ATC calculation in Deregulated Power System Using Power World Simulator

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Abstract: A fair competition needs open access and non-discriminatory operation of the transmission network. Available Transfer Capability (ATC) is a measure of the remaining power transfer capability of the transmission network for further transactions. Available transfer capability in the transmission network has become essential quantity to be declared well in advance for its commercial use in a competitive electricity market. The ATC values are estimated for DC power flow model and AC power flow model using Power transfer distribution factors (PTDFs) at different transactions. We predicted the PTDF is different for different transactions and ATC is also different for the transactions. Single transactions between one buyer bus and one seller bus have been carried out using Power World simulator tool on IEEE 14 bus test system for both AC and DC load flow model. The solutions obtained are quite encouraging and useful in the present restructuring environment.

Keywords*: *Available Transfer Capability (ATC), Power Transfer Distribution Factor (PTDF), Power World simulator

I. INTRODUCTION

Available transfer capability in the transmission network has become essential quantity to be declared well in advance for its commercial use in a competitive electricitymarket. Electric power industries throughout the world have been restructured to introduce competition among the market participants and bring several competitive opportunities. A fair competition needs open access and non-discriminatory operation of the transmission network. Open access to the transmission system places an emphasis on the intensive use of the interconnected network reliably, which requires knowledge of the network capability. Available Transfer Capability (ATC) is a measure of the remaining power transfer capability of the transmission network for further transactions.[1]

Its fast computation using DC load flow based approach is used worldwide for on line implementation. Many authors have proposed the ATC calculation based on DC/AC load flow approach. AC PTDF based approach has been proposed for multi-transaction cases using power transfer sensitivity and Jacobian calculated with three different methods. The methods can be implemented for any number of transactions occurring simultaneously.

The linear dc power transfer distribution factors (DC PTDF) based on dc power flow method, is possibly the only allocation technique presently in widespread use to allocate MW flows on the lines for a transaction in the system. However, this has a poor accuracy due to the assumptions involved in the dc power flow model.

In a fast decoupled power flow model for transmission allocation has been suggested, which is based on linearizing ac power flow equations and using incremental steps based on current power flow state. However, it does not allocate losses to individual transactions. In a physical flow-based transmission loss allocation scheme based on expressing loss explicitly in terms of all transactions in a power system network was proposed. However, error between the system losses evaluated by ac load flow (ACLF) and the losses using the methodology based on were relatively high. The ac power transfer distribution factors, computed at a base case, have been used to find various transmission system quantities for a change in MW transactions at different operating conditions.

This paper explains the calculation of ATC values using Power world simulator tool. The time consumption for determining ATC values are reduced by applying this tool. The transactions are considered as single transactions. The ATC value for both DC and AC load flow model is found. The proposed method is illustrated on IEEE- 14 bus system.

II. ATC PRINCIPLES

Available Transfer Capability (ATC) is a measure of the transfer capability remaining in the physical transmission network for further commercial activity over and above 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 (which includes retail customer service) and the Capacity Benefit Margin (CBM). All transmission provider and user entities are expected to abide by these Principles.

ATC calculations must produce commercially viable results. ATCs produced by the calculations must give a reasonable and dependable indication of transfer capabilities available to the electric power market.

ATC calculations must recognize time-variant power flow conditions on the entire interconnected transmission network. In addition, the effects of simultaneous transfers and parallel path flows throughout the network must be addressed from a reliability viewpoint.

ATC calculations must recognize the dependency of ATC on the points of electric power injection, the directions of transfers across the interconnected transmission network, and the points of power extraction. All entities must provide sufficient information necessary for the calculation of ATC.

Regional or wide-area coordination is necessary to develop and post information that reasonably reflects the ATCs of the interconnected transmission network.

ATC calculations must conform to NERC, Regional, sub regional, power pool, and individual system reliability planning and operating policies, criteria, or guides.

The determination of ATC must accommodate reasonable uncertainties in system conditions and provide operating flexibility to ensure the secure operation of the interconnected network.

As such, they are viewed as reasonable indicators of network performance and available transfer capability.

III. ATC CALCULATION

The calculation of transfer capability [2] is generally based on computer simulations of the operation of the interconnected transmission network under a specific set of assumed operating conditions.

$$ATC = TTC - TRM - CBM - ETC \qquad (1)$$

Where,

TTC is ***Total Transfer Capability*** and defined as the amount of electric power that can be transferred over the interconnected transmission network in a reliable manner while meeting all of a specific set of defined pre- and post-contingency system conditions.

TRM is ***Transmission Reliability Margin*** and defined as that amount of transmission transfer capability necessary to ensure that the interconnected transmission network is secure under a reasonable range of uncertainties in system conditions.

CBM is ***Capacity Benefit Margin*** and defined as that amount of transmission transfer capability reserved by load serving entities to ensure access to generation from interconnected systems to meet generation reliability requirements.

IV. METHODS FOR ATC CALCULATION

Network Sensitivity Factor based Approach: Real time congestion management requires very fast relief of congestion otherwise it threatens system security and stability both. So it very important for Independent system operator (ISO) to identify the most sensitive zones as quickly as possible. This network sensitivity methodhelps system operator (ISO) to provide accurate and fast information about the contribution of each generatorsand load to congestion line.

The two different methods to find network sensitivity factor is as shown below:

1) ATC calculation using Power Transfer Distribution Factor (PTCDF)DC Load Flow Based Approach (DC Method)

2) ATC calculation using Power Transfer Distribution Factor (PTCDF) AC Load Flow Based Approach (AC Method)

1. DC Power Transfer Distribution Factor Method

DC power transfer distribution factor method [3] is called linear sensitivity method because it relates one change (transaction) to other change (line flow). A transaction is a specific amount of power that is injected at one bus (generator bus) and removed at another bus (load bus). DC power transfer distribution method use DC load flow model.

Several assumptions are taken for DC load flow model.

1) Transmission lines are lossless.
2) Resistance is less than the Reactance.
3) Voltage Magnitudes at each bus is 1 per unit.
4) Small variation in angles.
5) Reactive power flow is not considered.
6) Only angles of complex bus voltages vary.

The amount of a transaction and line flow is represented by DCPTDF. It is also called sensitivity because it relates amount of one change to another change.With above assumptions, the Newton - Raphson load flow equations are modified.

$$DCPTDF_{ij,lm} = \frac{\Delta P_{ij}}{P_{lm}} \quad (2)$$

Where,

P_{ij} – power flow from bus I to bus j

P_{lm} – transaction from bus l to bus m

$$DCPTDF_{ij,lm} = \frac{X_{il} - X_{jl} - X_{im} + X_{jm}}{x_{ij}} \quad (3)$$

X_{ij} – entry in the ith row and jth column of bus reactance matrix

ATC is determined by recognizing the new flow on line from node i to j, due to a transaction from node l to m. The new flow on line is the sum of original flow and the change.

$$P_{lm,ij}^{max} = \frac{P_{ij}^{max} - P_{ij}^{0}}{DCPTDF_{ij,lm}} \quad (4)$$

$$ATC_{lm} = min\left(P_{lm,ij}^{max}\right) \quad \forall ij \quad (5)$$

2. *AC Power Transfer Distribution Factor*

Consider a transaction between a seller bus, m and buyer bus, n. Further consider a line, „l" carrying a part of the transaction power. Let the line be connected between a bus-i and a bus-j. For a change in real power transaction between the above seller and buyer say by, if the change in transmission line quantity is, the AC power transfer distribution factors can be defined as:

$$\Delta P_{lm} = \left[\frac{\partial P_{lm}}{\partial \delta_2}, \dots\dots, \frac{\partial P_{lm}}{\partial \delta_n} \frac{\partial P_{lm}}{\partial V_{g+1}}, \dots\dots, \frac{\partial P_{lm}}{\partial V_n}\right] [J^{-1}] \begin{bmatrix} 0 \\ \vdots \\ +P_t \\ 0 \\ \vdots \\ -P_t \\ 0 \end{bmatrix} = d_t P_t \quad (6)$$

ATC is determined by recognizing new flow from node l to node m, due to a transaction from node i to node j. the new flow on the line is sum of original flow and its change.

$$P_{lm}^{New} = P_{lm}^{0} + d_{lm,ij} P_{ij} \quad (7)$$

Where,

$d_{lm,ij}$ – PTDF for line lm due to transaction ij.

P_{lm}^{o} – base case flow on the line lm

P_{m}^{max} –maximum power that can be transferred

ATC is the minimum of minimum allowable transactions over all the lines.

$$P_{ij,lm}^{max} = \frac{P_{lm}^{max} - P_{lm}^{0}}{d_{lm,ij}} \quad (8)$$

$$ATC_{ij} = \min_{lm} P_{ij,lm}^{max} \quad (9)$$

V. ALGORITHM

ATC calculations have been carried over using optimization algorithms [4]. Based on the power transfer capacity limit, the system overloading is easily determined. This paper submits Power world simulator based ATC calculation in the deregulated power system.

The procedure for calculating the ATC is given as follows

Step1: Input data file & run base-case load flow.
Step2: Read line flows using Newton-Raphson method
Step3: Input number of transaction, seller bus & buyer bus.
Step4: Find PTDF for AC and DC load flow models
Step5: Find out Maximum Allowable transaction for all possible Transaction & for all line
Step6: Find ATC (Available transfer capacity) minimum of all possible maximum Allowable transaction.
Step7: Check for convergence (Is transaction is over?)
Step8: If "no" go to step (5)
Step9: If "yes" calculate final ATC & Print results.

V. SIMULATION RESULTS

In this chapter, the discussion about the results of Available Transfer Capability (ATC) with respect to Power Transfer Distribution Factors (PTDFs) for DC and AC load flow model at different transactions are described. The ATC values are only calculated without any outage of generator /load. The simulation results have been tested on IEEE 14 bus system. The test system has 4 generator buses, 9 load buses and bus1 as a slack bus. The maximum generating capacity is and the maximum load capacity is . The results include PTDF calculations for intact system in case of all transactions.

Based on the PTDFs, ATC have been calculated for all transaction cases. In this paper, ATC values for different transactions have been taken as single transaction only(single buyer to single seller bus) for DC as well as AC load flow models. These transactions have been categorized as:

T1: Transaction between seller buses **1**to buyer bus **2**
T2: Transaction between seller buses **2**to buyer bus **5**
T3: Transaction between seller bus **3 and** buyer bus 4
T4: Transaction between seller bus 6 and buyer bus **12.**
T5: Transaction between seller buses **4 and** buyer bus **5**

The PTDF values for Transaction 1 at AC and DC load flow models are given in Table1 and Figure.1

Table.1 PTDF value for Transaction1

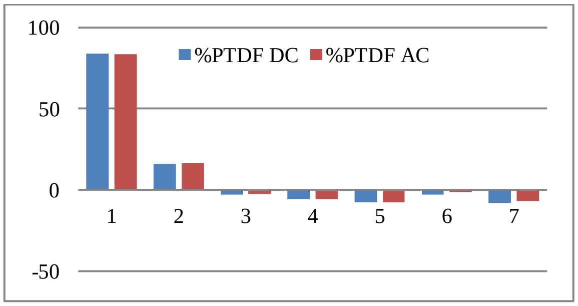
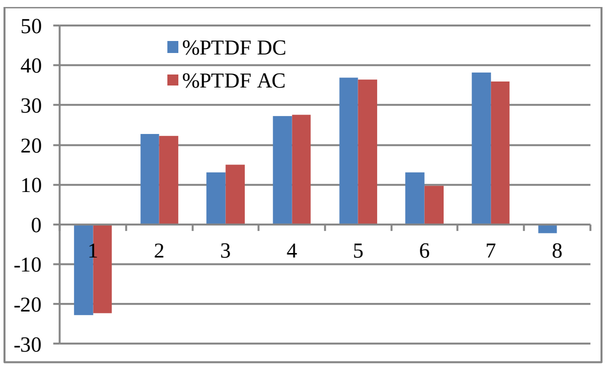


Figure.1 PTDF values for Transaction 1 at AC and DC load flow models

The PTDF values for Transaction 2 at AC and DC load flow models are given in Table1 and Figure.1

Table.2 PTDF value for Transaction 2



FROM BUS	TO BUS	DC	AC	
		%PTDF	%PTDF	%LOSSES
1	2	-22.75	-22.30	-1.25
1	5	22.75	22.30	2.32
2	3	13.04	14.99	5.23
2	4	27.29	27.59	3.55
2	5	36.92	36.37	3.07
3	4	13.04	9.77	-3.72
4	5	38.17	35.90	-1.47
5	6	-2.17	0	0

Figure.2 PTDF values for Transaction 2 at AC and DC load flow models

The PTDF values for Transaction 3 at AC and DC load flow models are given in Table 3 and Figure.3

S.No	FROM BUS	TO BUS	DC	AC	
			%PTDF	%PTDF	%LOSSES
1	1	2	-7.90	-8.17	-0.46
2	1	5	7.90	8.17	0.85
3	2	3	-38.07	-36.62	-13.46
4	2	4	17.34	17.71	2.28
5	2	5	12.83	13.20	1.12
6	3	4	61.93	42.45	-23.59
7	4	5	-91.62	-17.32	0.83

Table.3 PTDF value for Transaction 3

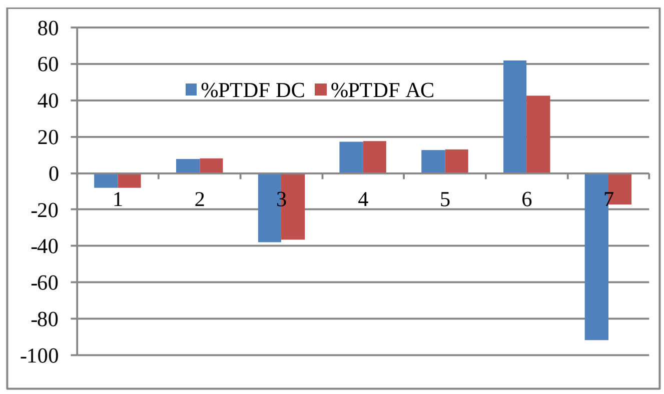


Figure.3 PTDF values for Transaction 3 at AC and DC load flow models

The PTDF values for Transaction 4 and Transaction 5 at AC and DC load flow models are given in Table4, Figure.4 and Table.5, Figure. 5 respectively

FROM BUS	TO BUS	DC	AC	
		%PTDF	%PTDF	%LOSSES
1	2	83.80	83.57	4.63
1	5	16.20	16.43	1.71
2	3	-2.73	-2.30	-0.80
2	4	-5.72	-5.61	-0.73
2	5	-7.74	-7.60	-0.65
3	4	-2.73	-1.50	1.04
4	5	-8.00	-6.95	0.34

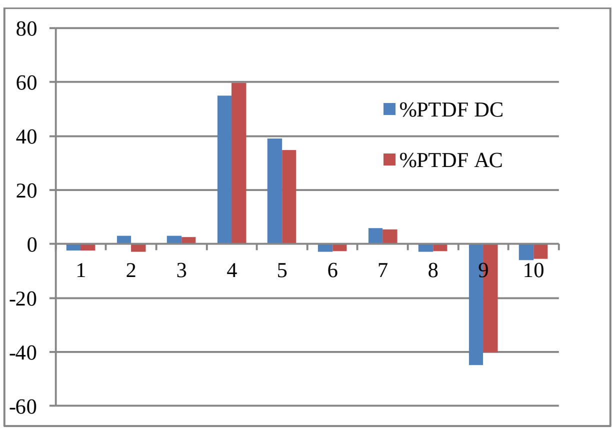
eISSN 1303-5150

NeuroQuantology| December 2022 | Volume 20 | Issue 20 | Page 1361-1366 | doi: 10.48047/NQ.2022.20.20.NQ109139

Table.5 PTDF value for Transaction 5

S.No	FROM BUS	TO BUS	DC	AC	
			%PTDF	%PTDF	%LOSSES
1	1	2	-5.69	-6.664	-0.37
2	1	5	5.69	6.64	0.69
3	2	3	-4.83	-6.97	-2.43
4	2	4	-10.11	-9.89	-1.25
5	2	5	9.24	10.60	0.90
6	3	4	-4.83	-4.54	0.73
7	4	5	80.49	81.26	-3.60
8	4	7	2.91	3.08	-0.00
9	5	6	-4.57	-4.95	-0.00
10	6	11	-2.71	-3.01	-0.00
11	7	9	2.91	3.08	-0.03
12	9	10	2.75	2.93	-0.01
13	10	11	2.75	2.94	-0.03

Table.4 PTDF value for Transaction 4



FROM BUS	TO BUS	DC	AC	
		%PTDF	%PTDF	%LOSSES
4	5	-2.46	-2.38	0.10
5	6	2.91	-2.95	0.00
6	11	3.00	2.63	0.03
6	12	55.03	59.65	0.13
6	13	39.05	34.76	0.14
9	10	-3.00	-2.57	0.01
9	14	5.92	5.35	-0.05
10	11	-3.00	-2.58	0.02
12	13	-44.97	-40.23	-0.14
13	14	-5.92	-5.47	-0.07

Figure.4 PTDF values for Transaction 4 at AC and DC load flow models

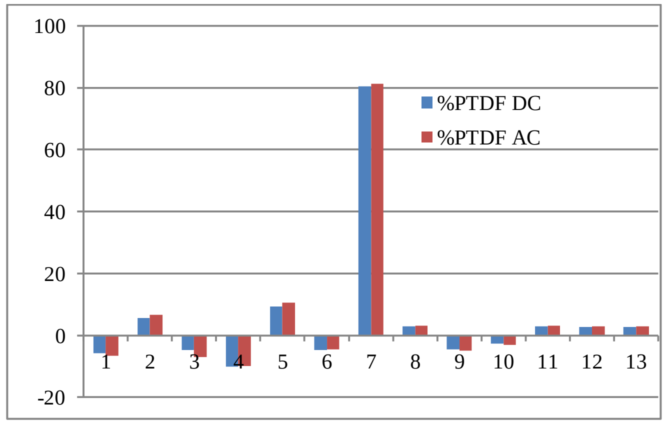


Figure.5 PTDF values for Transaction 5 at AC and DC load flow models

The ATC value for above discussed transactions are given in Table.6

TRANSACTIONS	ATC VALUE (Mw)	
	DC MODEL	AC MODEL
T1	73.08	76.04
T2	126.29	124.62
T3	-37.59	19.42
T4	46.56	46.21
T5	74	74.506

From Table6, it is clear that the value of ATC for AC load flow provides positive results than compared with DC load flow model. The ATC values are effectively calculated using Power world simulator tool within less time duration. The comparison of ATC value at DC and AC load flow model for the test system is shown in figure.6

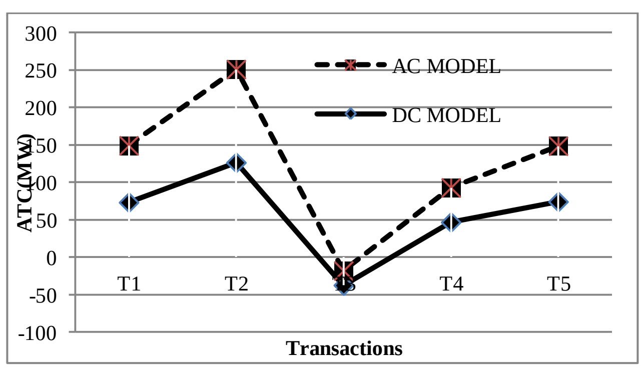


Figure.6 Comparison of ATC values

eISSN 1303-5150

The load flow diagram for the IEEE 14 bus test system using Power World Simulator tool is given in Figure.7

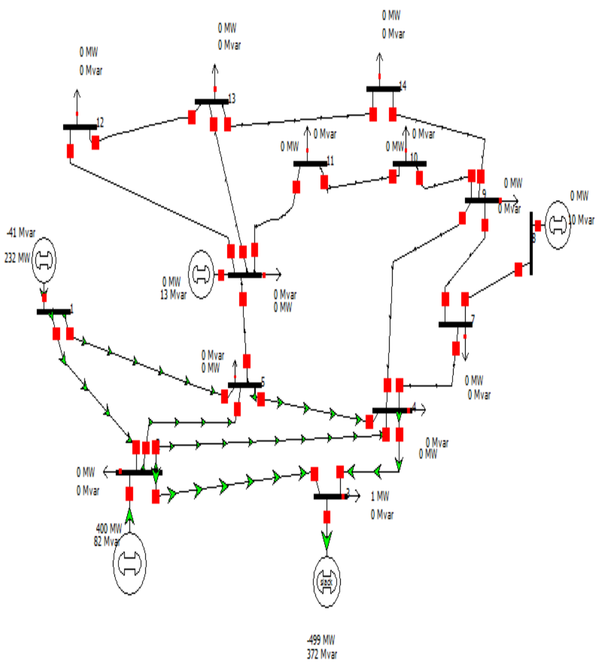


Figure.7 Power flow diagram of IEEE 14 bus system using Power World simulator tool

VI. CONCLUSION

It concludes that the development of the simulator tool as a suitable one for computing the change in any line quantity for a change in MW bilateral transaction. The proposed PTDFis more accurate as compared to power distribution factor. With ACPTDF and DCPTDF, the ATC can be calculated. Formultiple transactions ATC calculation is very important and mandatory too. In those cases, Power world simulator tool is applied for getting the transfer limits with less time consumption. ATC calculations can also be used tosolve congestion problem in restructured electrical power network.

Acknowledgement

The authors thank the management for preceding their research work within their institutions. The authors thank the staff members for their support and valuable suggestions.

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