

Available Transfer Capability Calculation Using ACPTDF & DCPTDF on IEEE-24 bus System Under Deregulated Environment

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Abstract - After the Deregulation of the Electric utility, the competition among different Generation & Distribution companies is growing day by day. Due to this competition, the transmission lines are more influenced with the transactions between sellers & buyers. This is the main reason for congestion in transmission lines. So, to manage the congestion in transmission lines, the ISO needs the value of Available Transfer Capability for each and every transmission line. So, the value of ATC is of at most priority before any transaction to be feasible. In this paper the ATC is found by AC power flow & DC power flow methods. The results are obtained on IEEE 24-bus system & compare these results with sample calculations.

Keywords – Available Transfer Capability (ATC), AC Power Transfer Distribution Factors (ACPTDFs), DC Power Flow, DC Power Transfer Distribution Factors (DCPTDFs).

1. INTRODUCTION

Due to the Deregulation of electric utility the chances of congestion in transmission lines is more pronounced. Due to this the value of Available Transfer Capability is very should be made available on a publically accessible Open Access Same-time Information System (OASIS) [1] & [2]. According to NERC definitions, ATC is defined as the transfer capability remaining in the physical transmission network for further commercial activity over and above committed uses [3]. It can also be given by Total Transfer Capability (TTC) less the existing transmission commitments (ETC) [4]. Important for ISO to avoid congestion. FERC admits that the Available Transfer Capability (ATC) information.

The value of ATC determination mainly depends on the value of maximum power that can be flow in a transmission line. It is simply the thermal rating of the transmission line beyond which the transmission line could break. The value of ATC is not fixed, because the conditions in a power system are not fixed. The value of ATC could be change due to transmission line breakage, shut down of a generator unit etc. so, the value of ATC needs to be calculated again & again. Due to line and generator outages the value of ATC varies continuously

and this varied value should be provided online to each & everyone. There are various methods available for ATC determination. These methods are: Continuation Power Flow (CPF) [6], Optimal Power Flow (OPF) [7], DC Power Flow [8], and AC Power Flow [9]. Continuation Power Flow method is very accurate method of ATC determination. By this method, the singularity of jacobian matrix is avoided. The predictor & corrector scheme is used in this method. The main disadvantage of the CPF method is that it take more iterations to solve a particular problem, hence it is very time consuming. Optimal Power Flow method uses the linear & non linear equations to optimize the problem. The whole problem is subjected to some constrains depending upon the objective function. This is very accurate method of ATC determination. DC Power Flow method is an approximate solution of ATC calculation. In this method, the system is assumed to be loss less & there is no reactive power flowing through the transmission lines. This method uses very less space & less time to solve a problem. The values obtained by this method are not much accurate but simply an indication about the values of ATC to the seller or buyer [10]. AC Power Flow method is very accurate method of ATC calculation. This method provide much accurate results which are very close to the real time system [11].

In this paper PTDF based scheme is used using the AC & DC Power Flow methods. In DC Power Flow model only the line reactance is used and a flat voltage start is assumed. The main objective of this is to calculate bus angles, so that the real power flows in each line can be calculated. ATC is calculated by using the AC & DC power flow methods and their results are compared. The results are obtained on IEEE 24- bus system.

2. DC POWER FLOW

In DC Power Flow model the line resistance is assumed to be zero, because the $r \ll x$, and voltage of each bus is 1 p.u. By considering all these assumptions the NR load flow equations becomes simple and are called DC power flow equations. DC power flow equations show the relationship between bus angle vector $[\delta]$ and power injection vector $[P]$ for an n-bus system. It is given by:

$$[P] = [B][\delta] \quad (1)$$

Where $[B]$ is the $n \times n$ susceptance matrix, whose elements are given by:

$$\begin{aligned} B_{ij} &= -b_{ij} \forall ij \neq j \\ B_{ii} &= \sum_{j=1}^n b_{ij} \quad i = 1, 2, \dots, n \end{aligned} \quad (2)$$

By selecting any bus to be the reference bus from the n -buses, the row and column corresponding to the reference bus can be eliminated from $[B]$ matrix.

The $[X]_{bus}$ can be obtained by simply taking the inverse of $[B]$ matrix.

3. ATC DETERMINATION FOR INTACT SYSTEM

The injected power ΔP_i is simply given by the generated power less the load at that bus. The element corresponding to the slack bus is taken equals to zero.

$$[\Delta \delta_i] = [X]_{bus} [\Delta P_i] \quad (3)$$

Where $[\Delta \delta_i]$ is a matrix which shows change in voltage angle at any bus i .

By using this we can find change in voltage angle of any of the lines, connected by two buses.

The real power flows in a line connected between bus i and j using DC power flow is given by [12]:

$$P_{ij} = [\delta_i - \delta_j] / x_{ij} \quad (4)$$

Where δ_i & δ_j are the phase angles of bus i & j respectively & x_{ij} is the line reactance.

DCPTDFs are defined as the coefficient of the linear relationship between the amount of a transaction and the flow on a line. As it relates the amount of one change i.e. transaction amount to another change i.e. the lone flow. PTFDF is the fraction of amount of a transaction from one zone to another over a specified transmission line. They express how the power flow in transmission lines changes in response to the transaction between a particular seller and buyer bus. The DCPTDFs for a line between buses i and j and a transaction between a seller bus m and buyer bus n can be given by:

$$DCPTDF_{ij-mn} = [X_{im} - X_{jm} - X_{in} - X_{jn}] / x_{ij} \quad (5)$$

Where x_{ij} is the reactance of the line between bus i and j & X_{im} is the element of reactance matrix.

A. ATC determination

Whenever a transaction occurs between two buses, the real power flows of the lines changes. This is due to the change in angle. This change in line flows is given by:

$$[\Delta P_{ij}] = DCPTDF_t^* P_t \quad (6)$$

Now the total line flows will be the sum of base case real power flow and the change in line flows. Mathematically it can be written as:

$$P_{tot} = P_{ij} + \Delta P_{ij} \quad (7)$$

P_t is a column matrix which indicates the amount of power transferred between seller bus and buyer bus. The seller bus acts the source and the buyer bus acts as the sink for the power or the positive injection and negative injection, respectively. The entries in this matrix is +1 for seller bus and -1 for the buyer bus, all other elements will be zero for single transactions.

The maximum allowable capability of the transaction using DCPTDF is given by:

$$P_{ij-mn}^{max} = [P_{ij}^{max} - P_{ij}] / DCPTDF_{ij,mn} \quad (8)$$

Where, P_{ij}^{max} is the maximum transfer limit of the line between bus i and j .

Now the ATC can be expressed mathematically as [13]:

$$ATC_{mn} = \min \{ P_{ij,mn}^{max} \mid ij \in nl \} \quad (9)$$

Where, nl is the total number of lines in the system.

4. AC POWER FLOW

The AC power flow method of ATC calculation is an iterative method. We first calculate the jacobian matrix for the line flow calculations by using the Y_{bus} matrix. After calculating the jacobian matrix, the ACPTDF are calculated. AC power transfer distribution factors are described as linear sensitivities calculated at initial operating point and can be derived from Jacobin matrix of an operating point load flow. The ACPTDF are given by the formula:

$$DCPTDF_{ij-mn} = \Delta P_{ij} / \Delta P_{mn} \quad (10)$$

For PTFDF calculation using AC load approach, the power flow sensitivity and Jacobian of power injection equations is required. The Jacobian can be calculated using N-R load flow based approach. The power flow equations in polar form can be represented as [14]:

$$P_i = \sum_{j=1}^N |V_i| |V_j| |Y_{ij}| \{ \cos(Q_{ij} - \delta_i - \delta_j) \} \quad (11)$$

$$Q_i = \sum_{j=1}^N |V_i| |V_j| |Y_{ij}| \{ \sin(Q_{ij} - \delta_i - \delta_j) \} \quad (12)$$

Where $|V_i|$ & $|V_j|$ are the voltages of sending end & receiving end buses. δ_i & δ_j are the bus angles.

Using taylor series expansion, the change in power flow at any bus I can be formulated in jacobian as:

$$\begin{pmatrix} \Delta P \\ \Delta Q \end{pmatrix} = \begin{bmatrix} J1 & J2 \\ J3 & J4 \end{bmatrix} \begin{pmatrix} \Delta \delta \\ \Delta V \end{pmatrix} \quad (13)$$

Where,

$$J1 = \partial P / \partial \delta ; J2 = \partial P / \partial V ; J3 = \partial Q / \partial \delta ; J4 = \partial Q / \partial V \quad (14)$$

Change in angle and voltage can be determined as:

$$\begin{pmatrix} \Delta \delta \\ \Delta V \end{pmatrix} = inv \begin{bmatrix} J1 & J2 \\ J3 & J4 \end{bmatrix} \begin{pmatrix} \Delta P \\ \Delta Q \end{pmatrix} \quad (15)$$

Consider that the base case load flow result at the operating point is available; hence the Jacobin matrix can be written as It is simply the Newton-Raphson method of line flow calculation.

5. TEST RESULTS

The results of this technique have been obtained for IEEE 24- bus system. The results include the value of DCPTDF & ACPTDF for different transactions. ATC is calculated for different transactions using both AC power flow & DC power flow. ATC is calculated for all the transmission lines in the IEEE 24- bus system.

Fig. 1 shows the single line diagram of IEEE 24- bus test system. Fig. 2 shows the value of DCPTDFs for all the transmission lines in graphical form. Fig. 3 shows the values of ATC for all transmission lines using DCPTDF.

Fig. 4 shows the value of ACPTDFs for all the transmission lines for linear ATC in graphical form. Fig. 5 shows the values of ATC for all transmission lines using AC Power Flow. Fig. 6 the values of ACPTDF's for all transmission lines considering reactive power. Fig. 7 the values of ATC for all transactions using AC Power Flow for reactive power. Table 1 shows the comparison of ATC values calculated using AC & DC power flow methods with sample calculations.

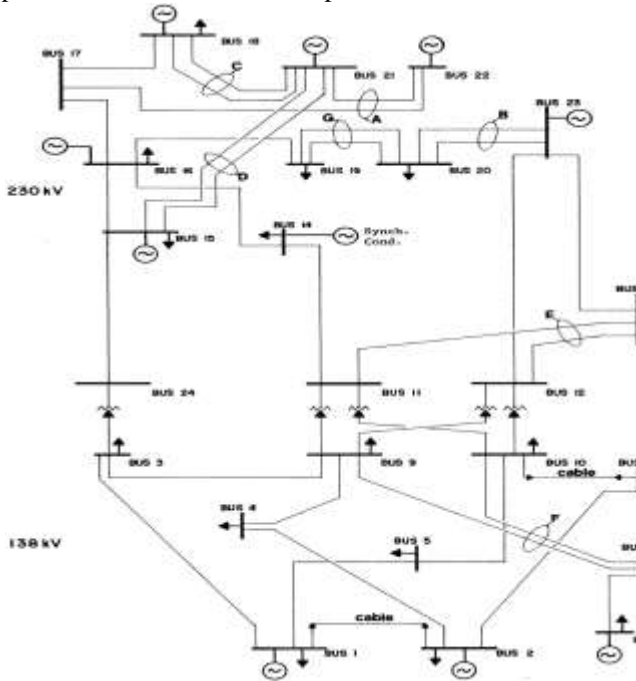


Fig. 1. Single line diagram of IEEE 24- bus system

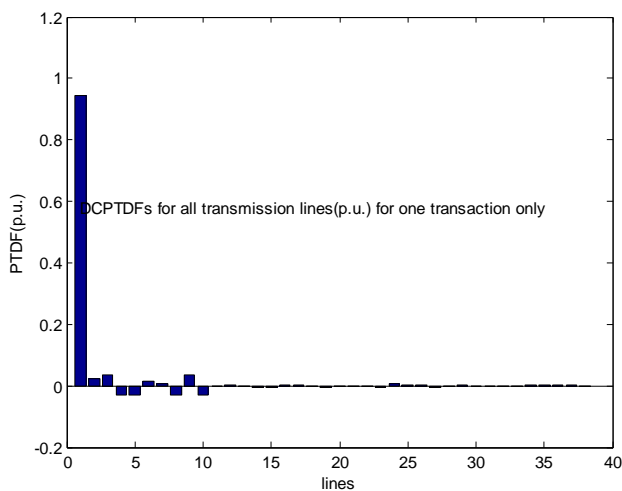


Fig. 2. DCPTDF for all transmission lines

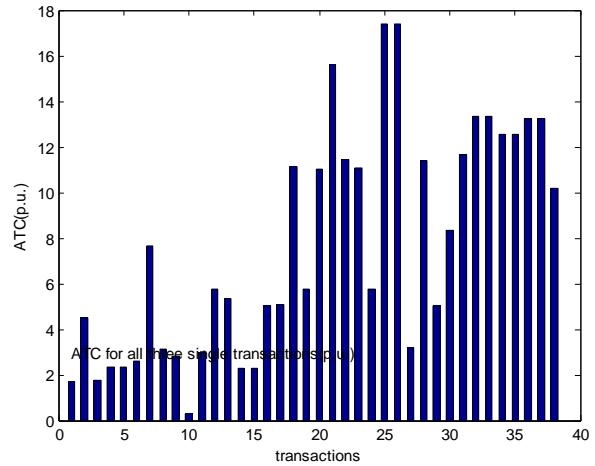


Fig. 3. Values of ATC for all transmission lines using DCPTDF

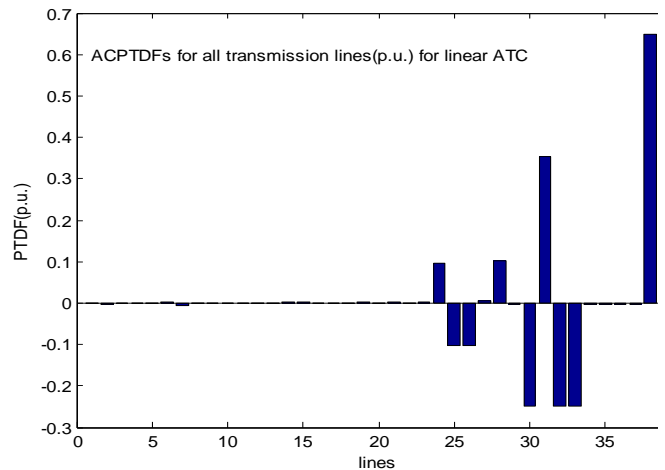


Fig. 4. ACPTDF for all transmission lines for linear ATC

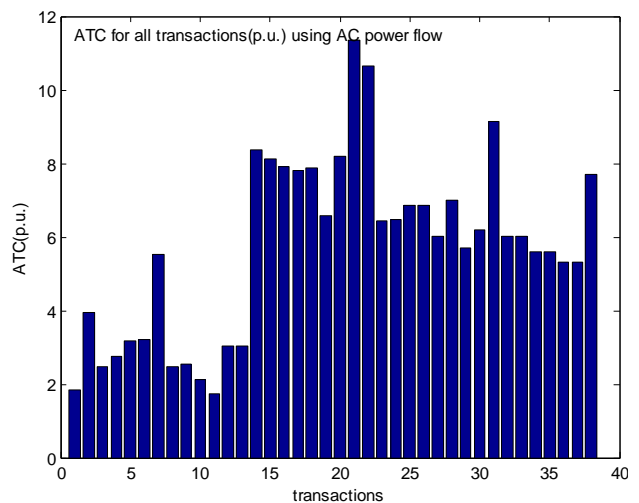


Fig. 5. The values of ATC for all transmission lines using AC Power Flow

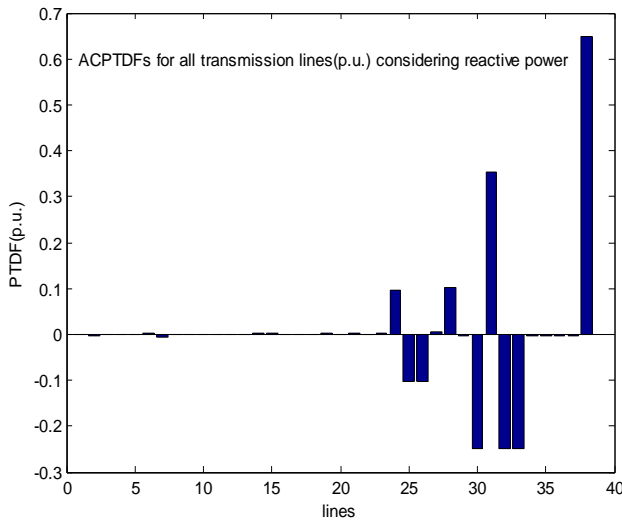


Fig. 6. The values of ACPTDF's for all transmission lines considering. Reactive Power

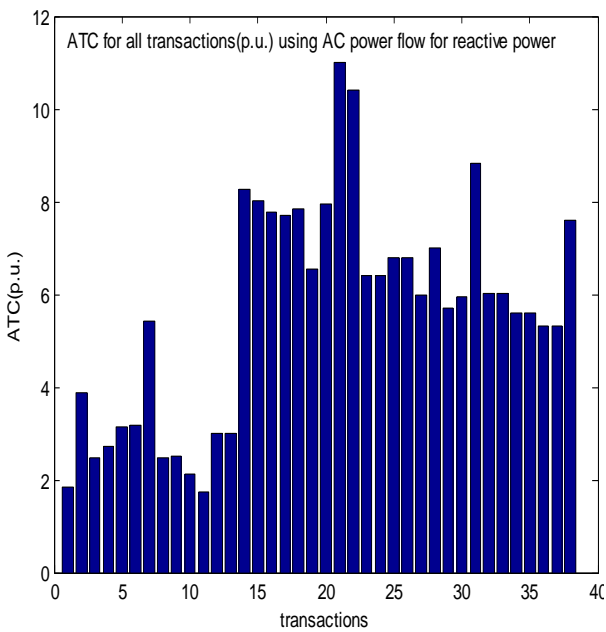


Fig. 7. The values of ATC for all transactions using AC Power Flow for reactive power

Table(1) comparison of ATC values using AC & DC Power Flow methods with sample calculations

	Sample Calculation	MATLAB Software Calculation
Method used	ATC for Transmission line (1- 2)	ATC for Transmission line (1- 2)
DC power flow	1.85	1.75
AC power flow	1.85	1.85

6. CONCLUSION

ATC is calculated using AC & DC power flow methods. The system is assumed to be intact. ATC calculation using DC power flow method is very fast because of no iterations. Most of the time this method is used to find the ATC, before any transaction. By this method operators can easily choose the maximum ATC value transaction, to maximize their profit. This method gives the approximate values of ATC, by which we can get a rough idea of ATC values without using much time. This simply gives an idea about the best transaction based on the value of ATC. But the AC power flow method is very accurate method of ATC calculation. The reactive power is also considered in this method. It is seen from the results that the ATC found by AC power flow method is less than the ATC found by DC power flow method.

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