Available Transfer Capability Enhancement with Thyristor Controlled Series Compensator

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***Abstract*— Determination and enhancement of available transfer capability (ATC) are important issues in deregulated operation of power systems. The main objective is to estimate available transfer capability (ATC) from source area to sink area in sample 6 bus system using AC Power Transfer Distribution Factors (ACPTDF) method and to enhance it using TCSC. Simulations are done on MATLAB programming.**

***Index Terms*— Available Transfer Capability (ATC), ACPTDF method, Thyristor Controlled Series Compensator (TCSC).**

I. INTRODUCTION

The main objective of deregulated system is to promote competitive markets for electric power trading. Under new environment, the main consequence of the nondiscriminatory open-access requirement is the substantial increase in power transfers. The Available Transfer Capability of a system is the unused transfer capabilities for the transfer of power for further commercial activity. The market participants use the value of ATC for their transaction planning. Hence it is essential to estimate ATC value accurately with lesser computation time. Various ATC boosting methods have been experienced by adjusting generators terminal voltages, under load tap changers (ULTCs), and rescheduling generator outputs.

With the capability of flexible power flow , FACTS technology has introduced a severe impact to the transmission system utilization.

II. RELATED WORK

There are many methods to compute ATC. Power transfer distribution factors based on DC load flow were proposed to calculate transfer capability[4]. The fact that DCPTDFs are easy to calculate and give quick estimate of ATC made them attractive. But because DC load flow ignores voltage and reactive power effects, ATC calculated using DC-PTDFs may lead to unacceptable results.AC power transfer distribution factors are introduced to study the impact of small power transaction and contingencies[5]. Recently use of AC-PTDFs for transfer capability calculation is investigated. AC-PTDFs are based on derivatives around the given operating point.

Another most common approach to calculate transfer capability is continuation power flow . This method requires repeated solution of power flow. ATC results obtained by CPF based methods are accurate because it considers system non-linearity and control changes. It becomes very time consuming when applied on larger systems and cannot be used in real-time[3].

A new iterative method for ATC calculation, which uses the base case power flow solution as the starting point was also proposed in[12]. It considers the control changes and does not require sequential solution of power flow, making it accurate and fast for real time application. However, the assumption is made that system has large stability margin for both generator and voltage stability. The ATC value obtained from this method is lesser when compared to ACPTDF method[12].

ATC is calculated using ACPTDF and Available Transfer Capability is enhanced using TCSC . The inductive reactance of the line is compensated by connecting TCSC in series with the line. Both bilateral and multilateral transactions are considered[13].

III. METHODOLOGY

Available Transfer Capability (ATC) is a measure of the transfer capability remaining in the physical transmission network for further commercial activity over and above the already committed uses. Mathematically, ATC is defined as the Total Transfer Capability (TTC) less the Transmission Reliability Margin (TRM), less the sum of existing transmission commitments and the Capacity Benefit Margin(CBM).

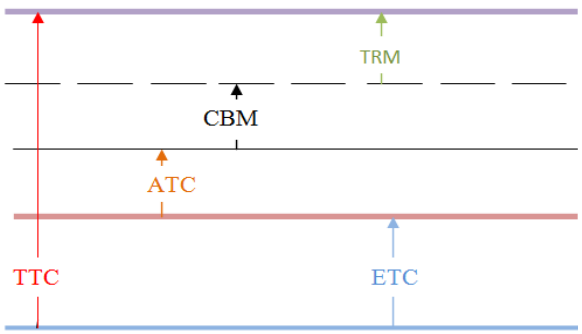

Fig.1 ATC Definition

ATC at base case, between bus m and bus n using line flow limit (thermal limit) criterion is mathematically formulated using ACPTDF (or) PTDF as

$$ATC_{mn} = min\{T_{ij,mn}\}, i,j \in N_L \tag{1}$$

$$T_{ij,mn} = \begin{cases} \frac{P_{ij}^{max} - P_{ij}^{0}}{PTDF_{ij,mn}} \; ; PTDF_{ij,mn} > 0 \\ \infty(infinite); \; PTDF_{ij,mn} = 0 \\ \frac{-P_{ij}^{max} - P_{ij}^{0}}{PTDF_{ij,mn}} ; PTDF_{ij,mn} < 0 \end{cases} \tag{2}$$

where P_{ij}^{max} is the MW power limit of a line between bus i and j

P_{ij}^{0} is the base case power flow in line between bus i and j

$PTDF_{ij,mn}$ is the power transfer distribution factor for the line between bus i and j when a transaction is taking place between bus m and n

N_L is the total number of lines

A. ACPTDF Method

ACPTDFs proposed for the calculation of ATC were used to find various transmission system quantities for a change in MW transaction at different operating conditions. Consider a bilateral transaction tk between a seller bus m and buyer bus n. Line 1 carries the part of the transacted power and is connected between buses i and j. For a change in real power, transaction among the above buyers and sellers by Δtk MW, if the change in a transmission line quantity ql is Δql, PTDFs can be defined as,

$$ACPTDF_{ij,mn} = \frac{\Delta ql}{\Delta tk} \tag{3}$$

The transmission quantity ql can be either real power flow from bus i to j (Pij)or j to i (P ji). The above factors have been proposed to compute at a base-case load flow results using the sensitivity properties of NRLF Jacobian.

$$\begin{pmatrix} \Delta\delta \\ \Delta V \end{pmatrix} = \begin{pmatrix} \frac{\partial P}{\partial \delta} & \frac{\partial P}{\partial V} \\ \frac{\partial Q}{\partial \delta} & \frac{\partial Q}{\partial V} \end{pmatrix}^{-1} \begin{pmatrix} \Delta P \\ \Delta Q \end{pmatrix} = \begin{pmatrix} J_T \end{pmatrix}^{-1} \begin{pmatrix} \Delta P \\ \Delta Q \end{pmatrix}$$

In the above equation the change in active power flow of line i-j with respect to changes in state variables is determined as :

$$\frac{\partial P_{ij}}{\partial \delta_e} = \begin{cases} 0 & \text{for } e \neq i,j \\ -V_i V_j Y_{ij} \sin(\delta_i - \delta_j - \theta_{ij}) & \text{for } e = i \\ V_i V_j Y_{ij} \sin(\delta_i - \delta_j - \theta_{ij}) & \text{for } e = j \end{cases} \tag{4}$$

$$\frac{\partial P_{ij}}{\partial V_e} = \begin{cases} 0 & \text{for } e \neq i,j \\ -2V_i Y_{ij} \cos\theta_{ij} + V_j Y_{ij} \cos(\delta_i - \delta_j - \theta_{ij}) & \text{for } e = i \\ V_i V_j Y_{ij} \sin(\delta_i - \delta_j - \theta_{ij}) & \text{for } e = j \end{cases}$$

(5)

B. MODELING OF TCSC

TCSC has been modeled as a variable reactance inserted in series with the transmission line. The model of TCSC is shown in Fig.2

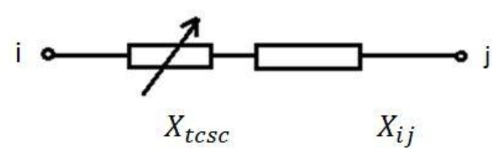

Fig. 2 Equivalent circuit of a line with TCSC

$$X_{line} = X_{ij} + X_{tcsc} \tag{6}$$

$$X_{tcsc} = r_{tcsc} \times X_{ij}$$

(7)

where X_{ij} is the reactance of the transmission line and r_{tcsc} is the degree of compensation of TCSC

C. PROPOSED ALGORITHM

The basic steps involved in enhancing ATC values with TCSC device are given below:

Step1: Read the system line data and bus data.

Step 2: Run the base case power flow.
Step 3: Consider wheeling transactions.
Step 4:Compute AC power transfer distribution factors.
Step 5: Take transactions as variables ,line flow, real and reactive power limits of generators as constraints and compute ATC.
Step 6: Find the limiting element in the system buses ie, that carry power close to thermal limit.
Step 7: Place TCSC in the limiting element.
Step 8: Calculate ATC after incorporating TCSC.
Step 9: Is any other transaction has to be carried, then consider the next transaction and go to step 3, otherwise stop the procedure.

IV. RESULTS AND DISCUSSION

The assessment of ATC using ACPTDF method has been conducted on sample 6 bus system. It has 3 generators and 11 transmission lines. Code1, Code2, Code3 are used for slack bus, voltage-controlled buses and the load buses respectively.

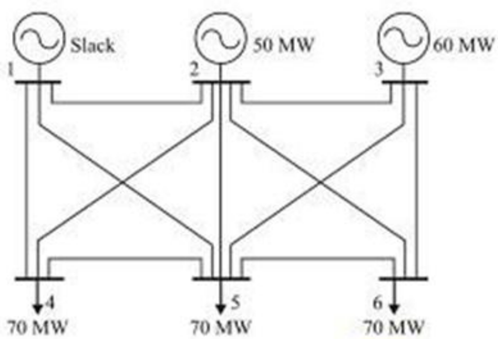

Fig.3 Sample six bus system

The obtained ATC values after placing TCSC in limiting element line number 4 (from bus 2 to bus 3) is as shown below.

Table 1:ATC – Sample 6 bus system

Line No	ATC without TCSC(MW)	ATC with TCSC(MW)
1	1.8477	9.5703
2	4.8971	124.077
3	6.6850	22.343
4	0.2996	6.3778
5	0.3731	7.6575
6	0.7902	5.0779
7	0.3227	16.1633
8	0.9326	51.7427
9	0.8381	26.7650
10	1.8575	10.0808
11	0.3426	20.8880

V. CONCLUSION

In this paper, a simple and efficient method for determining the available transfer capability of the system under normal condition has been studied. The calculation of ATC value for 6-bus system is defined by MATLAB programming. Simulation results shows that ATC value has enhanced when TCSC is placed in the limiting line.

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BIOGRAPHY

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