement. Voltage instability leads to a shortage of reactive power and diminishing voltage. This phenomenon can be seen from the continuation power flow plot of the power transferred versus the voltage at receiving end. The plots are popularly referred to as PV curve or “nose” curve. Maximum load that the system can cater before reaching the nose point is called loading margin of the system. As the power transfer increases the voltage at the receiving end decreases. This eventually leads to the critical point at which the system reactive power is low in power supply. Any further increase in active power transfer will always lead to rapid decrease in voltage magnitude. Before reaching the critical point, the large voltage drop takes place due to more reactive power losses. At this condition, only way to save the system from voltage collapse is by reducing the reactive power load demand or add additional reactive power. In practice reactive power is compensated at weak bus.[2-5]

3. Characteristic of TCSC and STATCOM

A. TCSC

A TCSC is a capacitive reactance compensator, which consists of a series capacitor bank shunted by a thyristor controlled reactor in order to provide a smoothly variable series capacitive reactance. TCSC is the type of series compensator. The structure of TCSC is capacitive bank and the thyrister controlled inductive brunch connected in parallel. The principle of TCSC is to compensate the transmission line in order to adjust the line impedance, increase load ability, and prevent the voltage collapse.

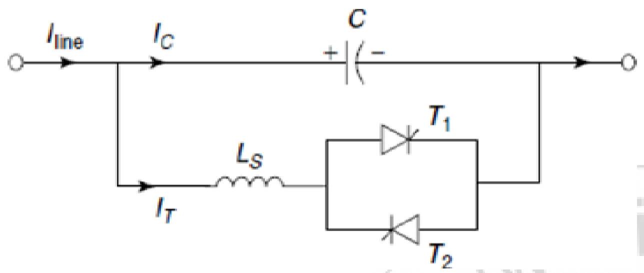

Figure 1: The basic TCSC module

The characteristic of the TCSC depends on the relative reactance of the capacitor bank and thyristor branch. Even through a TCSC in the normal operating range in mainly capacitive, but it can also be used in an inductive mode. The power flow over a transmission line can be increased by controlled series compensation with minimum risk of subsynchronous resonance (SSR) TCSC is a second generation FACTS controller, which controls the impedance of the line in which it is connected by varying the firing angle of the thyristors. A TCSC module comprises a series fixed capacitor that is connected in parallel to a thyristor controlled reactor (TCR). A TCR includes a pair of anti-parallel thyristors that are connected in series with an inductor. In a TCSC, a metal oxide varistor (MOV) along with a bypass breaker is connected in parallel to the fixed capacitor for overvoltage protection. A complete compensation system may be made up of several of these modules.[1]

B. STATCOM

The STATCOM is a FACTS controller based on voltage sourced converter (VSC). A VSC generate a synchronous voltage of fundamental frequency, controllable magnitude and phase angle. If a VSC is shunt-connected to a system via a coupling transformer as shown in Figure 2, the resulting STATCOM can inject or absorb reactive power to or from the bus to which it is connected and thus regulate the bus voltage magnitude. STATCOM provides reactive power support even during at very low voltages unlike SVC.

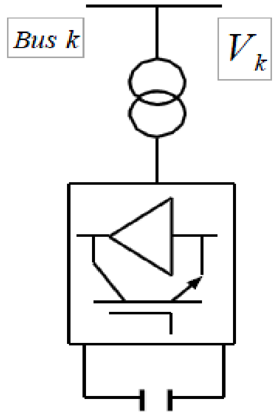

Figure 2: Steady State Model of STATCOM

STATCOM has no long term energy support on the dc side and it cannot exchange real power with the ac system. In the transmission systems, STATCOMs primarily handle only fundamental reactive power exchange and provide voltage support to buses by modulating bus voltages during dynamic disturbances in order to provide better transient characteristics, improve the transient stability margins and to damp out the system oscillations due to these disturbances.[1]

4. Test System Simulation

This section will discuss about the test system that is used to analyze the work in purpose of studying the effect of TCSC and SVC in increasing the voltage stability of the system and its optimal location. IEEE 9 bus system is use in the project simulation and it is done by using Power System Analysis Toolbox (PSAT). Several steps have been achieved the objectives, the step that had been recognized were:

(a) Modeling the system by using PSAT[6 7].
(b) Perform the congested case.
(c) Perform the power flow analysis to analyze the Performance of the system.
(d) Perform the CPF and draw PV curve to determine weak bus of the system. SVC is placed at this bus.
(e) Identify the suitable line to place TCSC so it gives optimal Performance.

Simulation model of IEEE 9 bus system is shown in Figure 3, while the data of test system is shown in Table I to Table III.

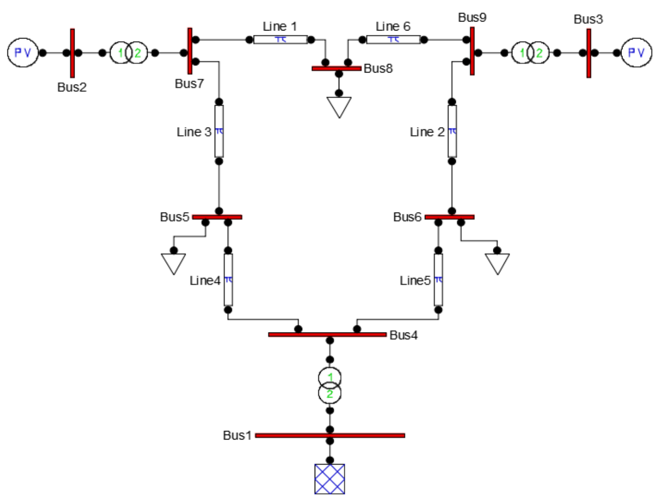

Figure 3: IEEE – 9 Bus Systems

Table 1: Bus Data of IEEE – 9 Bus System

Bus No.	*Bus Type*	*Voltage Magnitude (pu)*	*Phase Angle (rad)*	*Active Power (pu)*	*Active Power (pu)*
1	Slack	1.04	0.00	0.80	-
2	PV	1.025	-	1.63	-
3	PV	1.025	-	0.85	-
5	PQ	-	-	1.87	0.75
6	PQ	-	-	2.70	0.90
8	PQ	-	-	1.00	0.35

Table 2: Transformer Data of IEEE – 9 Bus Systems

Line	S(MVA)	V(KV)	KV /KV	R (pu)	X (pu)
1 – 4	100	16.5	16.5 /230	0.00	0.0576
2 – 7	100	18	18 / 230	0.00	0.0625
3 – 9	100	13.8	13.8 /230	0.00	0.0586

Table 3: Transmission Line Data of IEEE – 9 Bus System

Line No.	From Bus – To Bus	Resistance R (pu)	Reactance X (pu)	Susceptance B (pu)
1	7 – 8	0.0085	0.072	0.149
2	6 – 9	0.039	0.170	0.358
3	5 – 7	0.032	0.161	0.306
4	4 – 5	0.01	0.085	0.176
5	4 – 6	0.017	0.092	0.158
6	8 – 9	0.0119	0.1008	0.209

5. Result and Discussion

This section will tabulate and discuss the result implemented. The discussion on IEEE-9 bus system will be focused on how to determine the optimal location of TCSC in power system.

A. Weak Bus Identification

Weak bus is defined as the bus which is near to experience a voltage collapse. The weakest bus is one that has a large ratio of differential change in voltage to differential change in load. Usually, placing adequate reactive power support at the weakest bus enhances static voltage stability margins. Changes in voltage at each bus for a given change in system load are available from the tangent vector, which can be readily obtained from the predictor steps in the CPF process. CPF is run for all construing limits such as voltage control, flow control, reactive power generation limit. [7,8,9]. The optimal location of TCSC and SVC can be achieved by determining the weakest voltage bus of the system. This can be done by continuation power flow analysis, The P-V curve plotted from continues power flow analysis can be use to determine the weakest bus of the system. Figure 4 shows the P-V curve of IEEE - 9 Bus systems.

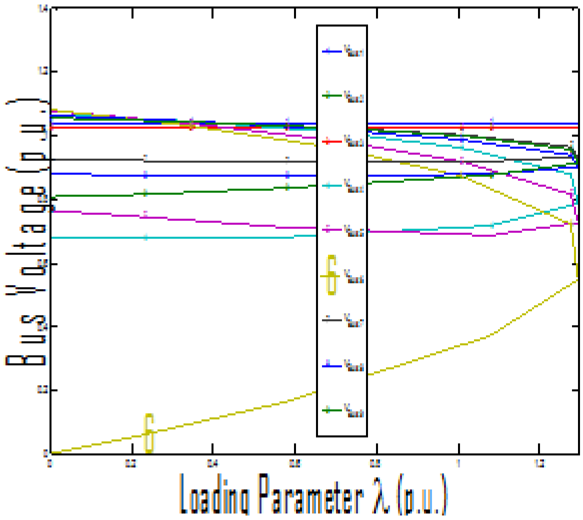

Figure 4: P-V curve of IEEE - 9 Bus system

From figure 4, P-V curve of bus -6 voltage (yellow color) is the weakest bus among all the buses of the system.

B. Optimal Location of TCSC

Most of the weakest bus has more than one transmission line connected to it. These cause difficulties in choosing the best line to install TCSC. It has been proposed that TCSC should be placed at the line which gives smaller results in power system losses. The result of bus 6 voltage and total losses of IEEE 9 bus system with and without using TCSC series compensation is shown in Table.

Sr. No.	Location of TCSC		Bus – 6 Voltage (pu)	Total Losses (pu)	
	Line	From bus To bus		Real Power	Reactive Power
1	No TCSC		0.5493	0.72267	6.10114
2	Line – 2	9-6	0.59088	0.6319	9.76354
3	Line – 5	6-4	0.664871	0.69945	10.0720

From above table best location of TCSC is on line 5 because it gives lowest power losses on the system when TCSC be install at that particular also it give better improvement in bus 6 voltage.

C. Optimal Location of STATCOM

Now STATCOM is connected at weak bus 6 to see its effect. Variation in bus 6 voltage and total losses of IEEE-9 bus system with placement of STATCOM is shown in following table.

Table 5: Variation in bus 6 voltage and total losses with placement of STATCOM

Sr. No.	Location of STAT-COM	Bus–6 Voltage (pu)	Total Losses (pu)	
			Real Power	Reactive Power
1	No STATCOM (Base Case)	0.5493	0.719539	6.466873
2	STATCOM at bus-6	0.86255	0.321788	2.584408

From table we can conclude that with placement of STATCOM at bus 6 give considerable improvement in bus-6 voltage as well as reduction in total system losses. Figure 5 shows that impact of TCSC and STATCOM on various bus voltages.

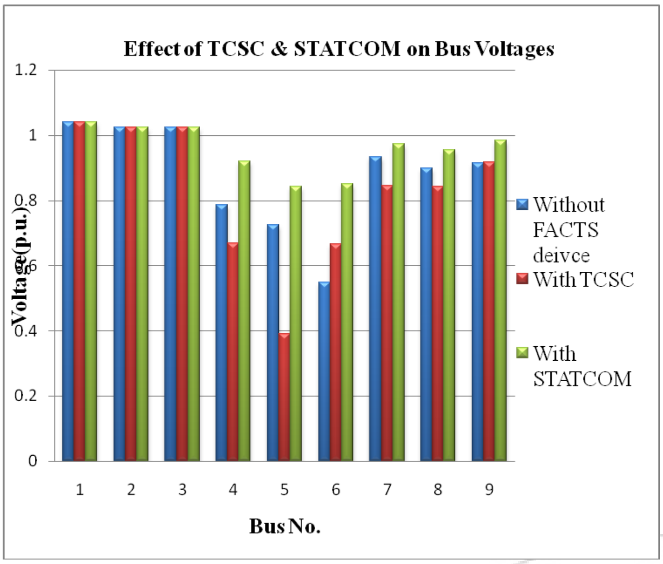

Figure 5: Effect of TCSC & STATCOM on Bus Voltages

6. Conclusion

Following conclusion are drawn from the work:

- Optimal placement of TCSC &STATCOM can give better result.
- TCSC and STATCOM improve voltage stability
- It also performs reliably under variable load condition.
- STATCOM give better result in comparison to TCSC as it gives better Voltage profile.

References

[1] Hingorani, N. G. and Gyugyi. L. (1999), Understanding FACTS: Concept and Technology of Flexible AC Transmission Systems. IEEE Press.

[2] Zhang, X.P., Rehtenz, C. and Pal, B. (2006). Flexible AC Transmission System: Modeling and Control. Verlag Berlin Heidelberg: Springer.

[3] B. GAO, G.K. Morison, P. Kundur, "Towards the development of a systematic approach for voltage stability assessment of large-scale power systems," IEEE Trans. Power Syst. 11, pp. 1314–1324, August 1996.

[4] C.A. Canizares A.C.Z. De Souza , V.H. Quintana, "Comparison of performance incises for detection of proximity to voltage collapse," IEEE Trans. Power Syst. 11, pp. 1441-1447, August 1996.

[5] B.H. Lee, K.Y. Lee, "A study on voltage collapse mechanism in electric power systems," EEE Transaction on Power System 6, pp. 966-974, August 1991.

[6] Federico Milano, An Open Source Power System Analysis Toolbox, IEEE Transactions on Power System, Vol. 20, No. 3, August 2005.

[7] www.uclm.edu/area/gsee/Web/Federico/psat.htm