Power Transmission Congestion Management Using Optimal Placement of Static VAR Compensator

Rahul Goyal, Shimpy Maheshwari

Abstract— **Power transmission congestion plays a major role for power crisis, because with transmission congestion power transmission capacity reduced so it is necessary to reduce the congestion issues in transmission system in order to maximum utilization as much as possible. This is achieved by applying flexible AC transmission system device (FACTS) for providing reactive power to compensate the transmission system. In this paper, simulation of IEEE 12 Bus model with static Var compensator (SVC) developed in the electrical transient analysis program (ETAP). Simulation on IEEE 12 Bus Transmission system is done to analysis the load flow study and safe & economic power transaction without congestion in stable transmission system environment. The performance of stable transmission system calculate by comparison of random placement and optimal placement of static Var compensator. The result obtained show that optimal placement of SVC is more economic than random placement of SVC to stable transmission system.**

Index Terms— **Transmission congestion, Static VAR compensator (SVC), Flexible AC Transmission System (FACTS), Electrical Transient Analysis Program (ETAP).**

1. INTRODUCTION

An increase in demand of power cause the transmission system more complex and it is more important to stable the transmission system to supply quality power without violate any parameter. The transmission system congest due to missmatch demand with transmission line supply capacity and to match the demand upto maximum capacity of transmission line, Reactive power is supply for the stable operation of system. In deregulated structure of power transmission, the congestion management involves precautionary as well as remedial action on system operator's part that a system operator allow only that set of transaction which taken together, keeps the transmission system within limit.

In real time, the transmission corridors may get overloaded due to unscheduled flow. The system operator use some remedies like use of FACTS devices. Identifying the location and size of the facts devices is very important to improve the power system efficiency to get more benefits. Static Var compensator (SVC) is member of facts family that is connected in shunt with the system. The primary purpose of shunt FACTS devices are to support bus voltage by injecting reactive power. They are also capable of improving the transient stability by increasing the power transfer capability. Shunt control SVC is more popular due to it's lower cost, voltage profile under different contingencies, transmission losses, maximum loading margin, stability.

The ability of interconnected transmission networks to reliable transfer electric power may be limited by thermal limit, voltage limit and stability limit. In order to consider all these parameter, SVC devices rating and quantity must be as minimum as necessary for stable transmission operation by optimal placement at bus bars. So that SVC's cost and thermal generation due to these devices are kept minimum as possible.

There are many approaches for optimal power flow available which include interior point methods. In the study, optimal power flow with SVC is solved by Newton Raphson method. This model is constructed in electrical transient analysis program for better and easy result formulation.

2. DESIGN MODEL FOR VARIOUS SYSTEM

The simulation model of the power flow in transmission system is test in electrical transient analysis program (ETAP) is shown in figure 1. The power delivered in each bus load at optimal capacity is set by static Var compensator to avoid congestion in transmission line. Optimal placement and rating SVC for the load flow analysis is done in the ETAP environment. The fact taken into account is voltage profile at buses and loss in transmission lines .

The model display by the ETAP shows voltage magnitude, power flow and transmission line loss. when transmission system is stable ,all buses colour code is in black, when system is marginally stable some of busses turns pink and red for completely unstable.

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Rahul Goyal, (M.tech Student), Department of Electrical Engineering, GZSCCET Bathinda, 151001, Punjab, India.

Shimpy Maheshwari, (Assistant Professor), Department of Electrical Engineering, GZSCCET Bathinda, 151001, Punjab, India.

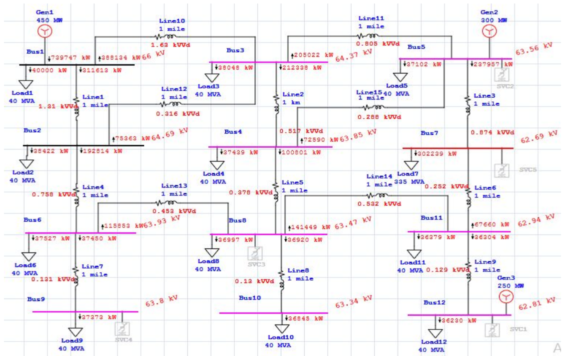

Fig.1: Model of IEEE12 bus transmission system

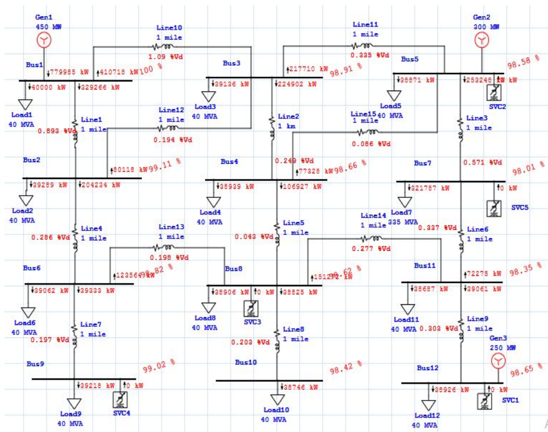

Fig.2: Model of IEEE12 bus transmission system with random placed svc

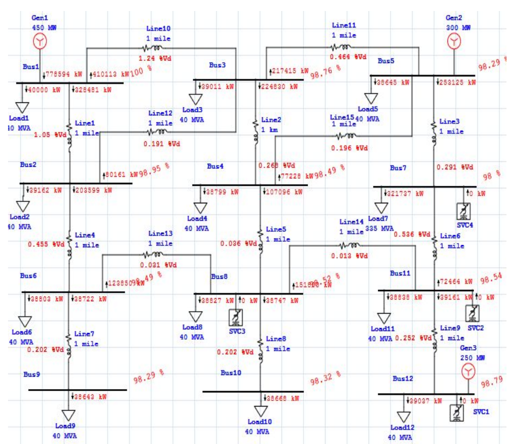

Fig.3: Model of IEEE12 bus transmission system with optimal placed svc

3. STATIC VAR COMPENSATOR

A static VAR compensator is a set of electrical devices for providing fast-acting reactive power on high-voltage electricity transmission networks. SVCs are part of the Flexible AC transmission system device family, regulating voltage, power factor, harmonics and stabilizing the system.

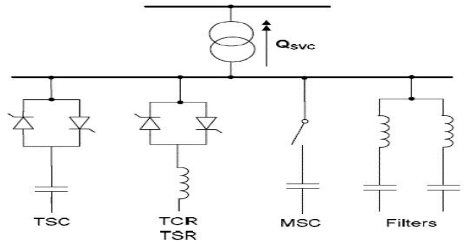

Fig.4. static var compensator

The equivalent circuit of SVC may be modeled as a shunt connected variable susceptance BSVC at bus-p is shown in fig.5.

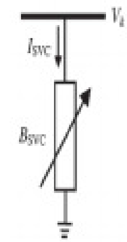

Fig.5. Variable shunt susceptance model

With reference to fig.1, the current drawn by the SVC is,

$$I_{SVC} = j\, B_{SVC}\, E_p \quad (1)$$

And the reactive power drawn by the SVC, which is also the reactive power injected at bus p, is

$$Q_{SVC} = Q_p = -E_p^2\, B_{SVC} \quad (2)$$

The equivalent susceptance BSVC is taken to be the state variable.

$$\begin{bmatrix} \Delta P_p \\ \Delta Q_p \end{bmatrix}^{(k)} = \begin{bmatrix} 0 & 0 \\ 0 & Q_p \end{bmatrix}^{(k)} \begin{bmatrix} \Delta \theta_k \\ \dfrac{\Delta B_{svc}}{B_{svc}} \end{bmatrix}^{(k)} \quad (3)$$

At the end of the iteratin (k), the variable shunt susceptance BSVC is updated according to

$$B_{svc}^{(k)} = B_{svc}^{(k-1)} + \left(\frac{\Delta B_{svc}}{B_{svc}}\right)^{(k)} B_{svc}^{(k-1)} \quad (4)$$

For constant active power flow and supply voltage Ep, the required capacitive VAR is the difference between the pre compensation VAR and the required compensated VAR as given in (2).

QSVC = QSVC – Q uncompensated

4. POWER SYSTEM STABILITY

The representation by colour code of the buses and the voltage display in figure help us to judge the stability of the system according to the IEEE -519 limits of stable voltage are shown as calculated. The system predicts it stability as soon as load flow analysis is done which is according to the percentage voltage values table 1 as shown.

Table 1 VALUES OF SYSTEM FOR STABILITY ANAYSIS

Alert	Critical (%)	Marginal (%)
Loading	100	95
Under voltage	105	102
Overvoltage	95	98

The system under load gets instable as the voltage dips at the voltage bus. The generator 1 is made the swing bus, whereas generator 2 and generator 3 are voltage control. Except at Bus 1 all other voltage buses voltage distorts on application of load. Bus 2-11 all are marginally unstable and bus -12 is completely unstable. Load flow of the system on applying load at each bus, the system gets unstable, the table.2 predicts the unstability .Pink colour shows the bus which is marginally unstable and the bus red in colour is critically unstable. To find the effects of load and power quality analysis techniques are employed. For each outage, all lines and voltages in the network are checked against their respective limits.

V. Simulation Results

The variation of voltage with respect to location of static var compensator at various buses can be represented in the form of graphs as under, which show the improvement in the actual voltage upon loading and after applying harmonic filter with and without the optimal placement .The improvement of voltages at the buses is shown in table 1 and improvement in branch losses is shown in table 2. These values are as generated by the load flow analysis in the ETAP environment. Also, the graphs predicted for the table are using MS excel for simplicity and clarity upon the results we get after improvement.

Table 2 Voltage Probile Before And After Improvement At Bus

Bus no	Voltage profile of transmission line		
	On load voltage without svc	Voltage with random placement of svc	Voltage with optimal placement of svc
1	66	66	66
2	64.69	65.41	65.3
3	64.37	65.28	65.18
4	63.85	65.12	65
5	63.56	65.06	64.87
6	63.93	65.22	65
7	62.69	64.69	64.68
8	63.47	65.09	65.03
9	63.8	65.35	64.87
10	63.34	64.96	64.89
11	62.94	64.91	65.03
12	62.81	65.11	65.02

The voltage profile is analysed and graph predicting the voltage is shown in figure 6 which is drawn with the static var compensator when applied and when not applied. results can be easily analyzed from the graphs.

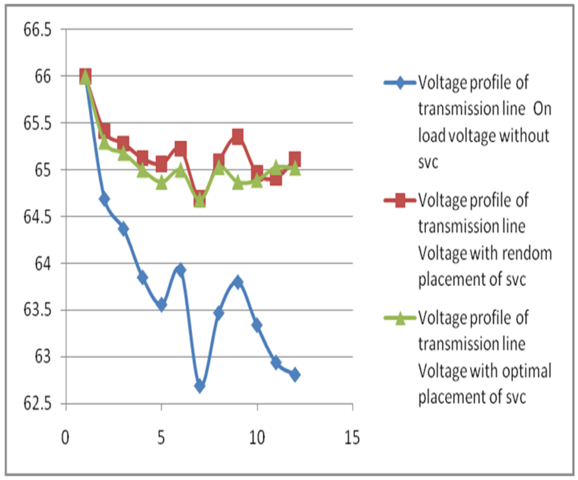

Fig.6: graph of voltage at each bus

Analysis of voltage at transmission lines is also analysed by load flow studies using ETAP .the values of voltage drop at each line is as shown in table 2. And also the change in voltage values upon improvement using the static var compensator in rendom and optimal placement.

Table 3 .Voltage Profile At Transmission Lines

Transmission line no	Voltage profile of transmission line		
	Voltage drop without svc	Voltage drop with random placed svc	Voltage drop with optimal placed svc
1	1.31	0.589	0.695
2	0.517	0.164	0.177
3	0.874	0.377	0.192
4	0.758	0.189	0.3
5	0.378	0.028	0.024
6	0.252	0.223	0.354
7	0.131	0.13	0.134
8	0.13	0.134	0.134
9	0.129	0.2	0.167
10	1.63	0.717	0.821
11	0.805	0.221	0.306
12	0.316	0.128	0.126
13	0.453	0.131	0.021
14	0.532	0.183	0.009
15	0.288	0.057	0.129

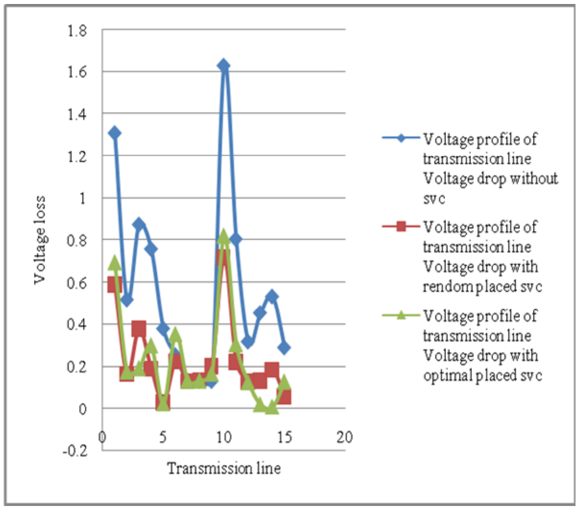

Fig.7: graph of voltage drop at transmission line

The voltage drop at transmission lines is shown in graph for analysis of the change on employing static var compensator. The graph fig.7 obtained is made from the values calculated using load flow analysis as shown in the above table3 and the graph is plotted using MS-excel so as to clearly check upon the values of voltage obtained after the placement of static var compensator.

Table 4 .SVC Rating & Number At Different Bus

Bus no	Rating in MVA	
	Random placement of svc	Optimal placement of svc
1	-	-
2	-	-
3	-	-
4	-	-
5	500	-
6	-	-
7	600	655
8	520	500
9	550	-
10	-	-
11	-	500
12	500	500

CONCLUSION

The load which distorts the system voltage is to be stabilized using static var compensator placement. The voltage which is marginally stable and unstable is stabilized using svc which is placed and tested using Load Flow Analysis in the Electrical Transient Analyzer Program (ETAP) software environment. Parameters of svc, sizing and location is done by keeping a check at the voltage profile through the Load Flow Analysis. Simulation is done on the system without and with optimal placement of svc which gives us desirable results.

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Rahul Goyal M.Tech (Power Engineering) student in GZS Campus Collage of Engineering & Technology, Bathinda has done B.Tech in Electrical Engineering from AIET, Faridkot in 2010.The author is doing research on her topic of master thesis,"Power Transmission Congestion Management Using SVC controller" under the guidance of co-author.

Shimpy Maheshwari is Assistant Professor in Electrical Engineering Department, GZS Campus Collage of Engineering & Technology constituent Collage of Maharaja Ranjit Singh State Technical University, Bathinda. The author received B.Tech (Electrical Engineering) in 2011, M.Tech (Power Engineering) in 2013 from GZS Campus Collage of Engineering and Technology & Guru Nanak Dev Engineering Collage respectively. She has taught graduate and post graduate students. She is guiding thesis in power quality, transmission line congestion and power system stability. Area of interest is Power System Operation and Control, Control System and Power System Stability.