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Optimal Location Of TCSC For Congestion Management In Restructured Power System

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ABSTRACT—Traditionally electric power sector had over all activities in generation, transmission and also in distribution of power within its domain of operation. Such utilities referred to as vertically integrated utility (VIU).Due to continuous increase in industrialization and urbanization there is need of electrical energy. This gives rise into rapid growth of power system. The main focus of engineers to reshape three components of VIU. The restructuring is used to increase customer focus, power system performance and reduce the cost revenue. Congestion is one of the technical issue in power system restructuring. In restructured power system transmission congestion occurs when there is insufficient transmission capacity to simultaneously accommodate all constraints for transmission of a line. This paper proposes to relieve congestion using TCSC device without affecting on economic matter. Further a methods to determine the optimal location of TCSC has been suggested based on reduction of total system reactive power loss.

***KEYWORDS*—**Congestion management, optimal location, restructured power system, Thyristor Controlled Series Capacitor (TCSC), Vertically Integrated Utility (VIU).

I. INTRODUCTION

Electricity is the most important and essential need of Today's society. Near 1980's, major challenges have been introduced into restructure of vertically integrated utility (VIU).The main reason of restructuring is to improve efficiency and make continuity in operation of the power. The success of reforms in communication sector and airlines shows importance of deregulation. United Kingdom was first to restructure. Then this same followed by Norway, Australia, New Zealand and United States. In India, during mid-1990's Orissa starts first to restructure then same followed by Andhra Pradesh, Uttar Pradesh, Rajasthan, Haryana and Maharashtra [1]. There are several complexities in restructure of electric utility. As electricity cannot be stored easily, and transportation of electricity is followed by physical laws .This have to be satisfied at all times in order to maintain reliability and security of the power system. Due to violation of this constraints, leads to unwanted voltage profile and congestion in transmission lines. Congestion management deals with the relief of congested transmission networks in restructured power system. If congestion is not relief then it may lead to tripping of overloaded lines, consequential tripping of other lines and in some cases to voltage stability problems. Hence to avoid such problem congestion need to be solve.To operate restructure power system in secure state independent system operator (ISO) or transmission system operator (TSO)has to relieve the congestion, for this ISO or TSO can use following methods:[2]

1) Cost free methods:
  i) Operation of transformers taps/phase shifters
  ii) Outageing of Congested lines
  iii) Operation of FACTS devices particularly Series FACTS devices.

2) Cost based methods:
  i) Load curtailment
  ii) Rescheduling generation.

Cost free methods have more advantageous than cost based such as without disturbing economic matter. FACTS device, [3] like Thyristor Controlled Series Capacitor (TCSC) have found to be more useful than other devices. In this respect, looking from literature objective of problem formulation for transmission congestion management is to provide relieve to congested line through optimal location of TCSC has been proposed. The proposed mechanism would be realized through proper computational techniques so that the power flow through designated path relieving line congestion.

II. CONSTRUCTION,CHARACTERISTICS AND STATIC MODELLING OF TCSC

A. Construction and Characteristics

Fig.1 shows TCSC construction, capacitor is in series with line and Thyristor controlled inductorconnected in parallel with it. TCSC is under series compensator device which increases transmission linecapacity by decreasing lines series impedances also increase network reliability. The bi-directional thyristor valve is fired with an angle α ranging between 90° and 180° with respect to the capacitor voltage.Because of this TCSC becomes much economic than other compensating FACTS devices.

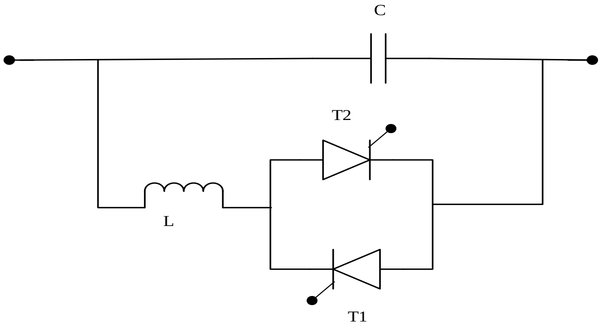

Fig. 1. Schematic diagram ofTCSC

Fig. 2 shows impedance characteristics of a TCSC device [3] [4].It is drawn effective reactance of TCSC Vs firing angle α. The effective reactance of TCSC starts increasing from X_L value to till occurrence of parallel resonance condition X_L (α) $=X_C$, theoretically X_{TCSC} is an infinity. This region is an inductive region. Further increasing value of X_L (α) gives capacitive region. Thus, following impedance characteristics of TCSC shows that both capacitive and inductive region are possible though varying firing angle (α).

- $\alpha_{clim} \le \alpha \le \frac{\pi}{2}$ Capacitive region
- $0 \le \alpha \le \alpha_{Llim}$ Inductive region

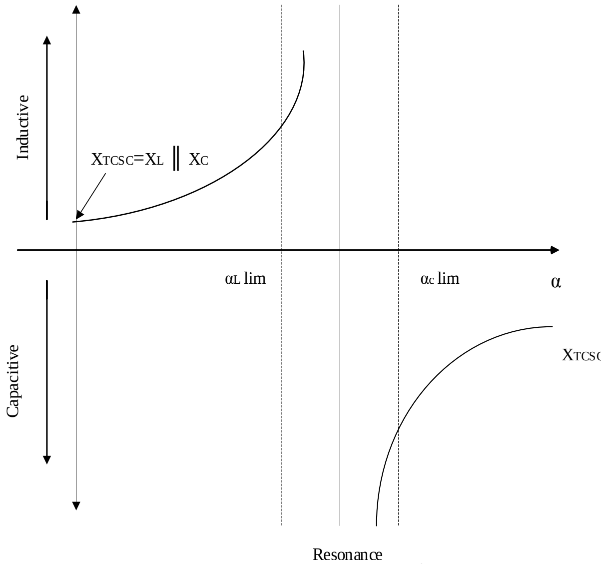

Fig. 2. Impedance characteristics of TCSC

While selecting inductance, $X_L$should be sufficiently smaller than that of the capacitor X_C. The capacitive region is possible in impedance characteristics, if $X_C < X_L$. In shunt circuit, effective value of reactance follows the lesser reactance present in branch. Hence only one capacitive reactance region will appears. Also X_L should not be equal to X_C value; or else a resonance develops that result in infinite impedance an unacceptable condition.

B. Static Modelling

Following Fig. 3 (a) shows a simple transmission line represented by its lumped πequivalent parameters connected between bus-a and bus-b. Let complex voltage at bus-a and bus-b are Va∠δa and Vb∠δb respectively. The real and reactive power flow from bus-a to bus-b can be written as follows, [5] [6] [7]

$$P_{ab} = V_a^2 G_{ab} - V_a V_b [G_{ab}\cos(\delta_{ab}) + B_{ab}\sin(\delta_{ab})] \quad (1)$$

$$Q_{ab} = -V_a^2 (B_{ab} + B_{sh}) - V_a V_b [G_{ab}\sin(\delta_{ab}) - B_{ab}\cos(\delta_{ab})] (2)$$

Where$\delta_{ab} = \delta_a - \delta_b$. similarly, the real and reactive power flow from bus-b to bus-a is,

$$P_{ba} = V_b^2 G_{ab} - V_a V_b [G_{ab}\cos(\delta_{ab}) - B_{ab}\sin(\delta_{ab})] (3)$$

$$Q_{ba} = -V_b^2 (B_{ab} + B_{sh}) + V_a V_b [G_{ab}\sin(\delta_{ab}) + B_{ab}\cos(\delta_{ab})] (4)$$

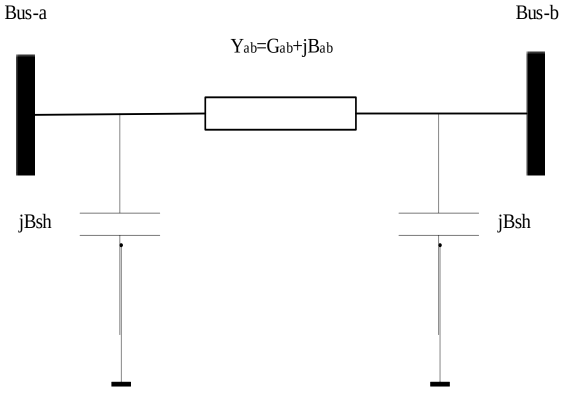

Fig. 3 (a).Model of Transmission line

The model of transmission line with a TCSC connected between bus-a and bus-b is shown in Fig.3 (b). During the steady state the TCSC can be considered as a static reactance $-jx_c$. The real and reactive power flow from bus-a to bus-b, and from bus-b to bus-a of a line having series impedance and a series reactance are as follows,

$$P_{ab}^T = V_a^2 G_{ab}' - V_a V_b [G_{ab}'\cos(\delta_{ab}) + B_{ab}'\sin(\delta_{ab})] \quad (5)$$

$$Q_{ab}^T = -V_a^2 (B_{ab}' + B_{sh}) - V_a V_b [G_{ab}'\sin(\delta_{ab}) - B_{ab}'\cos(\delta_{ab})] (6)$$

$$P_{ba}^T = V_b^2 G_{ab}' - V_a V_b [G_{ab}'\cos(\delta_{ab}) - B_{ab}'\sin(\delta_{ab})] \quad (7)$$

$$Q_{ba}^T = -V_b^2 (B_{ab}' + B_{sh}) + V_a V_b [G_{ab}'\sin(\delta_{ab}) + B_{ab}'\cos(\delta_{ab})] (8)$$

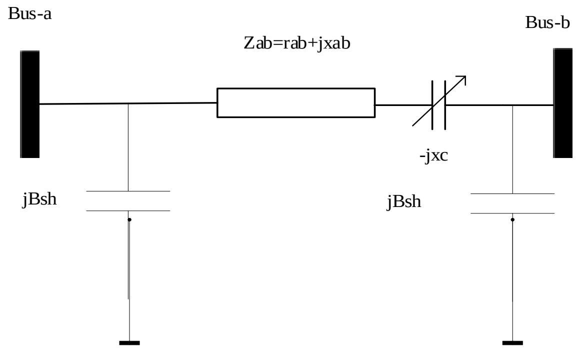

Fig. 3 (b). Model of TCSC

The active and reactive power loss in line having TCSC can be written as follows,

$$P_{Loss} = P_{ab} + P_{ba} = G'_{ab}(V_a^2 + V_b^2) - 2V_aV_bG'_{ab}\cos(\delta_{ab}) \quad (9)$$

$$Q_{Loss} = Q_{ab} + Q_{ba} = -(V_a^2 + V_b^2)(B'_{ab} + B_{sh}) + 2V_aV_bB'_{ab}\cos(\delta_{ab}) \quad (10)$$

Where $G'_{ab} = \frac{r_{ab}}{r_{ab}^2 + (x_{ab} - x_c)^2}$ and $B'_{ab} = \frac{-(x_{ab} - x_c)}{r_{ab}^2 + (x_{ab} - x_c)^2}$

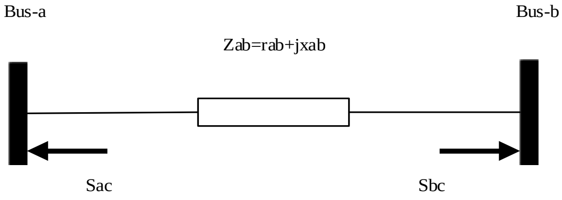

Fig.3 (c). Injection Model of TCSC

The change in the line flow due to series capacitance can be represented as line without series capacitance with power injected at the receiving and sending ends of the line as shown in Fig.3(c). The real and reactive power injections at bus-a and bus-b can be written as follows,

$$P_{ac} = V_a^2\Delta G_{ab} - V_aV_b[\Delta G_{ab}\cos(\delta_{ab}) + \Delta B_{ab}\sin(\delta_{ab})] \quad (11)$$

$$P_{bc} = V_b^2\Delta G_{ab} - V_aV_b[\Delta G_{ab}\cos(\delta_{ab}) - \Delta B_{ab}\sin(\delta_{ab})] \quad (12)$$

$$Q_{ac} = -V_a^2\Delta B_{ab} - V_aV_b[\Delta G_{ab}\sin(\delta_{ab}) - \Delta B_{ab}\cos(\delta_{ab})] \quad (13)$$

$$Q_{bc} = -V_a^2\Delta B_{ab} + V_aV_b[\Delta G_{ab}\sin(\delta_{ab}) + \Delta B_{ab}\cos(\delta_{ab})] \quad (14)$$

Where,

$$\Delta G_{ab} = \frac{x_c r_{ab}(x_c - 2x_{ab})}{(r_{ab}^2 + x_{ab}^2)(r_{ab}^2 + (x_{ab} - x_c)^2)}$$

And

$$\Delta B_{ab} = \frac{-x_c(r_{ab}^2 - x_{ab}^2 + x_c x_{ab})}{(r_{ab}^2 + x_{ab}^2)(r_{ab}^2 + (x_{ab} - x_c)^2)}$$

Due to high cost of FACTS devices, it is necessary to find out optimal location of these devices.

III. OPTIMAL LOCATION OF TCSC

A. Reduction of total system reactive power loss

Following method shows sensitivity of the total system reactive power loss with respect to the control variable of the TCSC. Consider net line series reactance as a control parameter for TCSC placement between buses a and b. Sensitivity with respect to net line series reactance called as control parameter of TCSC placed between buses a and b can be written as, [5]

$$a_{ab} = \frac{\partial Q_L}{\partial x_{ab}} = [V_a^2 + V_b^2 - 2V_aV_b\cos\delta_{ab}]\cdot\frac{R_{ab}^2 - X_{ab}^2}{(R_{ab}^2 + X_{ab}^2)^2} \quad (15)$$

B.Selection Criteria for Optimal Location:

In this, FACTS device should be placed on the most sensitive line. Following criteria can be used for its optimal placement:

In reduction of total system reactive power loss method TCSC should be placed in a line having the most positive sensitivity index.Following flow chart followed for effective location of TCSC in network. By using this flow chart congestion relief is possible in given network.

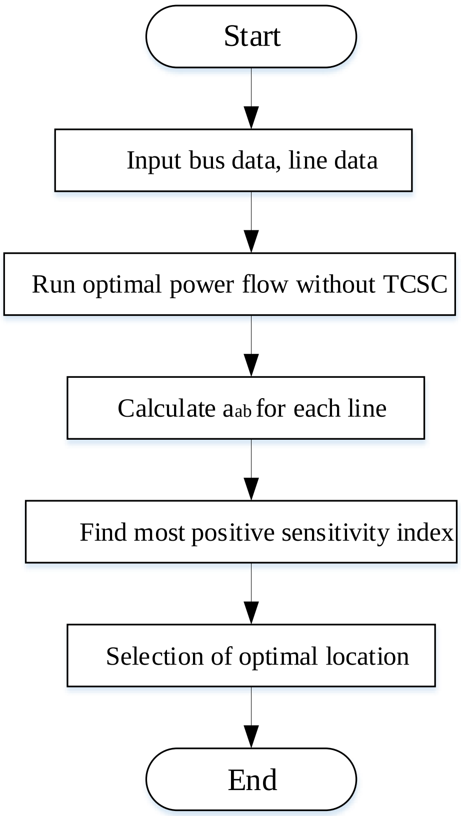

Fig.4.Flow chart for proposed method for effective location of TCSC in network

IV. SIMULATION AND RESULTS

To find out optimal location of TCSC, the analysis has been implemented on IEEE 14-bus system as shown in Fig.5 below.MATLAB has been used for simulation.

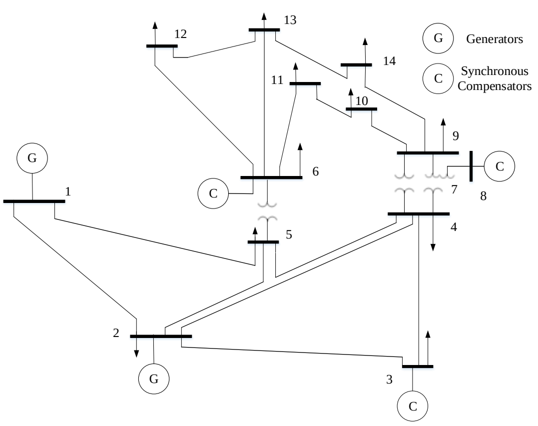

Fig. 5. IEEE 14-Bus System

Power flow of above IEEE 14-Bus system are calculated.

TABLE I.CALCULATED SENSITIVITY INDICES

Line	a-b	a_{ab}
1	1-2	-0.00595006
2	1-5	-0.00035675
3	2-3	-0.0468019
4	2-4	-0.0103158
5	2-5	-0.00194678
6	3-4	-0.0930999
7	4-5	-0.0607541
8	4-7	-0.363047
9	4-9	-0.0435306
10	5-6	-0.000964287
11	6-11	-0.218674
12	6-12	-0.16367
13	6-13	-0.572332
14	7-8	-0.116021
15	7-9	-0.00835645
16	9-10	-0.00222447
17	9-14	-0.000117934
18	10-11	-0.000784551
19	12-13	**0.000011997**
20	13-14	-0.00366461

The sensitive of real power flow performance index sensitivity indices with respect to TCSC control parameter has been calculated and are shown in Table I. The sensitive lines are highlighted in Table I. It can be observed from Table I that line 19 is more sensitive as per reduction of total system reactive power loss method. Power flow result after placing TCSC in line 19 is as shown in Table II.The value of control parameter of TCSC for computing power flow is taken as 0.139916 p.u. It can be observed from Table IIcongestion is relieved in line 17after placing TCSC.

TABLE II. POWERFLOW RESULT AFTER PLACING TCSC

Line	Power flow without TCSC in p.u.	Power flow with TCSC in Line-19 in p.u.
1	1.651	1.650
2	1.227	1.226
3	-0.531	-0.531
4	1.556	1.555
5	0.796	0.796
6	-1.719	-1.719
7	-3.424	-3.422
8	1.163	1.161
9	0.650	0.649
10	-1.588	-1.588
11	-27.194	-27.194
12	2.398	2.434
13	0.130	0.099
14	-0.163	-0.161
15	1.163	1.161
16	-6.117	-6.114
17	**7.636**	**7.629**
18	-6.216	-6.213
19	-0.883	-0.848
20	-7.307	-7.301

V. CONCLUSION

From above discussion, it is observed that congestion is major problem in restructured power system and need to be solve.TCSC device is found to be useful to reduce power flow in heavily congested lines. Because of high cost of TCSC device, it is important to follow flow chart given in this paper to obtain optimal location of TCSC device in given network.

The results of IEEE14bus presented in this paper shows that the method would very effective to solve congestion problem with optimal placement TCSC device.

REFERENCES

[1] Text book by A.R.Abhyankar, Prof.S.A.Khaparde, “Introduction to deregulation in power industry”

[2] L.Rajalakshmi, M.V.Suganyadevi, S.Parameswari “Congestion Management in Deregulated Power System by Locating Series FACTS Devices” International Journal of Computer Applications (0975 – 8887) Volume 13– No.8, January 2011

[3] Text Book by N.G.Higorani & Laszlo Gyugyi “Understanding FACTS Concept and technology of Flexible AC Transmission Systems”

[4] Anwar S. Siddiqui, Rashmi Jain, Majid Jamil and Gupta C. P. “Congestion management in high voltage transmission line using thyristor controlled series capacitors” Journal of Electrical and Electronics Engineering Research Vol. 3(8), pp.151-161,October2011,Available online at http://www.academicjournals.org/JEEER , ISSN – 2141 – 2367 ©2011 Academic Journals

[5] Seyed Abbas Taher, Hadi Besharat, “Transmission Congestion Management by Determining Optimal Location of FACTS Devices in Deregulated Power Systems” American Journal of Applied Sciences 5 (3): 242-247, 2008

[6] Dipak S. Yeole, Dr.P.K.Katti, "Transmission Congestion Management in Deregulated Power System", Advance Computing & Communication Technologies (pp.179-182),ISBN:978-93-83083-38-1.

[7] Verma K.S., Singh S.N., Gupta H.O., 2001. FACTS devices location for enhancement of total transfer capability, Power Engineering Society Winter Meeting, IEEE, Vol. 2: 522-527.