Result Analysis of Voltage profile and Real Power Losses in IEEE-9 Bus System Using FACTS Devices with Different Loading Condition

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Abstract - **This paper contains the result analysis of voltage profile, real power losses in IEEE 9 Bus System Using FACTS device like TCSC and SVC with different loading condition.. Voltage stability is the ability of a power system to maintain steady state voltages at all buses in the system under normal operating conditions and after being subjected to a disturbance. This paper present the analysis of voltage profile and real power losses improving by using TCSC and SVC in power system for IEEE standard 9 bus test system by using different types of loading to change the value of active and reactive power.**

Keywords - **Voltage Stability, FACTS Devices, TCSC, SVC, Voltage profile, Real power losses, Different loading condition.**
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I. INTRODUCTION

FACTS devices play a vital role in Power Generation and Transmission. It is very complex process, requiring the working of many components of the power system to maximize the output. One of the main components in transmission line is the reactive power in the system. Inductive type's load which absorb the reactive power in the system.so It is required to compensate the voltage to deliver the active power through the lines. Loads like inductive loads and other loads require reactive power for their operation. To improve the performance of ac power systems, we need to control this reactive power in an efficient way and this is known as reactive power compensation which is efficiently controlled by using different 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 various parameters in transmission system. These types of devices can enhance the stability of power system and can support voltage with better controllability of their parameters such as impedance, current, phase angle and voltage. They have ability to control the voltage magnitude and phase angle at specified buses. FACTS devices consist Thyristor Controlled Series Reactor (TCSC), Static Var Compensator (SVC), Unified Power Flow Controller (UPFC), and Static Compensator (STATCOM). [1,2]

There are various types of 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 whereas Thyristor Controlled Series Compensator (TCSC), Static Synchronous Series Compensator (SSSC) is series connected fact devices. FACTS controller improves the real power handling capacity, voltage profile 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 SVC and TCSC FACTS controller. [3,4]

II. CHARACTERISTIC OF TCSC AND SVC

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. [5]
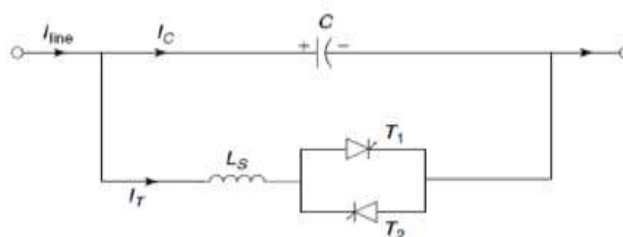

FIGURE.1 THE BASIC TCSC MODULE

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 sub synchronous 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 thyristor. 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 thyristor 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.[6,19]

B. SVC

The SVC uses conventional thyristor to achieve fast control of shunt-connected capacitors and reactors.The configuration the SVC is given in Fig. 2. 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.

Uses thyristor valves to rapidly add or remove shunt connected reactors and or capacitors often in co-ordination with mechanically controlled reactors and/or capacitors.

An SVC is typically made up of the following major components:
1. Coupling transformer
2. Thyristor valves
3. Reactors
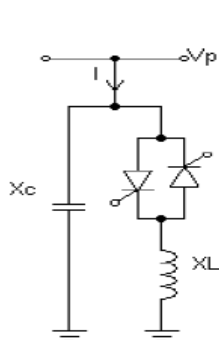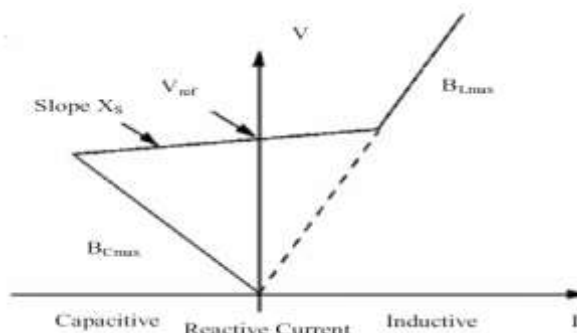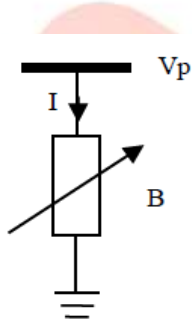4. Capacitors (often tuned for harmonic filtering) [7,19]

FIGURE.2 STRUCTURE OF SVC   FIGURE.3 SVC CONTROL SCHEME

III.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 Analysi s Toolbox (PSAT). Several steps have been achieved the objectives, the step that had been recognized were:
(a) Modeling the system by using PSAT
(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.[8,9]

Simulation model of IEEE 9 bus system is shown in Figure 4, while the data of test system is shown in Table I to Table III.
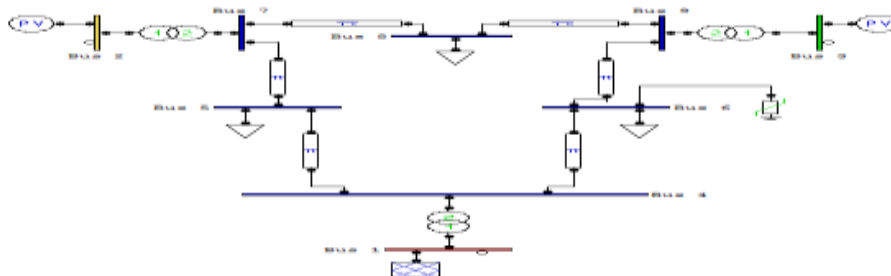

FIGURE.4 IEEE – 9 BUS SYSTEMS

TABLE I:- TRANSMISSION LINE DATA OF IEEE – 9 BUS SYSTEM

Bus No.	Bus Type	Voltage Magnitude (pu)	Phase Angle (rad)	Active Power (pu)	Reactive 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 II :- BUS 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

TABLE III:- 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

IV.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. [10,19]

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. [11,12]

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 5 shows the P-V curve of IEEE - 9 Bus systems. From figure 5, P-V curve of bus -6 voltages (yellow color) is the weakest bus among all the buses of the system. [13,14]
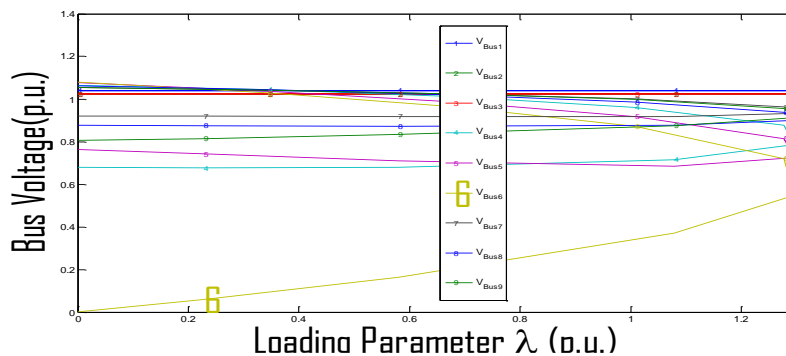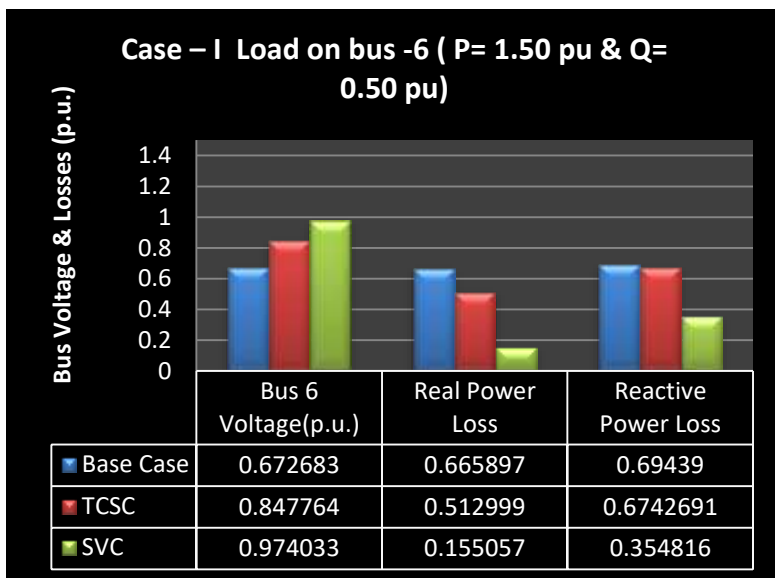

FIGURE.5 P-V CURVE OF IEEE - 9 BUS SYSTEM

COMPARISON OF TCSC &SVC WITH DIFFERENT LOADING CONDITION

Case – I Load on bus -6 (P= 1.50 pu & Q= 0.50 pu) [9,19]
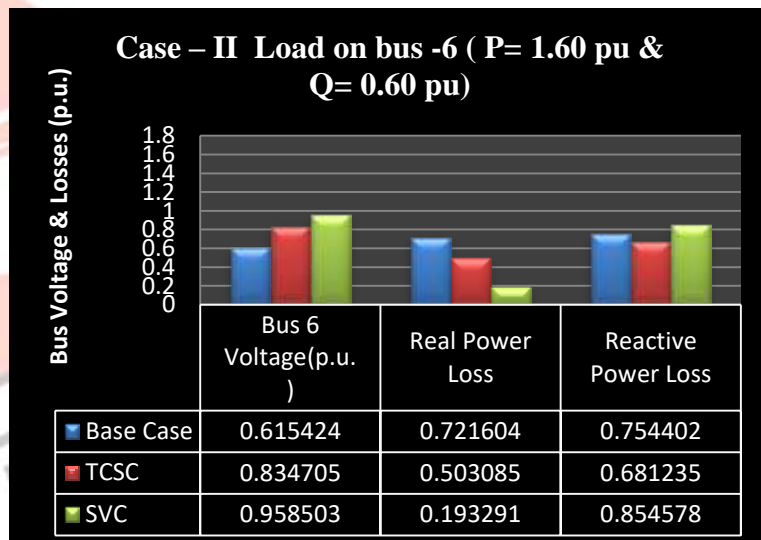**Variation in bus 6 voltage and total losses in case-I**

Sr. No.	Location of FACTS device	Bus–6 Voltage (pu)	Total Losses (pu)	
			Real Power	Reactive Power
1	Base case (No FACTS device)	0.672683	0.665897	0.694398
2	TCSC between Bus 6-9	0.847764	0.512999	0.674269
3	SVC at bus -6	0.974033	0.155057	0.354816

Case – I Load on bus -6 (P= 1.50 pu & Q= 0.50 pu)

Bus Voltage & Losses (p.u.)

	Bus 6 Voltage(p.u.)	Real Power Loss	Reactive Power Loss
Base Case	0.672683	0.665897	0.69439
TCSC	0.847764	0.512999	0.6742691
SVC	0.974033	0.155057	0.354816

Case – II Load on bus -6 (P= 1.60 pu & Q= 0.60 pu)
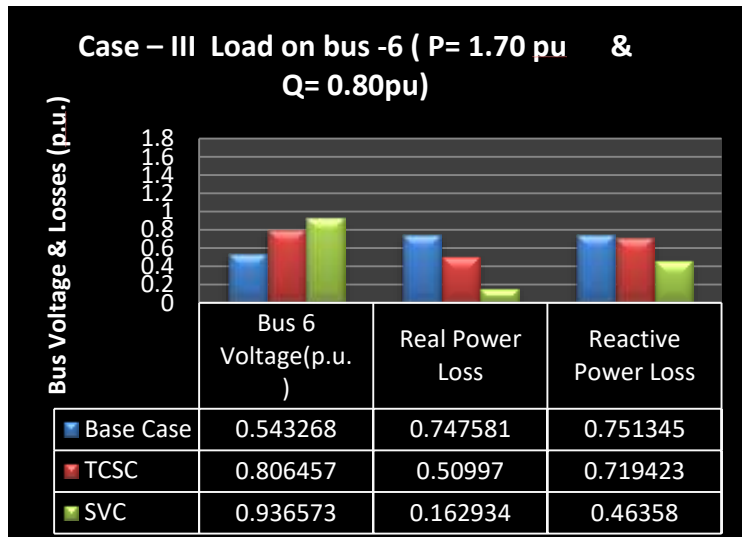**Variation in bus 6 voltage and total losses in case-II**

Sr. No.	Location of FACTS device	Bus–6 Voltage (pu)	Total Losses (pu)	
			Real Power	Reactive Power
1	Base case (No FACTS device)	0.615424	0.721604	0.754402
2	TCSC at line -2	0.834705	0.503085	0.681235
3	SVC at bus - 6	0.958503	0.193291	0.854578

Case – II Load on bus -6 (P= 1.60 pu & Q= 0.60 pu)

Bus Voltage & Losses (p.u.)

	Bus 6 Voltage(p.u.)	Real Power Loss	Reactive Power Loss
Base Case	0.615424	0.721604	0.754402
TCSC	0.834705	0.503085	0.681235
SVC	0.958503	0.193291	0.854578

Case – III Load on bus -6 (P= 1.70 pu & Q= 0.80 pu)
**Variation in bus 6 voltage and total losses in case-III**

Sr No.	Location of FACTS device	Bus-6 Voltage (pu)	Total Losses (pu)	
			Real Power	Reactive Power
1	Base case (No FACTS device)	0.543268	0.747581	0.751345
2	TCSC between Bus 6 - 9	0.806457	0.50997	0.719423
3	SVC at bus - 6	0.936573	0.162934	0.46358

Case – III Load on bus -6 (P= 1.70 pu & Q= 0.80pu)

Bus Voltage & Losses (p.u.)

	Bus 6 Voltage(p.u.)	Real Power Loss	Reactive Power Loss
Base Case	0.543268	0.747581	0.751345
TCSC	0.806457	0.50997	0.719423
SVC	0.936573	0.162934	0.46358

Case – IV Load on bus -6 (P= 1.90 pu & Q= 0.85 pu

Variation in bus 6 voltage and total losses in case-IV

Sr. No.	Location of FACTS device	Bus–6 Voltage (pu)	Total Losses (pu)	
			Real Power	Reactive Power
1	Base case (No FACTS device)	0.49174	0.81103	0.7848615
2	TCSC at line - 2	0.795261	0.50792	0.7375743
3	SVC at bus - 6	0.950207	0.144094	0.1493157

Case – IV Load on bus -6 (P= 1.90 pu & Q= 0.85pu)

	Bus 6 Voltage(p.u.)	Real Power Loss	Reactive Power Loss
Base Case	0.49174	0.81103	0.7848615
TCSC	0.795261	0.50792	0.7375743
SVC	0.950207	0.144094	0.1493157
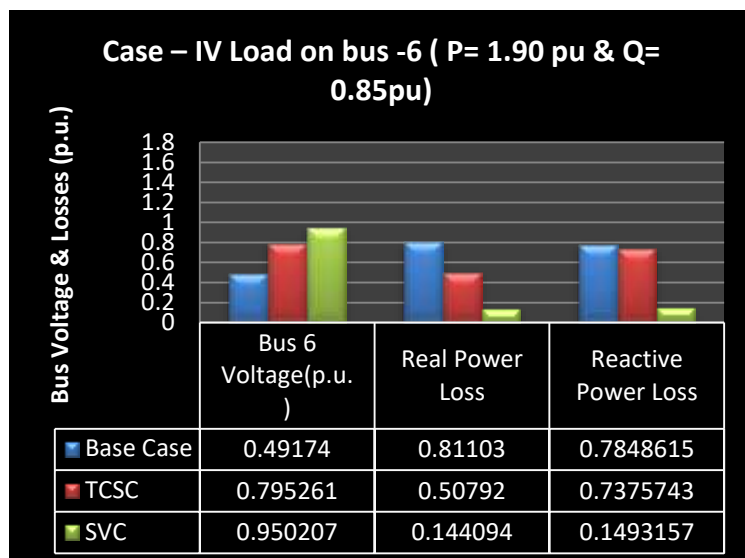
CONCLUSION

This paper conclude and present the review of TCSC and SVC FACTS devices which are used in transmission line for improve voltage profile and control voltage. It gives better result of real power losses and reactive power control. By changing the value of load bus means change in value active power and reactive power. Then we get better results of voltage profile and decrease in real power and reactive power losses.

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