Available Transfer Capability Determination using Linear Sensitivity based PTDF Method in Restructuring Power System

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Abstract---The demand of electricity is continuously increases day by day in today's market scenario and complexity arises all over the world due to huge population and modernization in developing countries. To meet the rapidly increasing demand and for the reliable operation we support private participation to generate the electricity. In the last few years the concept of deregulated market is more useful instead of regulated. Thus government has invited the private sectors into the power generation, transmission and distribution by fixing some certain rules over it called as restructuring power system. Having present of so many private participates congestion should be there. This type of competition in the power industry, there has been a search for the better utilization of the transmission facilities. In this contest Available Transfer Capability (ATC) indicates how much inter area power transfers can be increased without change in system security must be considered. Thus ATC calculation gives us an important indication of relative system security and reliability.

Keywords: Restructuring, available transfer capability, regulation, deregulation, ptdf

I. INTRODUCTION

Form the last few years restructuring scheme is adopted by the most of the developed and developing countries in today's electricity market. In restructuring market so many private Generation Company and Distribution Company are allowed to participate for electricity generation and distribution. The restructuring process starts with the unbundling of the originally vertically integrated utility. The unbundling of power industry involves separating transmission activity from the generation activity. Further, distribution can be separated from transmission. In the deregulated environment all the participants (producers and buyers of electrical energy) desire to produce or consume large amounts of energy and may force the transmission system to operate beyond one or more transfer limits. This kind of operation leads to congestion of the system. To handle this type of situation congestion management is necessary. Available transfer capability based congestion management is one of the method to solve this type of situation. Therefore accurate determination of available transfer capability is essential to ensure the system security and reliability for different power transactions.

II. ATC BASIC PRINCIPAL

In broad terms, ATC is defined as the maximum amount of additional MW power transfer possible between two parts i.e. Source to sink of a power system. With reference to the (NERC) report Available Transfer Capability is a measurement of the transfer capability remaining in the physical transmission network for further commercial activity, over and above already committed uses. In this market ISO (Independent system operator) has to disseminate the ATC between pair of source and sink at every periodic interval of the day. ISO would be responsible for monitoring its regional transmission and calculate its ATC for inside the network. ATC values for next hour in future are placed on website known as open access same time information system (OASIS) operated by ISO. Transfer capability of a transmission system is a measure of unutilized capability of the system at a given time and depends on a number of factors such as the system generation dispatch, system load level, load distribution in network, power transfer between areas and the limit imposed on the transmission network due to thermal limit, voltage limit and stability limit considerations. Different method is used for calculating the ATC such as linear sensitivity based method, continuous power flow, and optimal power flow. Among all of them linear sensitivity based PTDF method is extensively used in this market.

III. POWER TRANSFER DISTRIBUTION FACTOR

In any electric network power is transfer from one node to another. From the power flow point of view power injected in to the system at a one bus by generator is extracted by a load at another bus which is known as transaction. Transaction can be found from the linear property of DC load flow model using sensitivity factor PTDF. Power transfer distribution factor (PTDF) is defined as the coefficient of the linear relationship between the amount of a transaction and the flow on a line.

We can also say that PTDF is the fraction of amount of a transaction from one bus to another over a specified transmission line. PTDF rlsm, ikjk represents the fraction of a transaction from ik bus to bus jk that flows over a transmission line connecting bus rl to sm.

$$PTDF_{rlsm,ikjk} = \frac{\Delta p_{rlsm}}{p_{ikjk}}$$

The linear ATC values are calculated using DC based model is called DC power transfer distribution factor, and AC based model is called AC power transfer distribution factor. To finding a quick result DCPTDF method is more useful. In this paper we use DCPTDF method to calculate the ATC. A DC power model for the power system is being formulated where the following conditions are being assumed.

1) All the voltages magnitudes are constant
2) Line resistance is neglected since it is small compared to line reactance.

3) Only angles of the complex bus voltage vary and variation in angle is small.

4) Reactive power flow is ignored and all the transmission lines are lossless.

With these assumptions, power flow over transmission lines connecting bus ik and bus jk is given as under:

$$P_{rl,sm} = \frac{1}{x_{rl,sm}}(\theta_{rl} - \theta_{sm})$$

The total power flowing into the bus is

$$P_{ik} = \sum_{jk} P_{ikjk} = \sum_{jk} \frac{1}{x_{ikjk}}(\theta_{ik} - \theta_{jk})$$

This can be expressed in a matrix form as:

$$\begin{bmatrix} P_1 \\ M \\ P_n \end{bmatrix} = [B_X] \begin{bmatrix} \theta_1 \\ M \\ \theta_n \end{bmatrix}$$

Here, the elements of the succeptance matrix [BX] are functions of line reactance. One joint is assigned as a reference node by making its angle zero and deleting a corresponding row and column within the [BX] matrix. Thus,

$$[X_{\text{limit}}] = [B_X, \text{Re}\,duced]^{-1}$$

The dimension [Xlimit] of obtained is [n - 1 × n – 1] Let us augment it by adding zero column and row corresponding to reference bus. The equation can be found out reactance matrix is.

$$\begin{bmatrix} \theta_1 \\ M \\ \theta_n \end{bmatrix} = [X] \begin{bmatrix} P_1 \\ M \\ P_n \end{bmatrix}.$$

IV. ATC CALCULATION USING PTDF

Suppose there exists only one transaction in the system. Let the transaction be of 1 MW from bus ik to bus jk. Then, the corresponding entries in following equation Pi=1 and Pj = -1, All other entries will be zero so we get,

$$\theta_{rl} = [X_{rl} \quad rl \quad X_{rl,n-1}] \begin{bmatrix} 0 \\ +1 \\ -M \\ -1 \\ 0 \end{bmatrix}$$

Similarly we can write,

$$\theta_{sm} = [X_{sm} \quad sm \quad X_{sm,n-1}] \begin{bmatrix} 0 \\ 1 \\ M \\ -1 \\ 0 \end{bmatrix}$$

Thus we can write that,

$$\theta_{rl} = X_{rlik} - X_{rljk}$$

$$\theta_{sm} = X_{smik} - X_{smjk}$$

Using above equation PTDF can be calculated as, follow

$$PTDF_{rlsm,ikjk} = \frac{X_{rlik} - X_{smik} - X_{rljk} + X_{smjk}}{x_{rlsm}}$$

Where,

x_{rlsm} = Reactance of transmission lines connecting buses rl and sm

X_{rlik} = Entry rlth row and ikth column of the bus reactance matrix X.

ATC in the base case, between bus rl and bus sm using line flow limit criterion has been calculated using PTDF as follow,

$$P_{ikjk,rlsm}^{\max} = \frac{P_{rlsm}^{\max} - P_{rlsm}^{0}}{PTDF_{rlsm,ikjk}}$$

Where,

$P_{rlsm}^{\max}$ = MW power flow limit of a line between bus-rl and bus-sm.

P_{rlsm}^{0} = Base case power flow in the line between bus-rl and bus-sm.

$PTDF_{rlsm,ikjk}$ =Power Transfer Distribution Factors for the line between bus-rl and bus sm.

So finally we calculate ATC using following equation.

$$ATC_{ikjk} = \min(P_{ikjk,rlsm}^{\max})$$

Here we determinate the ATC value after calculation of PTDF using above equation. Maximum power flow limit of the line minus base case power flow through the same line divided by PTDF of the same line is the maximum power transfer capability of that line. The minimum of all these values is the ATC of the system.

V. CASE STUDIES AND RESULTS

A. *TEST CASE*

Here in this paper consider the IEEE 5-bus test system and IEEE-14 bus test system for ATC calculation using PTDF method at various transaction demands. The bus data and line data and also maximum power flow limit should be considered in this paper. The bus data and line data of the system is available on IEEE standard. IEEE-5 bus system has a 1 slack bus, 1 generator bus, and 3 load bus shown in Figure 1 and also IEEE-14 bus system has 1 slack bus, 4 generator bus, 9 load bus and 20 transmission line as shown in figure 2.

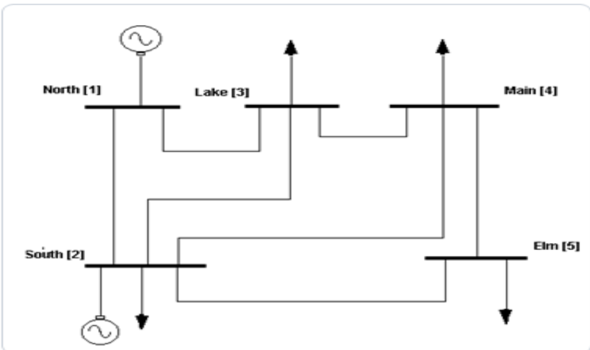

Fig. 1: IEEE 5-Bus Test System

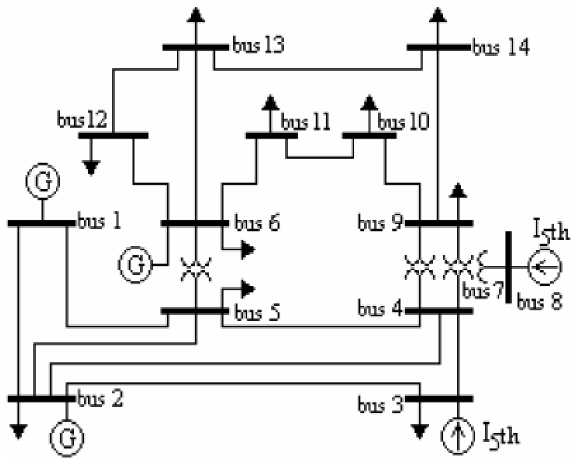

Fig. 2: IEEE 14-Bus Test System

VI. RESULTS AND DISCUSSION.

The formulated problem is solved in MATLAB. The results are taken on IEEE-5 and IEEE 14-bus sample system. To understand Sensitivity Analysis and ATC calculation of the System, we calculate PTDF among all the line for different transaction, and also actual line flows passing through different line. To obtain the reactance matrix called as [X] matrix is prime necessary for the calculation of PTDF. It is obtained when susceptance matrix is function of line reactance, and one node is assigned as reference node by making its angle zero and deleting corresponding row and column in it and takes the inverse of that matrix. After calculating the reactance matrix we get PTDF values among all the lines for different transaction.

Case 1, IEEE-5 bus system

The different transactions are chosen for IEEE-5 bus test system is as under.

T1: transaction between seller bus 1 to buyer bus 2.
T2: transaction between seller bus1 to buyer bus 3.

T3: transaction between seller bus 2 to buyer bus 3.

T4: transaction between seller bus 2 to buyer bus 4.

T5: transaction between seller bus2 to buyer bus 5.

T6: transaction between seller bus 3 to buyer bus 4.

T7: transaction between seller bus 4 to buyer bus 5.

Among all possible transaction PTDF values for transaction T1 and transaction T2 are shown in Table 1.

Lines	PTDF (p.u)	
	T1	T2
1-2	0.8509	0.6390
1-3	0.1598	0.3757
2-3	-0.0706	0.2879
2-4	-0.0561	0.2310
2-5	-0.0268	0.1169
3-4	0.0870	-0.3414
4-5	0.0287	-0.1148

Table.1: PTDF value at different transaction

First we are determined the PTDF for transaction T1 at lines 1-2,1-3,2-3,2-4,2-5,3-4 and 4-5.In this way we have seen in Table.1 that the PTDF values varied from positive to negative. The same procedure is done for transactions T2 to T7. When the transaction T1 is applied then we see the effect of transaction T1 on the lines with respect to buses in Figure.3 and same for transaction T2 in Figure.4.

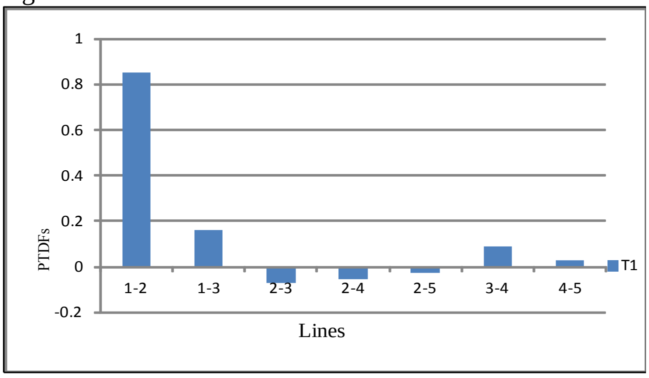

Fig.3: PTDFs for transaction T1

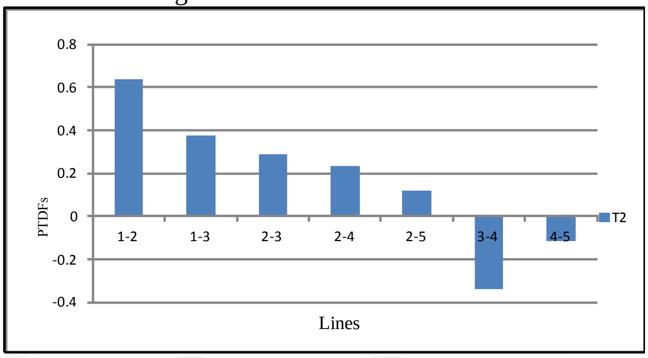

Fig. 4: PTDFs for transaction T2

The following Figure.5 shows the value of PTDF among all transaction T1 to T7. The Variation of PTDFs for different transactions is shown in the graphical form with different line. The different colour of the lines indicates its PTDF value at different transaction. The sensitivity of power flow to any transactions can be plotted and the slope of the curve can be observed corresponding to T1, T2, T3, T4, T5, T6 and T7 transactions.

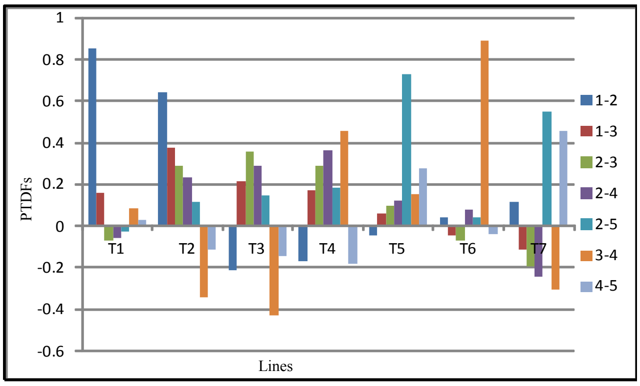

Fig. 5: variation of PTDF at different transaction

After calculating the PTDF we can determine the ATC value for that particular transaction. The minimum amount of transfer capability among all the line in particular transaction is taken ATC value of the network. ATC value also gives the indication of limiting line element. The value of ATC for Transaction T1 and T2 is shown in Table 2.

Transaction	ATC	Limiting line
T1(1-2)	60.70	Line1-2
T2(1-3)	80.82	Line 3-4

Table. 2: ATC value at different transaction

Here in Table 2 we can say that the value of ATC is 60.70 MW for transaction T1 and limiting line is line 1-2 also ATC value is 80.82 MW for transaction T2. The same procedure is follows to find the ATC value in a different transaction.

Case 2, IEEE-14 bus system

The same procedure is done for calculating ATC of IEEE-14 bus test system. The following transaction is considered here among all too determinate the value of power transfer distribution factor and available transfer capability in this network.

T1: transaction between seller bus 2 to buyer bus 3.

T2: transaction between seller bus 4 to buyer bus 7.

The value of PTDF for transaction T1, T2 among all 20 lines is shown in following Figure.6, Figure.7, respectively.

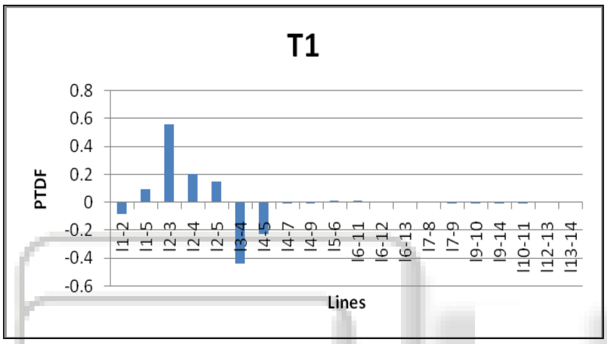

Fig. 6: PTDFs for transaction T1

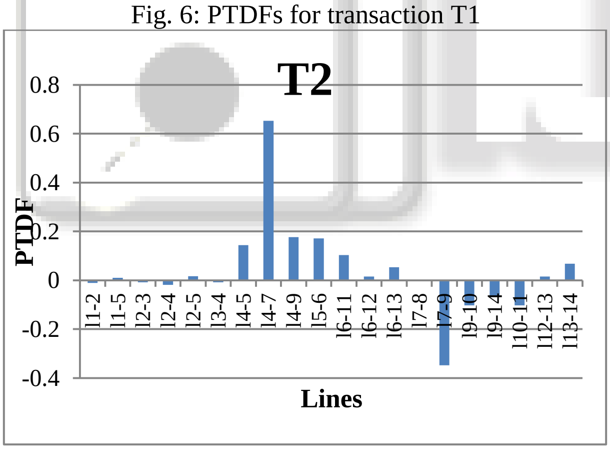

Fig. 7: PTDFs for transaction T2

The value of ATC for Transaction T1 and T2 in IEEE-14 bus system is shown in following Table 3

Transaction	ATC	Limiting line
T1(2-3)	48.26	Line 2-4
T2(4-7)	15.65	Line 5-6

Table.3: ATC value at different transaction

From the above result, for transaction T1 (2-3) the ATC value is 48.26 MW and limiting line is 2-4, and for transaction T2 (4-7), the ATC value is 15.65MW and limiting line is 5-6. We can analyse that the value of ATC is varied at different Transaction. So it is necessary for ISO to calculate the value of ATC after every hour because if loading condition or transaction is change the value of ATC is also changed. We can also conclude from the Table.3 that in transaction T1, ATC result gives the minimum amount of power transfer 48.26 MW is possible among all line without any violation for further commercial activity.

VII. CONCLUSION

The accurate determination of Available Transfer Capability is important to ensure the system security and reliability and also to relief congestion while serving a wide range of bilateral power transactions. To finding a quick result of a number of possible power transfer and outage become very difficult in a real time calculation. One of the easiest ways to finding a quick calculation is to use linear sensitivity based DC-PTDF method, and also it is less time consuming because it is non-iterative method. Once the value of PTDF is defined for a particular system operator can easily computed the value of ATC in case of change in loading and put the value of ATC on the website called open access same time information System. So it is prime necessary to calculate the ATC to serve better services and reliable operation in this restructuring power system.

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