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Available Transfer Capability Enhancement with TCSC using Firefly Algorithm

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ABSTRACT: The main objective is to estimate available transfer capability (ATC) in sample 6 bus system using AC Power Transfer Distribution Factors (ACPTDF) method and to enhance it using TCSC. Optimal location of FACTS devices such as Thyristor Controlled Series Capacitor (TCSC) is to be done on sample 6 bus system using Firefly algorithm. Firefly algorithm is a nature inspired meta-heuristic algorithm for solving optimization problems which mimics the flashing behaviour of fireflies. Simulations are done on MATLAB programming.

KEYWORDS: Available Transfer Capability (ATC), ACPTDF method, Firefly Algorithm (FA), 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.

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 powerflow . 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 proposedin[12]. It considers the control changes and does not require sequential solution of power flow, making it accurate and fast for realtime 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]. Population based,search algorithms are very popular in the recent years in the research arena of computational intelligence. PSO [11] and GA [8] are some well established search algorithms implemented successfully to solve complex problems.

GA is population based search approach motivated by evolution as seen in nature. PSO is obtained from the simulation of social behaviour. PSO and GA are used to obtain optimal settings of TCSC . The results are obtained for both IEEE 30 bus and IEEE 118 bus systems[13].Effectiveness of Self Adaptive Firefly Algorithm for optimally placing

SVC tominimise transmission losses in power system is done in [14].The method has been tested on IEEE 14,30 and 57 bus test systems.

II.AVAILABLE TRANSFER CAPABILITY

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).

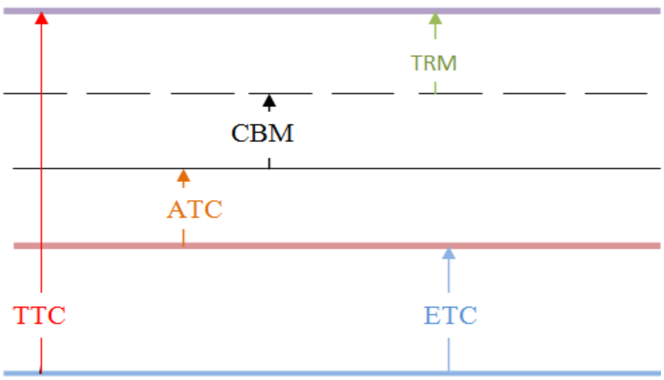

Fig.1ATC Definition

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

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

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

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

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,

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

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.

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

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

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

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

III. MODELING OF TCSC

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

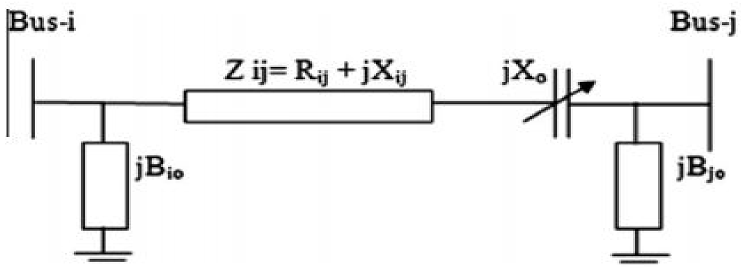

Fig 2 Equivalent circuit of a line with TCSC

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

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

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

IV.FIREFLY ALGORITHM

FA is a nature inspired meta-heuristic algorithm which has been developedby Xin She Yang at Cambridge university in 2007.The algorithm mimics the flashing behaviour of fireflies. It is similar to other optimization algorithms employing swarm intelligence such as PSO. But FA is found to have superior performance in many cases.

• All fireflies are unisexual, so that one firefly will be attracted to all other fireflies.

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• Attractiveness is proportional to their brightness, the less brighter one will be attractedtowards the brighter one.

• If there are no fireflies brighter than a given firefly, it will move randomly

The number of fireflies in the swarm is known as the population size, N.The selection of population size depends on the specific optimization problem. A population size of 20 to 50 is used for PSO and FA for most applications.

Each m_{th} firefly is denoted by a vector x_m as

$$x_m = [x_m^1, x_m^2, \ldots x_m^{nd}]$$

Every time the algorithm is executed and the optimization process starts with a different setof initial points. In each case, the algorithm searches for the optimum solution. In the case of multiple possible sets of solutions, the proposed algorithm may converge on different solutions each time. Although each of those solutions will be valid as they all will satisfy the requirement. The light intensity of the m_{th}firefly,I_m is given by

$$I_m = Fitness(x_m)$$

The attractiveness between m_{th} and n_{th} firefly, $\beta_{m,n}$ is given by

$$\beta_{m,n} = (\beta_{max,m,n} - \beta_{min,m,n})exp(-\gamma_m r_{m,n}^2) + \beta_{min,m,n}$$

where

$$r_{m,n} = \|x_m - x_n\| = \sqrt{\sum_{v=1}^{nd} (x_m^k - x_n^k)^2}$$

$r_{m,n}$ = Cartesian distance between mth and nth firefly

γ= Absorption parameter

k= Number of Iterations

The value of $\beta_{m,n}$ is taken as 0.2 and the value of β_{max} is taken as 1.γ is another constant whose value is related to the dynamic range of the solution space.The position of firefly is updated in each iterative step.If the light intensity of n_{th} firefly is larger than the intensity of the m_{th} firefly, then the m_{th} firefly moves towards the n_{th} firefly and its motion at the k_{th} iteration is denoted by the following equation.

$$x_m(k) = x_m(k-1) + \beta_{m,n}(x_m(k-1) - x_m(k)) + \alpha(rand - 0.5)$$

The random movement factor α is a constant whose value depends on the dynamic range of the solution space. At each iterative step, the intensity and the attractiveness of each firefly is calculated. The intensity of each firefly is compared with all other fireflies and the positions of the fireflies are updated . After sufficient number of iterations, the global optimum is achieved.

V.PROPOSED ALGORITHM

The basic steps involved in enhancing ATC values with TCSC device using Firefly algorithm 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.

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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: Run Firefly algorithm to obtain settings of TCSC.

Step 9: Calculate ATC after incorporating TCSC.

Step 10 : Is any other transaction has to be carried, then consider the next transaction and go to step 3, otherwise stop the procedure.

VI. SIMULATION 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 andthe load buses respectively.

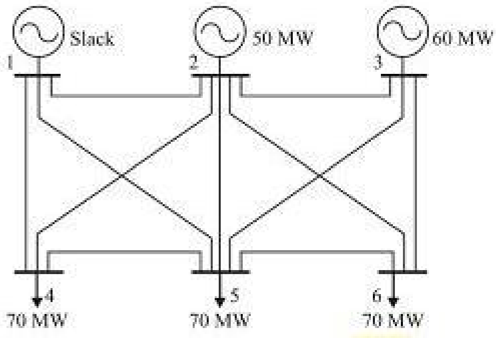

Fig.3 Sample six bus system

The optimal location obtained using firefly algorithm is line 9 (from bus 3 to bus 6) and the obtained ATC values after placing TCSC 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	143.2873
3	6.6850	21.9326
4	0.2996	6.4072
5	0.3731	7.5038
6	0.7902	5.0358
7	0.3227	19.3180
8	0.9326	49.0170
9	0.8381	18.6075
10	1.8575	10.1088
11	0.3426	15.9308

ATC values has enhanced when TCSC is placed in the optimal location of sample 6 bus system.

VII.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

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programming.Simulation results shows that ATC value has enhanced when TCSC is placed at the location obtained using Firefly Algorithm.

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