Voltage Improvement by Using Thyristor Controlled Series Capacitor in Deregulated Power System

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Abstract : RPC (reactive power compensation) plays a major role for reducing the power loss of transmission line & maintain voltage. Voltage disturbance is a phenomenon which has been result for major blackout. To maintain security for those systems it is important to plan some suitable cautions for improving power system (PS) security & increase voltage stability. Series FACTS devices are used to reduce this problem. FACTS devices are leading to control the line flow & maintaining the bus voltages in desired level for improving voltage stability. In this paper modelling of TCSC (as one of the series FACTS devices) is considered for solving the low voltage problems. Performance evolution can be observed in IEEE 30 bus system by using POWERWORLD SIMULATOR 20.

***Keywords* - Voltage stability, FACTS, TCSC, powerworld simulator (PWS) software.**

I. INTRODUCTION

Voltage stability is nothing but, it is the strength of power system (PS) to maintain stable voltages at all buses in the system from a given initial operating point. Voltage stability is sometimes refer to a local phenomenon when only a particular bus or buses in a particular region have voltage stability issue and this may not be affect to the entire system and is refer to a global phenomenon when many of the buses in the system experience voltage stability problem, hence can be affect to the entire system. In some cases a voltage stability problem start as a local problem and tends to global stability problem.

Due to increasing demand of electricity, the transmission system will be stressed. For this reason the system becoming harm to voltage stability, it is an important phenomenon in the planning & operation of power system. Voltage collapse is one of the process in this the appearance of sequential events together with the voltage instability in a large system area can lead to the case of unacceptable low voltage condition in the network.

Voltage collapse is generally linked with reactive power demand of load is not met due to shortage of reactive power production in transmission system. After this point, the ordinary load flow solution is never converging, which in turn it forces the system to reach the voltage to its stable limit. The margin is measured from its base case solution to the maximum convergence point in the load flow computation determines at a particular bus in the system.

Present days they are so many FACTS devices are used in power electronics technology, especially the series FACTS devices. These new devices are more efficient in controlling present transmission and distribution systems faults. In this study, Power flow model of TCSC (one of the series FACTS devices) have been considered. In this investigation first the Optimal Power Flow (OPF) analysis is done using PWS software. TCSC is used for improving the voltage at bus by replacing it at low voltage bus lines. TCSC is a series device it controls the RP injection in lines using power electronics switching components. The reactive source is the combination of capacitors and reactors.

II. MATHEMATICAL MODELLING OF TCSC

TCSC is connected in series with the line. It is a reactance controller is connected to the line in series for compensating the utility of inductance in line. The reactance in line is reduces and lead to increase power transfer capability. The voltage is also increased at buses due to the insertion of TCSC in transmission lines. Series compensation is a preferable alternative method to increase the power flow capability of lines as comparing to the other devices like shunt devices. Ratings for series compensators are enormously small.

The effect of TCSC in the network is seeing as a controllable reactance inserted in series with the transmission line for compensate the line reactance in which it is connected. It may be inductive or capacitive characteristics to increase or decrease the line reactance XL respectively. Their values are functions of reactance of the line where the device is located. Moreover, for avoiding over compensation of the line, the working range of thyristor controller series capacitor is considered from -0.39XL to 0.39XL [1]. It increases power transfer in that line along with voltage improvement.

The transmission line with a TCSC is connected in between two buses, they are bus i & bus j, shown in Figure1a. Equivalent π model is used for representing the transmission line. TCSC is considered as a static reactance of magnitude equivalent to -jXc. The controllable reactance Xc is directly used as control variable, to be implemented in power flow equation.

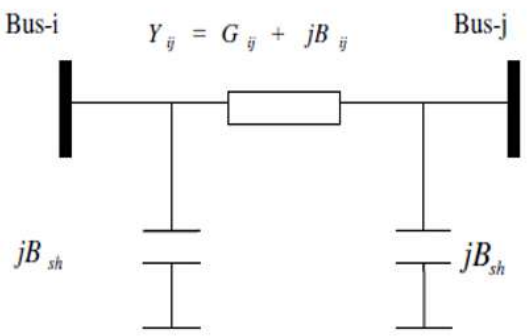

Fig .1a : Transmission line model

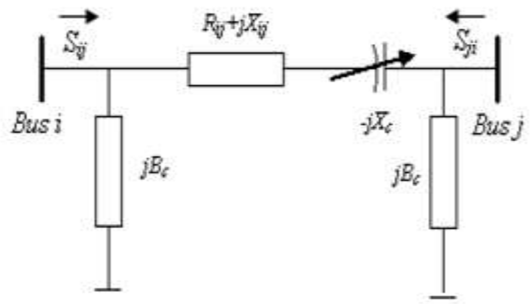

Fig .1b: TCSC model

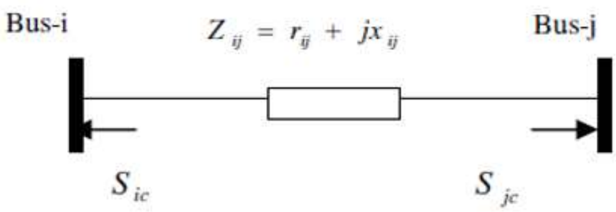

Fig.1c: TCSC injection model

The fallowing equations are used for modelling the TCSC.

Let the voltages at the bus i and bus j are represented by $v_i<\delta_i$ & $v_j<\delta_j$

The complex power between bus i and j is

$$S^*_{ij} = P_{ij} – Q_{ij} = V_i^* I_{ij\,I} \quad (1.1)$$

$$= V^*_i[(V_i\text{-}V_j)^*Y_{ij} + V_i^*(jB_c)] \quad (1.2)$$

$$= V^*_i\{[G_{ij} + j^*(B_{ij} + B_c) – V^*_iV_j^*(G_{ij} +jB_{ij})]\} \quad (1.3)$$

Where

$$G_{ij} + jB_{ij} = 1^*(R_L + jX_L – jX_c)^{-1} \quad (1.4)$$

From the above equations the real power and reactive power equations can be written as

$$P_{ij} = Vi2^*Gij – V_iV_jB_{ij}^* \cos(\delta_i \text{-}\delta_j) – ViVjBij^*\sin(\delta_i - \delta_j) \quad (1.5)$$

$$Q_{ij} = V_i^2{}^*(B_{ij} + B_c) – V_iV_j G_{ij}^* \sin(\delta_i \text{-}\delta_j) + ViVjBij^*\cos(\delta_i - \delta_j) \quad (1.6)$$

Similarly the real and reactive powers of bus i and bus j are represented as replacing V_i by V_j.

III. SIMULATION RESULTS AND DISCUSSION

In this study, choosing an IEEE thirty bus system standard data. The IEEE thirty bus system is drawn in PWS software is shown below.

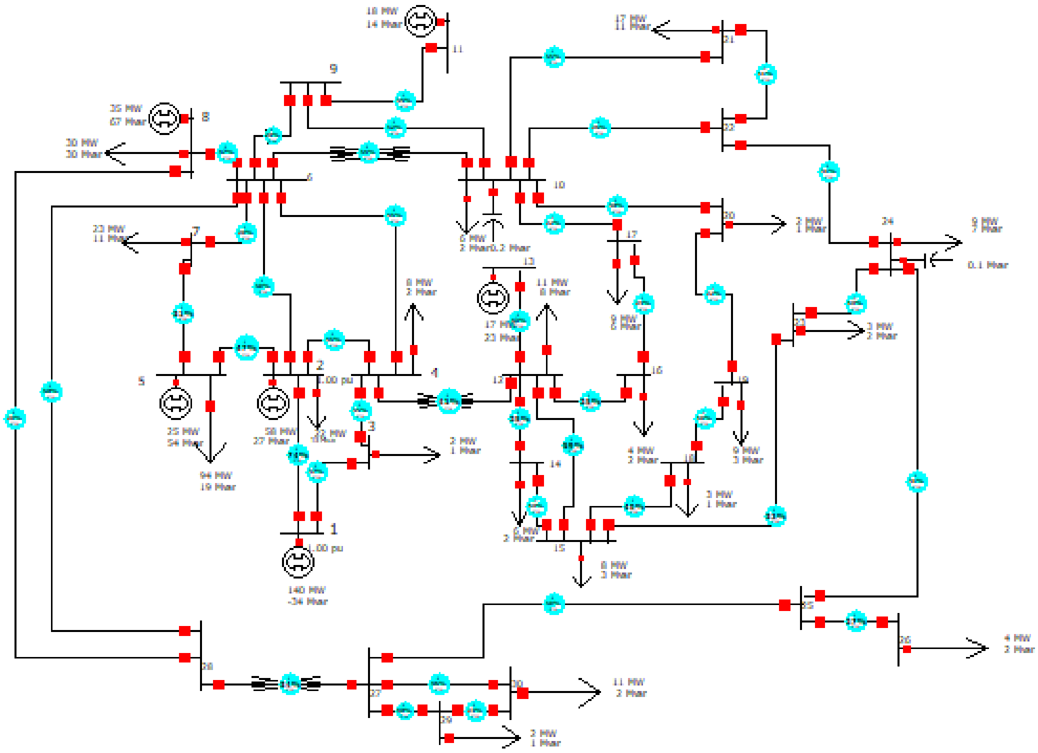

Fig 2: Standard IEEE thirty bus system without TCSC

Above figure shows the transmission line flows without thyristor controlled series capacitor. After observing the values of this case, at 24th bus the voltage will be low comparing with the remaining buses. At 24th bus it contains three lines they are 24 to 25, 22 to 24, and 23 to 24. This means it is required to check these three lines with thyristor controlled series capacitor. The lists of power flows in lines without thyristor controlled series capacitor (TCSC) are shown in below table.

TABLE I

30 BUS RESULTS WITHOUT TCSC

Bus no	**Nominal volt in kv**	**Volt (pu)**	**Volt (kv)**	**Angle (deg)**	**Gen mw**	**Gen mvar**
1	138.00	1.00000	138.00	0.00	139.95	-32.9
2	138.00	1.00000	138.00	-3.34	57.56	30.2
3	138.00	0.98758	136.287	-5.22		
4	138.00	0.98450	135.862	-6.26		
5	138.00	1.00000	138.00	-10.43	24.56	55.3
6	138.00	0.98413	135.810	-7.27		
7	138.00	0.98218	135.542	-9.11		
8	138.00	0.99418	137.196	-7.43	35.00	60
9	138.00	0.97061	133.945	-8.95		
10	138.00	0.95714	132.085	-11.07		
11	138.00	1.00000	138.00	-6.75	17.93	14.47
12	138.00	0.97388	134.395	-10.37		
13	138.00	1.00000	138.00	-9.27	16.91	23.91
14	138.00	0.95753	132.139	-11.4		
15	138.00	0.95251	131.447	-11.48		
16	138.00	0.95898	132.339	-10.99		
17	138.00	0.95188	131.360	-11.29		
18	138.00	0.94085	129.838	-12.16		
19	138.00	0.93738	129.358	-12.34		
20	138.00	0.94146	129.921	-12.09		
21	138.00	0.94453	130.345	-11.59		
22	138.00	0.94541	130.467	-11.57		
23	138.00	0.94185	129.975	-11.88		

24	**138.00**	**0.93677**	**129.274**	**-12.00**		
25	138.00	0.95626	131.964	-11.89		
26	138.00	0.93741	129.362	-12.36		
27	138.00	0.97755	134.902	-12.28		
28	138.00	0.97806	134.972	-7.75		
29	138.00	0.95668	132.022	-13.63		
30	138.00	0.94461	130.356	-14.60		

After placement of TCSC in three lines, line 24 to 25 is the best location for TCSC optimal placement. Voltages at 24th bus for different compensations after placement of TCSC are shown in below table.

TABLE II

VOLTAGES AT 24^{TH} BUS FOR DIFFERENT COMPENSATIONS

TCSC compensation	Nominal volt (kv) at 24^{th} bus	Voltage in pu at 24^{th} bus	Voltage in kv at 24^{th} bus
10%	**138.00**	**0.94335**	**130.182**
20%	138.00	0.94311	130.150
30%	138.00	0.94272	130.095
40%	138.00	0.94260	130.079
50%	138.00	0.94233	130.042
60%	138.00	0.94204	130.002
70%	138.00	0.94175	129.961
80%	138.00	0.94145	129.920
90%	138.00	0.94115	129.878
100%	138.00	0.94085	129.838

Maximum voltage will be obtained at 10% compensation. The voltage variations for different compensations can be observed in MATLAB. The plot between TCSC compensation values and voltage (pu) is shown below.

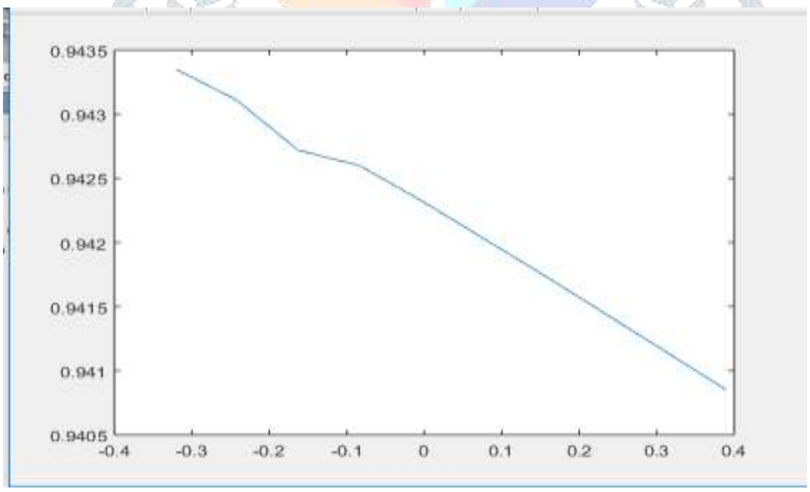

Fig.3 Voltage profile with TCSC

IV. CONCLUSION

Series FACTS devices are used to maintain the vol stability in deregulated PS. Thus the mathematical modelling for TCSC (as one of the series FACTS devices) has been done. The simulation for 30 bus system is done in power world simulator. Optimal power flow using TCSC as variable inductive reactance or capacitive reactance is performed using PWS software. From the simulation results, it can be concluded that the TCSC being capacitive in nature because, in this method it increases the power flow in line and also improve voltage at bus, economic aspects or optimization algorithms are not considered. This paper can be used for corresponding to this issue of placement of series FACTS devices for improving voltage profile in deregulated PS.

V. ACKNOLDGEMENT

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