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Comparison between STATCOM and TCSC on Static Voltage Stability Using MLP Index

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Abstract: Traditionally shunt and series compensation is used to maximize the transfer capability of a transmission line. By using FACTS controllers one can control the variables such as voltage magnitude and phase angle at chosen bus and line impedance. There are five well known FACTS devices utilized by the utilities for this purpose. These FACTS devices are Static Var Compensator (SVC), Static Synchronous Compensator (STATCOM), Thyristor Controlled Series Capacitor (TCSC), Static Synchronous Series Compensator (SSSC) and Unified Power Flow Controller (UPFC). The voltage collapse occurs when a system is loaded beyond its maximum loadability point. Many analysis methods have been proposed and currently used for the study of this problem. Most of these techniques are based on the identification of system equilibrium where the corresponding jacobians become singular. These equilibrium points are typically referred to as points of voltage collapse and can be mathematically associated to saddle-node bifurcation. The voltage collapse points are also known as maximum loadability points.

Keywords: FACTS Devices; loadability; MLP; Voltage Stability

I. 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.

There are two aspects to the problem of reactive power compensation: load compensation and voltage support. Load compensation consists of improvement in power factor, balancing of real power drawn from the supply, better voltage regulation, etc. of large fluctuating loads. Voltage support consists of reduction of voltage fluctuation at a given terminal of the transmission line. Two types of compensation can be used: series and shunt compensation. These modify the parameters of the system to give enhanced VAR compensation. In recent years, static VAR compensators like the STATCOM have been developed. These quite satisfactorily do the job of absorbing or generating reactive power with a faster time response and come under Flexible AC Transmission Systems (FACTS). This allows an increase in transfer of apparent power through a transmission line, and much better stability by the adjustment of parameters that govern the power system.

By using FACTS controllers one can control the variables such as voltage magnitude and phase angle at chosen bus and line impedance. There are five well known FACTS devices utilized by the utilities for this purpose. These FACTS devices are Static Var Compensator (SVC), Static Synchronous Compensator (STATCOM), Thyristor-Controlled Series Capacitor (TCSC), Static Synchronous Series Compensator (SSSC) and Unified Power Flow Controller (UPFC). Each of them has its-own characteristics and limitations.

II MAXIMUM LOADING POINT

The voltage collapse occurs when a system is loaded beyond its maximum loadability point. All voltage stability studies carried out for the proposed studies consist on obtaining the maximum loadability margin and the voltage profiles for the given system considering critical contingencies, which is a typical procedure for voltage stability and transfer capability studies in power systems. Many analysis methods have been proposed and currently used for the study of this problem. Most of these techniques are based on the identification of system equilibrium where the corresponding jacobians become singular. These equilibrium points are typically referred to as points of voltage collapse and can be mathematically associated to saddle-node bifurcation. The voltage collapse points are also known as maximum loadability points.

Voltage instability is mainly associated with 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. As the system approaches the maximum loading point or voltage collapse point, both real and reactive power losses increase rapidly. Therefore, the reactive power supports have to be local and adequate. Usually, placing adequate reactive power support at the "weakest bus" enhances static-voltage stability margins. The weakest bus is defined as the bus, which is nearest to experiencing a voltage collapse. Equivalently, the weakest bus is one that has a large ratio of differential change in voltage to differential change in load (dV/dP_{Total}).

In static voltage stability, slowly developing changes in the power system occur that eventually lead to a shortage of reactive power and declining voltage. This phenomenon can be seen from the plot of the power transferred versus the voltage at receiving end. The plots are popularly referred to as P-V curve or "Nose" curve. As the power transfer increases, the voltage at the receiving end decreases. Eventually, the critical (nose) point, the point at which the system reactive power is short in supply, is reached where any further increase in active power transfer will lead to very rapid decrease in voltage magnitude. Before reaching the critical point, the large voltage drop due to heavy reactive power losses can be observed. The only way to save the system from voltage collapse is to reduce the reactive power load or add additional reactive power prior to reaching the point of voltage collapse

III STATCOM AND TCSC

A.STATCOM

STATCOM is a shunt connected device, which controls the voltage at the connected bus to the reference value by adjusting voltage and angle of internal voltage source. STATCOM is the Voltage-Source Inverter (VSI), which converts a DC input voltage into AC output voltage in order to compensate the active and reactive power needed by the system STATCOM exhibits constant current characteristics when the voltage is low/high under/over the limit. This allows STATCOM to delivers constant reactive power at the limits compared to SVC. One of the many devices under the FACTS family, a STATCOM is a regulating device which can be used to regulate the flow of reactive power in the system independent of other system parameters. 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.

B.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 loadability, and prevent the voltage collapse. 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

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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.

IV. RESULTS AND DISCUSSION

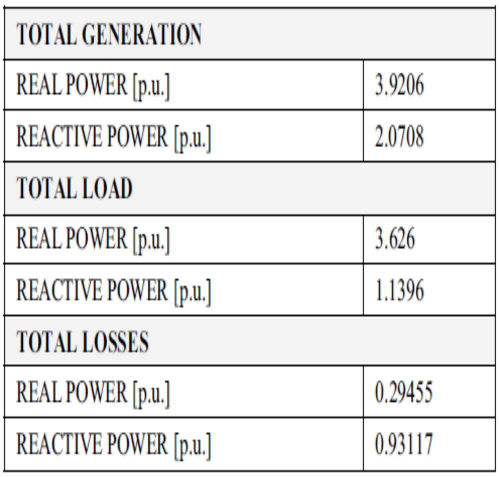
A 14-bus test system as shown in Figure 8 is used for voltage stability studies. PSAT [10] is power system analysis software, which has many features including power flow and continuation power flow. Using continuation power flow feature of PSAT, voltage stability of the test system is investigated. The behaviour of the test system with and without FACTS devices under different loading conditions is studied.

The MLP index that is described in section 2 is used to compare the effects of the FACTS devices in static voltage stability. Voltage stability studies are performed from an initial base load case. The load has been increased gradually to an extent. STATCOM is connected in parallel to the middle of the transmission line to regulate the voltage at chosen point by controlling the reactive power injection at that location based on the voltage-current curve of STATCOM. Their steady-state model can be obtained from their V-I characteristics. At capacitive limit STATCOM injects a fixed reactive power. At inductive limit STATCOM absorbs a fixed reactive power. These devices can be effectively utilized if located at the most critical transmission line.

TCSC is injected in a transmission line through a transformer connected in series with the system. The principle of TCSC is to compensate the transmission line in order to adjust the line impedance, increase loadability, and prevent the voltage collapse. 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) .

The conception of total power generated and losses are presented in table I. By applying the CPF for this test system, both voltage profiles in each bus and power flow in each line will change. In this system total generation, total power and total losses in MLP are shown in table II. According to this table, it can be seen that the capacity of CPF is more than that of the previous mode.

Table 1. Total power calculated after pf without FACTS



TOTAL GENERATION	
REAL POWER [p.u.]	3.9206
REACTIVE POWER [p.u.]	2.0708
TOTAL LOAD	
REAL POWER [p.u.]	3.626
REACTIVE POWER [p.u.]	1.1396
TOTAL LOSSES	
REAL POWER [p.u.]	0.29455
REACTIVE POWER [p.u.]	0.93117

From the CPF results which are shown in the Figure 3, the buses 4, 5, 9 and 14 are the critical buses. Among these buses, bus 14 has the weakest voltage profile and thus we improved its profile with FACTS devices. Maximum loading point (MLP) or bifurcation point where the Jacobian matrix becomes singular occurs at $\lambda_{max} = 2.7699$p.u

Table .2: Total power calculated in MLP without FACTS

TOTAL GENERATION	
REAL POWER [p.u.]	15.6114
REACTIVE POWER [p.u.]	25.4822
TOTAL LOAD	
REAL POWER [p.u.]	10.0438
REACTIVE POWER [p.u.]	3.1566
TOTAL LOSSES	
REAL POWER [p.u.]	5.5676
REACTIVE POWER [p.u.]	22.3256

The best location for shunt reactive power compensation, as far as the improvement of static voltage stability margin is concerned, is the weakest bus of the system. The weakest bus of the system can be identified using tangent vector analysis as presented in [7]. Introducing shunt compensation devices at this bus will improve the MLP the most. In this simulation, bus 14 is the weakest of the system, introducing STATCOM in this bus will increase the MLP to the maximum value. In order to get a rough estimate of reactive power support needed at the weakest bus and corresponding MLP, a synchronous compensator with no limit on reactive power was used at the weakest bus.

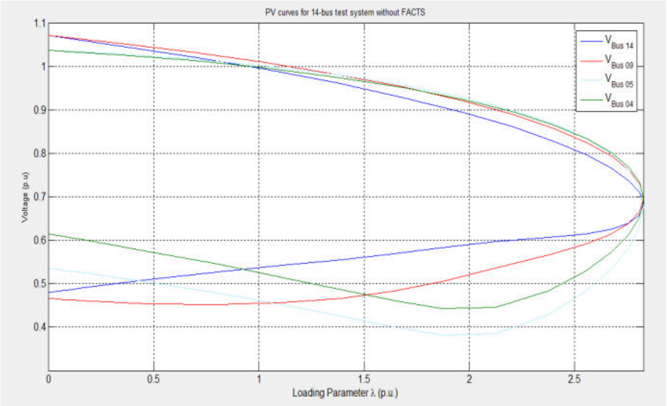


Figure 3: PV curves for 14-bus test system without FACTS

In table III the results of total power for STATCOM and TCSC. According to the above table, total losses in MLP with TCSC are less than other devices and the real power generation in MLP with STATCOM is more than that of other devices. The values of λ_{max} of STATCOM and TCSC are compared in Figure 6. Figure shows that STATCOM has suitable result and is better than TCSC.

TOTAL GENERATION	STATCOM	TCSC
REAL POWER [p.u.]	16.5582	15.8081
REACTIVE POWER [p.u.]	26.5901	25.9616
TOTAL LOAD		
REAL POWER [p.u.]	10.3359	10.1648
REACTIVE POWER [p.u.]	2.0603	3.1946
TOTAL LOSSES		
REAL POWER [p.u.]	6.2223	5.6433
REACTIVE POWER [p.u.]	24.5298	22.767

Table 3: The result of total power calculated in MLP with various FACTS device

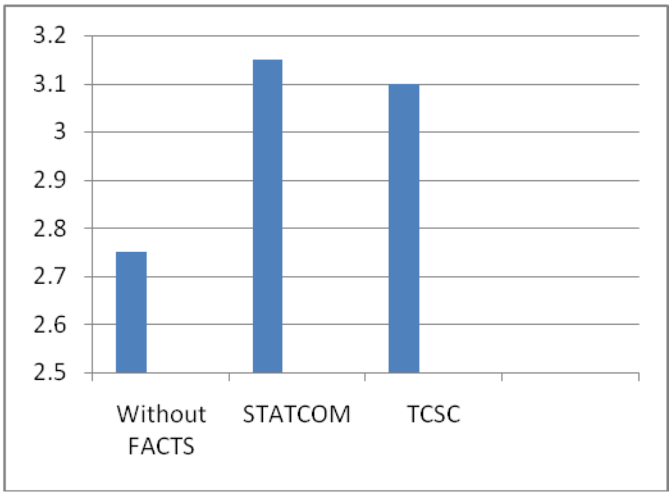


Figure 5: MLP in STATCOM and TCSC

In IEEE 14-bus test system, shunt compensation device provides a higher MLP and a better voltage regulation compared to series compensation device. Shunt compensation device injects the reactive power at the connected bus but series compensation device inserts the reactive power at the connected line. The test system needs reactive power at the load bus more than the line. The weakest bus (bus 14) of the system is located at the load area and it requires reactive power the most. Introducing reactive power at bus 14 or in its vicinity can improve voltage stability margin.

To analyze of static voltage stability to survey contingencies of power system with Psat software. The continuation power flow for normal system manner is done that all generation units and lines are in the network and in fact no contingencies has occurred in system. Maximum Loading Point is $\lambda_{max} = 2.97$ *p.u.*

Table 4: MLP and Bus Voltage in case of contingencies without STATCOM

GENERATION UNIT OUTAGE	BUS WITH LOWEST VOLTAGE MAGNITUDE	LOWEST VOLTAGE MAGNITUDE	MAXIMUM LOADING POINT
BUS 2	5	0.7282	2.2
BUS 3	3	0.6235	1.8
BUS 6	14	0.5283	1.6
BUS 8	9	0.5913	2.2

Table 4: MLP and Bus Voltage in case of contingencies with STATCOM

GENERATION UNIT OUTAGE	BUS WITH LOWEST VOLTAGE MAGNITUDE	LOWEST VOLTAGE MAGNITUDE	MAXIMUM LOADING POINT
BUS 2	14	0.9622	2.4
BUS 3	14	0.9537	2.0
BUS 6	4	0.9853	2.6
BUS 8	3	0.9932	2.3

VI. CONCLUSION

Static voltage stability assessment of the IEEE 14-bus test system with parallels and series FACTS devices using MLP index is studied. Using the continuation power flow with accurate model of the FACTS controllers the study was performed for test system. It is found that these controllers significantly increase the loadability margin of power systems. Parallel FACTS devices provide higher voltage stability margin than series FACTS devices. The test system requires reactive power the most at the weakest bus, which is located in the distribution level. Introducing reactive power at this bus using STATCOM can improve loading margin the most. TCSC on the other hand, are series compensation devices, which inject reactive power through the connected line. This may not be effective when the system required reactive power at the load level. In case of contingencies, STATCOM provides reactive power support and MLP and bus Voltage is higher than in the case of no STATCOM.

REFERENCES

[1] V. Ajjarapu and C. Christy, "*The continuation power flow: a tool for steady state voltage stability analysis*, "IEEE Transactions on Power Systems, vol.7, no. 1, pp. 416–423, 1992

[2] R. Natesan and G. Radman, "*Effects of STATCOM, SSSC and UPFC on Voltage Stability*," Proceedings of the system theory thirty- Sixth southeastern symposium, 2004, pp. 546-550.

[3] N. Talebi, M. Ehsan, S.M.T Bathaee, *"Effects of SVC and TCSC Control Strategies on Static Voltage Collapse Phenomena,"* IEEE Proceedings, Southeast Con, Mar 2004, pp. 161 – 168. [4] A. Kazemi, V. Vahidinasab and A. Mosallanejad, *" Study of STATCOM and UPFC Controllers for Voltage Stability Evaluated by Saddle-Node Bifurcation Analysis,"* First International Power and Energy Coference PECon/IEEE, Putrajaya, Malaysia, November 28-29, 2006, pp. 191-195.

[5] Arthit Sode-Yome, Nadarajah Mithulananthan and Kwang Y. Lee, *"Static Voltage Stability Margin Enhancement Using STATCOM, TCSC and SSSC,"* IEEE/PES Transmission and Distribution Conference & Exhibition, Asia and pacific, Dalian Chine, 2005,pp. 1-6.

[6] C. A. Cañizares, C. Cavallo, M. Pozzi, and S. Corsi, *"Comparing Secondary Voltage Regulation and Shunt Compensation for Improving Voltage Stability and Transfer Capability in the Italian Power System,"* Electric Power Systems Research, Vol. 73, No. 1, pp 67-76, January ,2005.