An Overview of Power Flow Analysis Incorporated with TCSC in Newton-Raphson Algorithm in IEEE 5 Bus Systems

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Abstract - An overview of power flow analysis exercising Thyristor Controlled Series Compensator with Newton-Raphson algorithm is shown in this paper. The incorporation of TCSC for power flow analysis in Newton-Raphson algorithm is depicted in this paper. The application of series compensation provides a smoothly variable series capacitor reactance in transmission line which is useful for improving the real power flow. In this method Newton-Raphson algorithm is used for the calculation of voltages and real power for power flow analysis of the system. Power flow study is carried out on IEEE 5 buses test systems. The result for power flow analysis for real power flow control without TCSC and with TCSC using Newton-Raphson algorithm in IEEE 5 bus test system is tabulated.

Keywords: Thyristor Controlled Series Compensator, Power flow analysis, Newton Raphson algorithm, FACTS devices.

I. INTRODUCTION

The transmission system is demanded to distribute power at good quality. Now to cope with demand the system operates at threshold limits. The basic idea to solving transmission system technical hitches in maximum efficient and organized approach is through the analysis of system. The power flow analysis provides data for the power system analysis by means of comparing the existing system values using standard and FACTS devices. With application of FACTS devices the transmission process is enhanced with minimum installation time and set-up as compared to out-dated solutions like new equipment, transmission lines and substations [1].

A power flow analysis is overall information of condition contained by the system from result calculation in equilibrium state. Thus the outcome of variation in system can be anticipated. The performance of power system under changes from factors such as network configuration, addition of loads, interconnecting line can be studied using power flow analysis [2]. The idea of employing advanced control systems, power electronic converters and solid state converters for controlling the basic characteristics like power flow, series and shunt impedance, voltage magnitude of power system is known as Flexible Alternating Current Transmission System (FACTS) [3].

Among several other FACTS devices TCSC is one significant device which permits fast and uninterrupted variation in transmission line impedance. The real power flow with compensated transmission line are kept in range of given value of operating conditions. In power flow analysis of power system the Thyristor Controlled Series Compensator can be characterised in many other different models [4]. The model in case [4] shows the TCSC firing angel is considered as state variable, controlled to attain the level of compensation necessary to realize given real power flow.

This paper presents the application of TCSC in power flow analysis using Newton-Raphson algorithm for enhancement of real power flow. The paper highlights on the real power flow without TCSC and with TCSC in transmission line. The paper examines the variation in power flow analysis without TCSC and with TCSC. The addition of Thyristor Controlled Series Capacitive Compensation will increase the capability of line to transfer power [5].

II. POWER FLOW ANALYSIS

The power flow analysis is the commonly exercised tool equally in control and growth planning studies of power system. Power flow analysis is employed to find: Ratings of equipment's; Losses in system; Voltage profile and angles at bus; loading of electrical equipment. In addition to this the power flow analysis is also used to estimate the cost and reduce the cost of power system [6]. With increase in complexity in power system new uncertainties arises in solving power system problems. The power flow analysis helps in solving these problems in economical way. The different system parameters are represented by set of non-linear equations. These equations are solved using different methods such as Gauss-Seidal method, NR method and fast-decoupled method. The Newton-Raphson algorithm is used to solve the system equations formed by control action of devices compiled with power flow equations.

III. FACTS

In the present scenario of increasing demand of electrical energy the ancient methods of improving transmission system are replaced by Flexible AC Transmission System (FACTS). The basic concept of FACTS technology is to transfer power over long distances in more efficient way by controlling the different parameters of transmission system [3]. The references [7] – [14] show many other features, and applications of FACTS devices.

One simple approach of classifying FACTS devices is by means of parameters controlled by any device, e.g. real power flow can be controlled using TCSC and voltage control using SVC or STATCOM. Thus FACTS devices can be classified as [7]:

1. Series type
2. Shunt type
3. Series and Shunt type
4. Series and Series type

The above classification of FACTS devices also indicate that all series type devices inject voltage in series with line and all shunt type devices inject current at point of connection into the system. Some significant types of FACTS devices are [3]:

1. Static Var Compensator (SVC),
2. Static Synchronous Compensator (STATCOM),
3. Thyristor Controlled Series Compensator (TCSC),
4. Thyristor Controlled Series Reactor (TCSR),
5. Interline Power Flow Controller (IPFC),
6. Unified Power Flow Controller (UPFC).

FACTS devices consequently have several advantages such as [11]:

1. Increase in stability of transmission system by increasing the transfer capability of long transmission lines.

2. Increase in uninterrupted power supply by reducing the chances of voltage dip and frequency variation.

3. These devices are also environmental friendly by reducing the requirement of new transmission line for enhanced power supply.

4. Offers more flexibility and economic benefits by reducing time of installation and utilizing the present installation in a more efficient way.

The demonstration and use of first generation of FACTS devices were started in 1974 in Nebraska. In India the use of FACTS devices is introduced in the year 2000 in Northern Grid on 400 kV line between Ballabghar (Haryana) and Kanpur (U.P.) using Fixed Series Compensation (FSC) and Thyristor Controlled Series Compensator (TCSC) [10].

IV. TCSC

Thyristor Controlled Series Compensator (TCSC) is a FACTS device used to control the real power flow or the line current in transmission line by changing its series reactance employing thyristor. Thus the constant change in transmission line impedance keeps the real power flow in transmission line at given range. TCSC is a transmission system approach utilizing the consistent and high-speed thyristor based high-speed power electronics controllers [14].

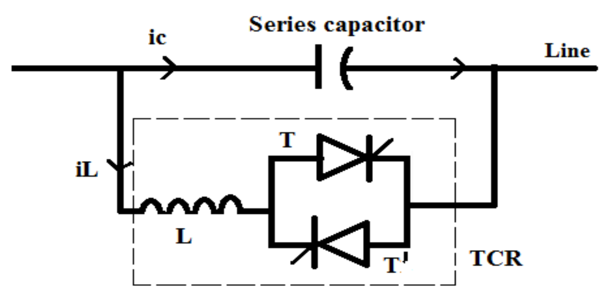

Fig. 1 Basic circuit of TCSC

In Fig. 1, Thyristor Controlled Reactor (TCR) is a variable reactor connected across a series capacitor bank forms a capacitive reactance compensator to allow a smoothly variable series capacitor reactance in transmission line. In a real TCSC system it consists of a cascaded group of TCSC units with a fixed-series capacitor [3]. For power flow analysis incorporating TCSC different network parameters are required to be calculated thus the modelling of TCSC is needed. Some known techniques of modelling TCSC are (1) power flow modelling, (2) variable impedance modelling and (3) firing angle modelling [12].

V. CASE STUDY

For power flow analysis by Newton-Raphson algorithm consider a standard IEEE 5 bus test system. To study the performance of TCSC device the IEEE 5 bus system is verified with TCSC and without TCSC in the network. The bus data is tabulated in Table-1. In Table-1 the nodal voltage magnitude and nodal voltage phase angle is given in per unit on MVA base of 100MVA and degree respectively.

TABLE 1. BUS DATA

Bus No.	Bus Type	Nodal Voltage		Load	
		VM (p.u)	VA (deg)	MW (p.u)	MVAR (p.u)
1	1	1.06	0	0	0
2	2	1.00	0	20	10
3	3	1.00	0	45	15
4	3	1.00	0	40	05
5	3	1.00	0	60	10

The generator data is tabulated in Table-2. The number of generation bus is 3. The injected MVAR is zero.

TABLE 2. GENERATOR DATA

BUS No.	PGEN MW (p.u)	QGEN MVAR (p.u)	QMAX (p.u)	QMIN (p.u)
1	0	0	50	-50
2	40	30	30	-30
3	0	0	0	0
4	0	0	0	0
5	0	0	0	0

The transmission line data is tabulated in Table-3. The transmission line resistance line reactance and line susceptance is given in per unit. The transmission line conductance is zero. Number of maximum iterations is 100.

TABLE 3. LINE DATA

Sending End Bus	Receiving End Bus	Transmission Line		
		R (p.u)	X (p.u)	B (p.u)
1	2	0.02	0.06	0.06
1	3	0.08	0.24	0.05
2	3	0.06	0.18	0.04
2	4	0.06	0.18	0.04
2	5	0.04	0.12	0.03
3	4	0.01	0.03	0.02
4	5	0.08	0.24	0.05

The result for power flow analysis for real power flow control using Newton-Raphson algorithm in IEEE 5 bus test system is tabulated in Table-4. The real power flow without TCSC and with TCSC is shown in Table-4. Thus the real power flow is increased.

TABLE 4. REAL POWER WITHOUT AND WITH TCSC

Bus No.	Real Power without TCSC MW(p.u)	Real Power with TCSC MW(p.u)
1	31.12	34.50

VI. CONCLUSION

The paper presented an introduction of power flow analysis and FACTS devices. The paper depicts the improvement in real power flow in transmission line when TCSC is connected in the transmission system. Newton-Raphson power flow algorithm is used for the analysis. The algorithm is tested on IEEE 5 bus test system. The result for real power flow is observed both for without TCSC and with TCSC. Thus the study clearly shows the advantages of including the TCSC in the transmission system.

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