Single/Multiple Transaction ATC Determination For Intact/Contingency Cases Using Sensitivity Factors

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Abstract: Due to the Deregulation of electricity industry, the competition is growing day by day between the Generators as well as in Distributors. But due to the competition in electricity market, it may cause congestion in the transmission lines and can cause black out in any area. This will affect not only the generation of electricity but also the consumers. To avoid this problem, in competitive electricity market it is very necessary to post the available transfer capability of a transmission network online, so that everyone can excess it and the congestion can be avoided. In this paper DC Power flow and power transfer distribution factors are used to calculate the available transfer capability of the network. The method used in this paper can be used for multiple as well as single transactions. In this paper some transactions are chosen and available transfer capability for both intact and contingency cases are calculated. The above said methodology is applied on IEEE 30-bus test system.

Keywords: Available Transfer Capability (ATC), DC Power Flow, DC Power Transfer Distribution Factors (DCPTDFs), Line Outage Distribution Factors (LODFs), and Generator Outage Distribution Factors (GODFs).

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I. INTRODUCTION

Before the deregulation of electric power industry, the number of transactions through a particular transmission network was limited. But after deregulation the number of bilateral/multilateral transactions increases tremendously. So to avoid the congestion into the transmission network, the value of ATC should be available to the operator before any transaction. FERCadmits that the Available Transfer Capability (ATC) information 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 canalsobe given by Total Transfer Capability(TTC)less the existing transmission commitments (ETC) [4]. The value of ATC determination mainly depends on the value of TTC. TTC is basically the thermal limit of a transmission line. It can also be given by themaximum power flow in a transmission line without overloading it. There are various factors whichaffect the value of ATC [5], like weather conditions, line contingencies, and generator contingencies. So, for calculating the accurate value of ATC we have to consider these factors. Due to line and generator outages the value of ATC varies continuously and this varied value should be posted on OASIS on regular basis.

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 methodgives accurate values of ATC and consider thermal limit, voltage limit, stability limit. But this method takes more time due to more iteration. Optimal Power Flow method is also accurate but it considers thermal limit and voltage limit. It is also more time consuming for larger systems. DC Power Flow method considers only the thermal limit. In this method only real power flow is considered. This method is not much accurate but it is a non-iterative method and provides ATC values very quickly.AC Power Flow method considers both the real and reactive power flow. This method gives more accurate results than the DC Power Flow, but due to the reactive power incorporation it is more complex. In this paper PTDF based scheme is used using the DC Power Flow method. In DC Power Flow model only the line reactance is used and all the bus voltages are set to 1 p .u. The main objective of this is to calculate bus angles, so that the real power flows in each line can be calculated. ATCis calculated for single as well as for multiple transactions. Line contingencies are used to show the effect of line removal on the value of ATC. Generator outage distribution factors are used to consider the generator contingencies and its effect on the value of ATC. This methodology is employed on IEEE-30 bus system.

II. DC POWER FLOW MODEL REVIEW

In DC Power Flow model the line resistance is assumed to be zero, because the r << 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:

$$[\boldsymbol{P}] = [\boldsymbol{B}][\boldsymbol{\delta}] \quad \textbf{(1)}$$

Where $[\boldsymbol{B}]$ is the n x n susceptance matrix, whose elements are given by:

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$$B_{ij} = -b_{ij} \forall_{ij} i \neq j$$

$$B_{ii} = \sum_{j=1}^{n} b_{ij} i = 1, 2, \ldots, n \quad (2)$$

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

III. 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:

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

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. PTDF 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:

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

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

A. Single Transaction 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.

B. Multiple transaction ATC determination

In multiple transaction, the value of P_t changes. During these transactions there will be two or more than two seller and buyer buses. P_t Will be +1 for all the seller buses and -1 for all the buyer buses. Mathematically this change in P_t can be expressed as:

$$P_t = \begin{bmatrix} 0 \\ +1 \\ . \\ . \\ 0 \\ -1 \\ 0 \\ 0 \\ +1 \\ . \\ . \\ -1 \end{bmatrix}$$

The DCPTDFs have been used to calculate the ATC of the intact system for different transactions. The seller bus is denoted by *m* and buyer bus is denoted by *n.* 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:

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

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

IV. ATC DETERMINATION USING LINE CONTINGENCY

Line contingencies have a significant effect on the value of ATC. Whenever a line is removed from a network, the value of ATC decreases for each transaction. The removal of any line from the network increases the burden on other lines, due to this they reach close to their thermal limit and their ATC value decreases.To show the effect of line contingencies, we have used the line outage distribution factors (LODFs) [8] in combination with the PTDFs. LODF is a sensitivity measure of how a change in line's status affects the line flows on other lines of the system. By using LODFs we can only remove a single line from the existing network. Outage transfer distribution factors (OTDFs) is the function of LODFs and PTDFs, used to find the ATC in line contingency case [11]. LODF can be expressed mathematically as:

$$DCLODF_{ij-rs} = \frac{x_{rs}(X_{ir} - X_{is} - X_{jr} + X_{js})}{x_{ij}[x_{rs} - (X_{rr} + X_{ss} - 2X_{rs})]} \quad (10)$$

The outage transfer distribution factors are given by:

$$OTDF_{ij,rs}=PTDF_{ij,mn}+LODF_{ij,rs}*PTDF_{rs,mn}\quad(11)$$

The ATC can be calculated using outage transfer distribution factors as:

$$ATC_{mn,rs}=\min\left\{\frac{[P_{ij}^{max}-P_{ij}]}{OTDF_{ij,rs}}\quad \mathrm{ij}\ \varepsilon\ nl\right\}\quad(12)$$

V. ATC DETERMINATION USING GENERATOR CONTINGENCY

Generator contingency means if any of the generators is out of the network due to any problem. Like line contingencies, generator contingencies also affect the value of ATC. To consider the effect of generator contingencies, we have to find the generator outage distribution factors (GODFs) [10]. Generator outage distribution factors are the sensitivity of the MW power flow on any line ij, due to the outage of generation at any bus k. The change in generation due to any generator outage is equally compensated by the opposite change at the reference bus.GODFs are simply equals to the PTDFs for this transaction. Due to the generator outage the power flow in the lines changes. This change in power flow is given by:

$$\Delta P_{ij,k}=GODF_{ij,k}*\ -P_k\quad(13)$$

Where, $P_k$is theamount of generation that the generator was generating before itsoutage.

$$P_{chg}=\Delta P_{ij,k}+P_{tot}\quad(14)$$

The ATC can be calculated by considering the generator outage as:

$$ATC_{mn,k}=\min\left\{\frac{[P_{ij}^{max}-P_{chg}]}{GODF_{ij,k}}\quad \mathrm{ij}\ \varepsilon\ nl\right\}\quad(15)$$

In this paper the generator outage and its effect on ATC values are shown.

VI. TEST RESULTS

The results of this technique have been obtained for IEEE 30 bus system. The results include the value of PTDF for different transactions and Real power flow is calculated for both intact and contingency cases. ATC is calculated for different transactions in both intact and contingency cases. Both the line contingency and generator contingencies are considered. ATC is also calculated for multiple line contingencies and for generator addition cases. Few transactions are chosen for which the results are shown. Those transactions are:

(i) Single transactions

- Transaction between bus 23 to bus 30
- Transaction between bus 17 to bus 4
- Transaction between bus 10 to bus 15

(ii) Multi-transactions

- Transaction between buses 23, 27 and buses 30, 1
- Transaction between buses 23, 17, 13 and buses 30, 4, 5

Fig. 1 shows the single line diagram of IEEE 30 bus test system. Fig. 2 shows the value of DCPTDFs for single transactions in graphical form for an intact system. Fig. 3 shows the results of DCPTDFs for multi-transaction for intact system. Fig. 4 shows the results for real power flows in all transmission lines for an intact system. Fig. 5 shows the values of ATC for all transactions for an intact system. Fig. 6 shows the values of LODFs for line 15 from the network. Fig. 7 shows the results of DCPTDF with line 15 out of the network. Fig. 8 shows the results for real power flow with the outage of line 15. Fig. 9 shows the results of ATC values for all transactions with outage of line 15. Fig. 10 shows the way real power flow changes with the outage of generator from bus 23. Fig. 11 shows the values of ATC with generator 23out of the existing network. Fig. 12 shows the result for the ATC with generator 27 out of the existing network.

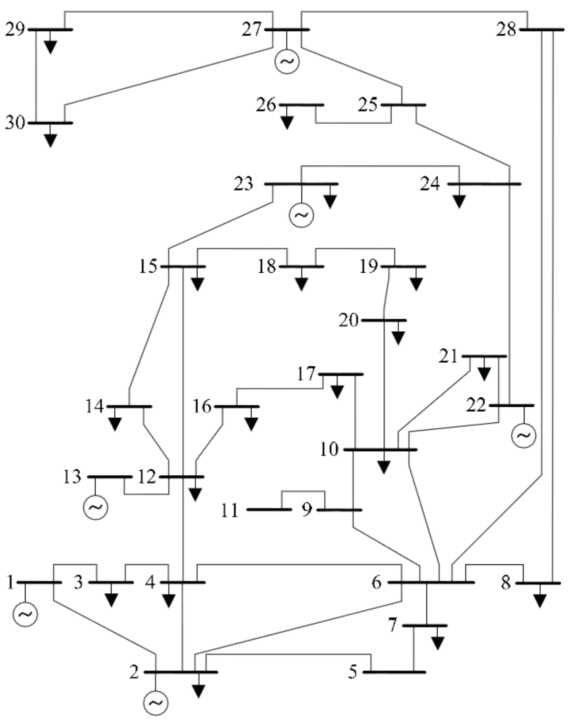

Figure 1: Single line diagram of IEEE 30 bus system

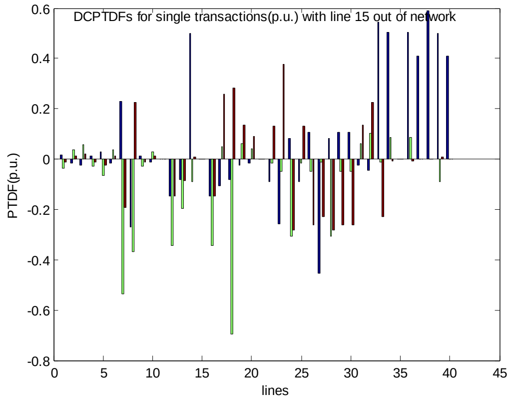

Figure 2: DCPTDF for single transactions for intact system

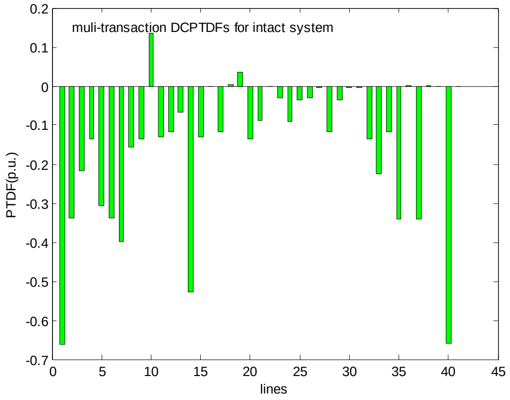

Figure 3: PTDF for multi-transaction for intact system

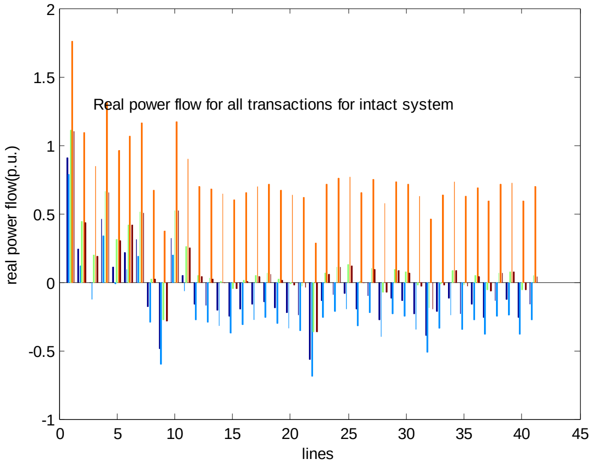

Figure 4: Real power flowsfor intact system

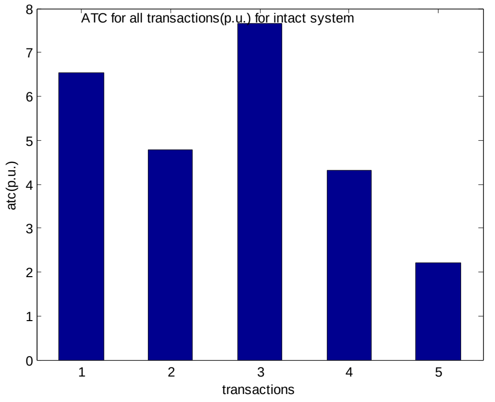

Figure 5: ATC of all transactions for intact system

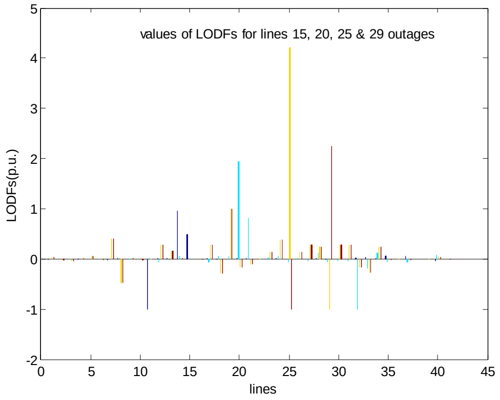

Figure 6: values of LODF for the outage of lines 15, 20, 25 & 29 from the network

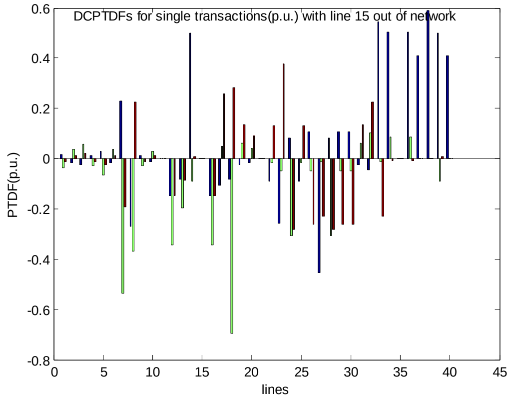

Figure 7: PTDF for single transactions with line 15 out of the network

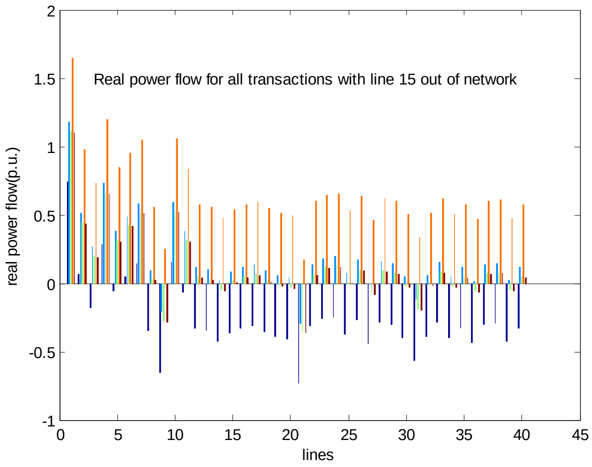

Figure8: Real power flows with line 15 out of network

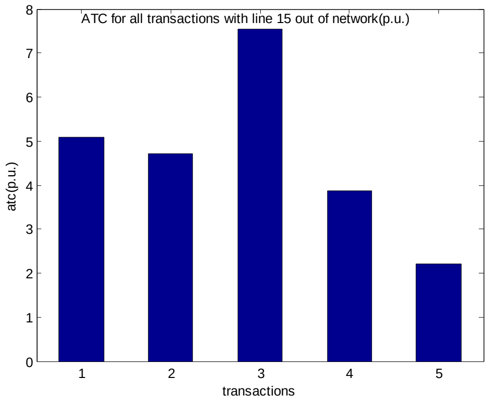

Figure 9: ATC for all transactions when line 15 out of the network

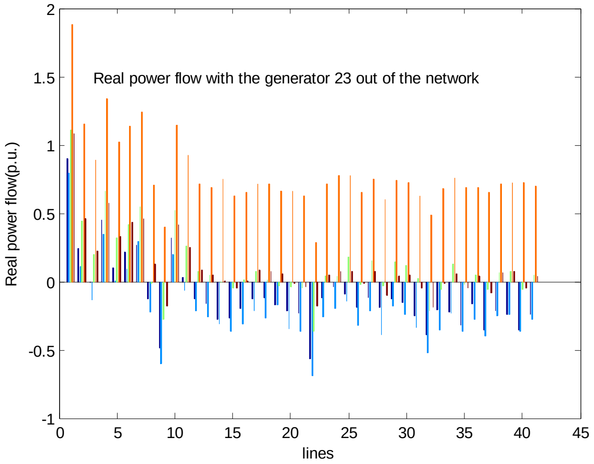

Figure 10: Real power flows with generator 23 out of the network

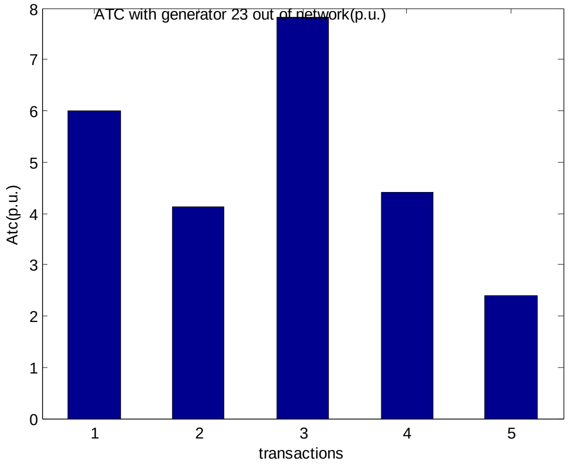

Figure 11: ATC for all transactions with generator 23 out of the network

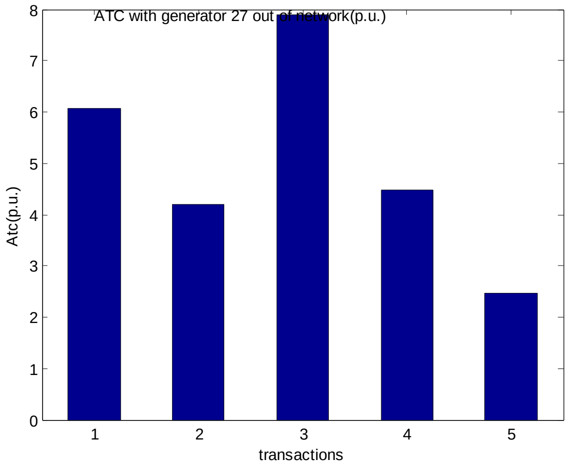

Figure 12: ATC for all transactions with generator 27 out of the network

VII. CONCLUSION

In this paper the ATC is calculated using DC power flow model for both single and multi-transactions. The ATC is calculated for both intact as well contingency cases. Two types of contingencies are used in this paper, one is line contingency and the other is generator contingency. GODFs are used to consider the generator contingencies. ATC calculation using DC power flow method is very fast because of no iterations. Most of the operators used this method to find ATC before any transaction. By this method operators can easily choose the maximum ATC value transaction, to maximize their profit. This simply gives an idea about the best transaction based on the value of ATC. This paper expresses how the real power flow for different transactions changes with both types of contingencies and hence the ATC.

VIII. REFERENCES

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