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CONGESTION MANAGEMENT IN COMPETITIVE POWER MARKET USING TCSC

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ABSTRACT

The Optimum Power Flow (OPF) in an interconnected power system is an imperative procedure with respect to transmission loss and other operating constraints. Deregulation of power industry leads to huge change in the process of operation and control strategy of optimum power flow. Increase in power demand leads to increase in power transaction and for satisfying those demands competition arise among the market players (GENCO's), which create stress on the power system. Thus leading the system to get congested. In this paper, Thyristor Controlled Series Compensator (TCSC) has been used to relieve congestion using conventional NR method. Allen J. Wood six bus systems have been considered as the test bus system. Simulation results with and without TCSC, before and after compensation has been discussed to analyse the impact of TCSC on the congestion levels of the six bus test system.

Keywords: optimum power flow (OPF), thyristor controlled series compensator (TCSC), newton raphson (NR) method.

1. INTRODUCTION

The deregulation of power system has made intensive usage of transmission grids. Here most of the time the power system operates near its rated capacity as the market players have an intention of maximizing profit by utilizing as much as of the existing transmission resources. Due to this an obvious technical problem called Congestion occurs. Congestion may result in preventing new contracts, infeasibility in existing contracts, price spike in some regions and market power abuse. Though congestion exists in both bundled and unbundled power systems, it is very complex in deregulated power system due to its unbundled nature. To relieve congestion, cost free and non-cost free congestion management methods are accessible. Cost free methods do not include GENCO and DISCO i.e., economical matters are not involved and congestion is relieved technically by incorporating phase shifters, transformer taps, and Flexible AC Transmission Systems (FACTS) devices in the power system. Whereas, non-cost free method were dealt economically. (FACTS) devices provide flexible control of power which is helpful in the operation of competitive power markets. Many studies have been focused on the implementation of FACTS in deregulated electricity market [1-9]. This paper presents the simulation studies of the power system which undergo various changes in its OPF when it is subjected to congestion and after it is alleviated from congestion by locating TCSC. Simulation studies are performed to investigate the impact of TCSC and OPF on congestion levels of the 6 bus test system [12].

The paper is organized as follows. Section 2 discusses the Power System Congestion and its management methods. The Mathematical model of TCSC is outlined in Section 3. Simulation Studies to investigate the functioning of the power system under various operational aspects are presented in Section 4 followed by Conclusion in Section 5.

2. POWER SYSTEM CONGESTION AND ITS MANAGEMENT METHODS

Congestion is a technical problem occurs in a deregulated power scenario when the producers and consumers of electric power desire to produce and consume in amounts that would cause the transmission system to operate at or beyond the transfer limits. It causes hindrance to the optimal power flow in the transmission lines and to the safe operation of power system. Generally two Congestion Management methodologies [2] are used:

A. Cost free method

- Out-ageing of congested lines
- Operation of transformer taps/phase shifters
- Operation of FACTS Devices.

B. Non-Cost free method

- Re-dispatching the generation amounts.
- Curtailment of loads and the exercise of load interruption options.

Cost free methods do not include GENCO and DISCO i.e., economical matters are not involved and congestion is relieved technically. Whereas, non-cost free method were dealt economically.

3. MATHEMATICAL MODEL OF TCSC

TCSC can be modeled as Power Injection Models (PIM) as discussed in [6]. PIM does not change the symmetrical structure of the admittance matrix. Hence can be used with ease in OPF problem. During steady state TCSC can be considered as an additional reactance $-jx_c$. The simple steady state model of TCSC connected between bus-I and bus-j and the power injection model of TCSC connected in the transmission line is shown in Figure-1(a) and Figure-1(b), respectively.

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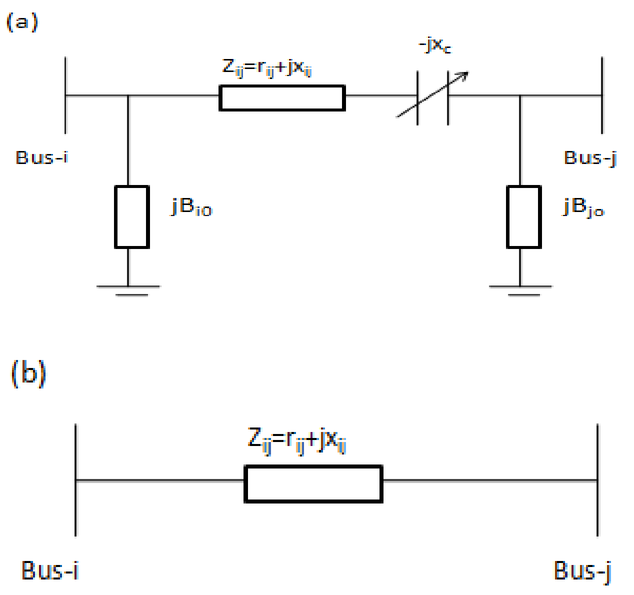

Figure-1. (a) Steady state model of transmission line with TCSC (b) Injection model of transmission line with TCSC.

By modifying the reactance of the transmission line, TCSC acts as capacitive or inductive compensation. The rating of the TCSC depends on the reactance of the transmission line where the TCSC is located [1-9].

$X_{ij} = X_{line}+X_{TCSC}$

Where,
$X_{TCSC} = -0.7\ X_{line}$ to $0.2X_{line}$

4. NEWTON RAPHSON POWER FLOW METHOD

Among the load flow solutions, Newton Raphson method is the solution method which has fast convergence. This is the conventional method of finding OPF of the system under study. The one line diagram of the six bus system [12] is shown in Figure-2 the system has three generators and three loads.

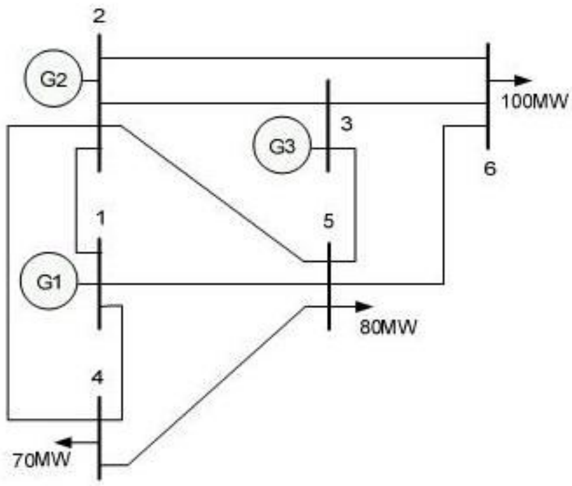

Figure-2. One line diagram - six bus system.

The cost function [12] is given in Table-1 where P is in MW and $ is a momentary unit which may be scaled by any arbitrary constant without affecting the results. P_{imin} and P_{imax} are the power limits of each generator.

Table-1. Bid prices of generators.

Generator	Price bids ($/h)	P_{imin}	P_{imax}
1	$0.00533P_1^2+11.669P_1+213.1$	50	200
2	$0.00889P_2^2+10.333P_2+200.0$	37.5	150
3	$0.00741P_3^2+10.833P_2+240.0$	45	180

A bilateral transaction of 50 MW is transacted between buses 2 and 5. The transaction produces congestion in some of the transmission lines. To relieve congestion TCSC is to be incorporated in the power system. As the FACTS device is much costlier and due to the uncertain market transactions care should be taken to choose the optimal location of FACTS device. In this paper, proper location is choosen by trail and error method. Compensation level is taken as 70% ($-0.7\ x_{line}$) [4, 6, 8, 9].

The Installation cost for the placement of TCSC is given by,

Installation Cost, IC = $\frac{C_{TCSC}\ x\ S_{TCSC}\ X\ 1000}{8760}$ $/hr

Where, $C_{TCSC} = 0.0015\ S^2_{TCSC} - 0.07130\ S_{TCSC}+153.75$ $/KVAR

S = operating range of TCSC which is normally – 0.7 Xl_{ine}

The Operational cost is obtained by

$$Y= \min \sum_{i=1}^{NG} Cpi(Pi) + IC$$

Where, $C_{pi}(P_i)$ is the cost function of generators N_G is no. of generators, 3.

5. SIMULATION RESULTS AND DISCUSSION

The behavior of the system has been analyzed in three cases.

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Case-1: The Load flow analysis of the 6 bus power system is performed with Newton Raphson Method. The line flow in MVA is given in Table-2.

Case-2: A bilateral transaction of 50 MW is made between the buses 2 and 5. It can be noticed that lines 2-3, 3-6 and 4-2 was congested whereas lines 2-1, 4-1 is almost transmitting Power below its rated capacity.

Table-2. Comparison of Power flows at various cases

Line		Line flows in MVA		
From	**To**	**Case A**	**Case B**	**Case C**
2	1	30.59	23.714	26.554
2	3	12.614	18.445	12.194
3	6	74.857	77.41	69.242
4	1	46.94	46.315	46.9
4	2	55.081	59.293	58.1

Case-3: TCSC is placed between buses 2 and 6. It can be seen that congestion has been relieved in the lines 2-3, 3-6 and 4-2. Moreover it improves the power transfer capability in the lines 2-1, 4-1.

The production cost of generators are given in Table-3.

Table-3. Production cost of generators.

	Power generated in MW	Generation cost in $
G1	33.83MW	613.9752
G2	95.42MW	1267.00
G3	80.74MW	1163.00

The Operational cost is found to be 611.5165 $/hr.

CONCLUSIONS

In this paper, simulation studies on the effects of TCSC in relieving congestion by conventional method tested on a standard six bus system has been presented. The level of compensation and location of TCSC in the power system was chosen by trial and error method. Though conventional method has been adopted, the results are much encouraging.

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