Power Flow Analysis Using Thyristor Controlled Series Capacitor (TCSC)

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Abstract: - In an A.C transmission system power flow can be controlled using TCSC. This paper presents a brief idea on load flow in power system, bus classification, improving stability of power system, advantages of using TCSC in series compensation. The application of series compensation provides a smoothly variable series capacitor reactance in transmission line which is useful for improving the real power flow [1].It presents the modeling scheme of TCSC and the advantages of using it in power flow network. The results obtained after simulation of network using MATLAB both with and without TCSC gives clear idea of various merits of use of reactive power compensators. This project concentrates on control the power flow effectively through line using TCSC and enhances system stability [2].

Key Words: — *Control Strategy, MATLAB, Power Flow, System Stability, Newton Raphson Algorithm, Thyristor controlled series capacitor (TCSC).*

I. Introduction

The transmission facilities are being overused due to higher industrial demands and deregulation of power supply. New ways of maximizing the power transfers of existing transmission system can be searched out. At the same time, maintaining acceptable levels of network reliability and stability. This scenario makes necessary the development of high-performance control of the power network. Recent advancement in power electronics has proven to satisfy this need by introducing the concept of flexible AC transmission system (FACTS). The FACTS controllers are used in regulating the power flows, transmission voltages and mitigate the dynamic disturbance. Since its inception the FACTS devices has developed in steps, the first generation being mechanically controlled capacitors and inductors.

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The second generation of FACTS devices replaced the mechanical switches by the thyristor valve control. This gave a marked improvement in the speed and the enhancement in concept to mitigate the disturbances. The third generation exploited the concept of converter-based devices. These devices provide multidimensional control of the power system parameters. Power flow in a transmission line can be controlled by regulating the voltage at the two ends of the line, the phase angle or the reactance of the line. Thyristor controlled series compensators works on the principal of regulating the voltage of the transmission line by injecting voltage employing capacitor or inductor. Converter based Unified power flow controller regulates the output voltage of the converter to control the power flow. In order to fully investigate the impact of these devices on power system effectively, it is essential to formulate their correct and appropriate model. Generally there are three types of models of FACTS devices available in the literature.

- Steady state model for system study state evaluation.
- Electromagnetic model for detailed equipment level investigation.
- Dynamic models for stability studies.

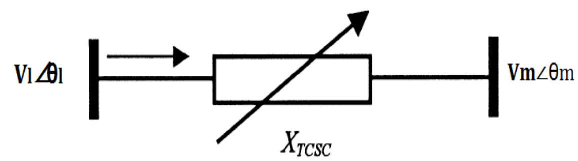
II. Power Flow Control

In a three phase AC power system active and reactive power flows from the generating station to the load through different networks buses and branches. The flow of active and reactive power is called power flow or load flow. Power flow studies provide asystematic mathematical approach for determination of various bus voltage, there phase angle active and reactive power flows through different branches, generators and loads under steady state condition. Power flow analysis is used to determine the steady state operating condition of a power system. Power flow analysis is widely used by power distribution professional during the planning and operation of power distribution system. In its most basic form the power transmission line can be represented by a two bus system l, m. The active power transmitted between bus nodes l and m is given by where V_l and V_m are the voltages at the nodes, $(\theta_l - \theta_m)$ the angle between the voltages and the line impedance. The power flow can be controlled by altering the voltages at a node, the impedance between the nodes and the angle between the end voltages.

III. Modeling of TCSC

TCSC vary the electrical length of the compensated transmission line which enables it to be used to provide fast active power flow regulation. It also increases the stability margin of the system and has proved very effective in damping Sub Synchronous Resonance (SSR) and power oscillations. The simpler TCSC model exploits the concept of a variable series reactance. The series reactance is adjusted automatically, within limits, to satisfy a specified amount of active power flow through it. The more advanced model uses directly the TCSC reactance–firing angle characteristic, given in the form of a nonlinear relation as in equation. The TCSC firing angle is chosen to be the state variable in the Newton Raphson power flow solution.

The power flow model of Thyristor controlled series compensator is based on the concept of variable series reactance, the value of which is adjusted to control the power flow. The variable reactance model is represented by X_T (equivalent reactance) connected in series to the transmission line between the buses l, m. The variable reactance develops a compensating voltage (reactive) which is a function of line current.



TCSC does not exchange real power with the AC system (except for losses). It only generates or absorbs the reactive power required for compensation by the capacitor or reactor banks and the thyristor switch are used to control only the combined reactive impedance these present to the AC system.

The Power flow equations of TCSC can be written as

$$P_l = V_l V_m B_{lm} \sin(\Theta_l - \Theta_m)$$

$$Q_l = -V_l^2 B_{ll} - V_l V_m B_{lm} \cos(\Theta_l - \Theta_m)$$

$$B_{lm} = 1/X_{TCSC}$$

$$B_{ll} = -1/X_{TCSC}$$

IV. Power Flow Analysis

4.1. Newton Raphson Computer Program for Load Flow Analysis without TCSC (Results)

By using theoretical knowledge and by analysis of performing MATLAB coding on 5 buses Network without using Thyristor controlled series capacitor the results that we have obtained by MATLAB code are shown in Table:1 and Table:2.

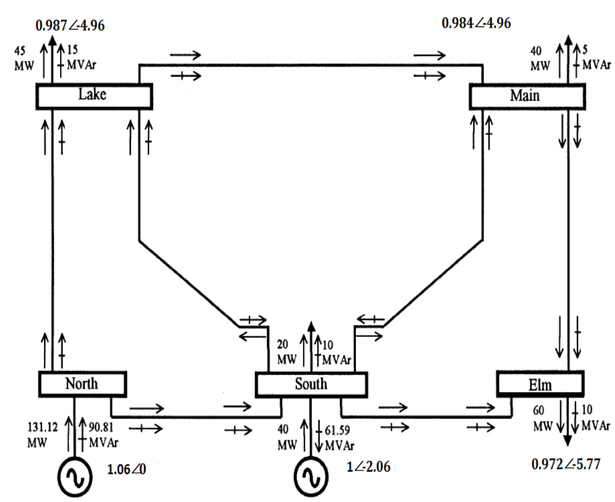


Fig.2. 5-Bus Network Load Flow Analysis before TCSC

- North – bus 1
- South – bus 2
- Lake – bus 3
- Main – bus 4
- Elm –bus 5

Bus no	Voltage (|V|,θ) pu	Load (MW, MVAR) pu	Generator (MW, MVAR) pu	Injected MVAR
1	(1.06,0.00)	(0.0,0.0)	(131.114,90.815)	0
2	(1.00,-2.06)	(20,10)	(40,-61.607)	0
3	(0.987,-4.63)	(45,15)	(0.0,0.0)	0
4	(0.984,-4.95)	(40,05)	(0.0,0.0)	0
5	(0.972,-5.76)	(60,10)	(0.0,0.0)	0

Table 1

Sending Bus	Receiving Bus	Line Resistance pu	Line Reactance pu	½ Line charging Susceptance pu
1	2	0.02	0.06	0.03
1	3	0.08	0.24	0.025
2	3	0.06	0.18	0.02
2	4	0.06	0.18	0.02
2	5	0.04	0.12	0.015
3	4	0.01	0.03	0.01
4	5	0.08	0.24	0.025

Table 2

4.2. Newton Raphson Computer Program for Load Flow Analysis With implementation of TCSC (Results)

By using theoretical knowledge and by analysis of performing MATLAB coding on 5 –buses Network using Thyristor controlled series capacitor the results that we have obtained by MATLAB code are shown in Table:3 and Table:4.

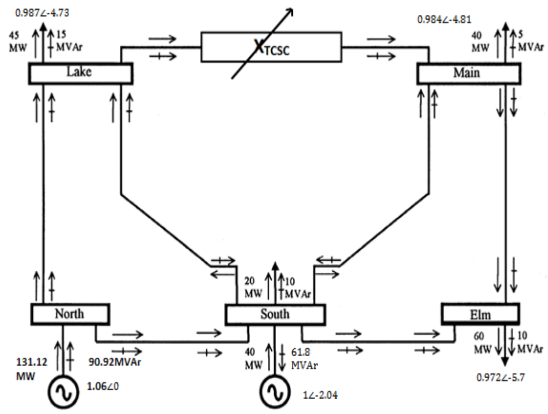


Fig.3. 5-Bus Network Load Flow Analysis after TCSC

Bus no	Voltage (|V|,θ) pu	Load (MW, MVAR) pu	Generator (MW, MVAR) pu	Injected MVAR
1	(1.06,0.00)	(0.0,0.0)	(131.12,90.92)	0
2	(1.00,-2.04)	(20,10)	(40,-61.8)	0
3	(0.987,-4.73)	(45,15)	(0.0,0.0)	0
4	(0.984,-4.81)	(40,05)	(0.0,0.0)	0
5	(0.972,-5.7)	(60,10)	(0.0,0.0)	0
6	(0.986,-4.798)	(0,0)	(0,0)	0

Table 3

Sending Bus	Receiving Bus	Line Resistance pu	Line Reactance pu	½ Line charging Susceptance pu
1	2	0.02	0.06	0.03
1	3	0.08	0.24	0.025
2	3	0.06	0.18	0.02
2	4	0.06	0.18	0.02
2	5	0.04	0.12	0.015
3	6	0.005	0.015	0.005
6	4	0.005	0.015	0.005
4	5	0.08	0.24	0.025

Table 4

V. Result & Discussion

Transmission Line losses are reduced due to TCSC, generators are generating more reactive power, the reactive power flow in case of TCSC is more for all the lines. Active power flow between buses 3 and 4 is increased. (Table 3)

A comparison of numerical values of active and reactive power flow with implementation of TCSC and without TCSC show that it increases the stability of margin of the system, provides the fast active power flow regulation. The TCSC varies the electrical length of compensated transmission line with little delay.

VI. Conclusion

The comparison of simulations of both the both the networks show the TCSC controller enhances stability of power system. From the transient analysis it is quite clear that electromechanical damping increases on using these controllers.

References

[1]. Sapna Meghwal, Dr. Sameena Elyas Mubeen. ”An Overview of Power Flow Analysis Incorporated with TCSC in Newton-Raphson Algorithm in IEEE 5 Bus System” International Journal of Scientific Progress and Research (IJSPR) ISSN: 2349-4689 Volume-09, Number - 01, 2015.

[2]. Guide- Prof. Katre Apurva D, Bhosale Pranita V, Ambi Trupti S, Nikam Harshada U, Mengane Nirmala N, Chavan Pradnyarani T. ”Power Flow Enhancement Using Thyristor Controlled Series Capacitor (TCSC)” International Journal of Scientific Research and Review, ISSN NO: 2279-543X, Volume 7, Issue 4, 2018.

[3]. S.Kamel, F. Jurado, and Z.Chen. “Power flow control for transmission networks with implicit modeling of static synchronous series compensator” International Journal of Electrical Power & Energy Systems Volume 64, January 2015, Pages 911-920.

[4]. Sreejith, S., Sishaj P. Simon, and M. P. Selvan. "Comparative evaluation of modelling methods for TCSC in optimal power flow studies." Power, Signals, Controls and Computation (EPSCICON), 2012 International Conference on. IEEE, 2012.

[5]. Lakshmi, G. Venkata, and K. Amaresh. "Optimal Power Flow with TCSC using Genetic Algorithm." Power Electronics, Drives and Energy Systems (PEDES), 2012 IEEE International Conference on. IEEE, 2012.

[6]. Kumar, G. Ravi, R. Kameswara Rao, and SS Tulasi Ram. "Power flow control and transmission loss minimization model with TCSC and SVC for improving system stability and security." Industrial and Information Systems, 2008. ICIIS 2008. IEEE Region 10 and the Third international Conference on. IEEE, 2008.

[7]. Yang, Ning, Qinghua Liu, and James D. McCalley. "TCSC controller design for damping interarea oscillations." Power Systems, IEEE Transactions on13.4 (2009): 1304-1310.

[8]. Khan, Baseem, et al. "A TCSC Incorporated Power Flow Model for Embedded Transmission Usage and Loss Allocation." AASRI Procedia 7 (2014): 45-50.

[9]. Sreejith, S., Sishaj P. Simon, and M. P. Selvan. "Power flow analysis incorporating firing angle model based TCSC." Industrial and Information Systems (ICIIS), 2010 International Conference on. IEEE, 2010.

[10]. Rao, G. Madhusudhana, S. Sundeep, and S. R. Reddy. "Optimal power flow controlling with TCSC using expert system." Sustainable Energy and Intelligent Systems (SEISCON 2011), International Conference on. IET, 2011.

[11]. Mubeen, Samina E., R. K. Nema, and Gayatri Agnihotri. "Comparison of Power flow control: TCSC versus UPFC." Power System Technology and IEEE Power India Conference, 2008. POWERCON 2008. Joint International Conference on. IEEE, 2010

[12]. Kamarposhti, Mehrdad Ahmadi, et al. "Comparison of SVC, STATCOM, TCSC, and UPFC controllers for static voltage stability evaluated by continuation power flow method." Electric Power Conference, 2008. EPEC 2008. IEEE Canada. IEEE, 2008.