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Location of FACT for enhancement of ATC using PTDF calculation

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Abstract: This paper discusses the PTDF determination using DC Load flow guidelines. The Power Transfer Distribution Factor for single-transaction case using succeptance matrices and we have seen the effect of one transaction to the other transactions. A explanation concept in the restructuring of the electrical power industry is the ability to accurately and very fast quantify the capabilities of the transmission system. By determination of PTDF we can find out the location of FACTs devices. Many authors have proposed the ATC calculation based on the DC load flow advance, however, the method for multi-transaction cases occurring simultaneously remains unattended using a DC load flow approach The results have been determined for intact as well single transaction case . The proposed method has been applied to an IEEE 5 bus system

Keywords: Available transfer capacity, Power Transfer Distribution Factor, FACTs devices and transactions.

I. INTRODUCTION

In modern energy management system security monitoring and analysis is an inner part but the implementation of real time investigation is a exigent task for the engineers [1]. The quickly restructure of electric power industry and mutual power transactions between the participating areas have necessitated the critical requirement of new methods for estimating and updating the available transfer capability (ATC) [2]. The first country to initiate the restructure of the power industry is United Kingdom followed by Australia and Norway. The Federal Energy Regulatory Commission (FERC) in conjunction with North American Electric Reliability Council (NERC) permitted the rearrangement of ATC information during internet based Open Access Same Time Information System (OASIS) for the use of energy market participants [3]. This information must be updated on the web based OASIS [4] for latest capacity suspicions and transactions.

The first country to initiate the restructure of the power industry is United Kingdom followed by Australia and Norway. The Federal Energy Regulatory Commission (FERC) in conjunction with North American Electric Reliability Council (NERC) approved the posting of ATC information through internet based Open Access Same Time Information System (OASIS) for the use of energy market participants. According to the power flow point of view power injected into the system at a point by the generator is extracted by a load at another point which is known as transaction. The transaction can be found from the linear property of the DC load flow model using sensitivity factor PTDFs [5]. The transmission management problem under deregulation will be defined in general terms, identifying the issues that must be addressed by any deregulated structure. Next, an example power system will be introduced, with a discussion of the calculation of transmission power flow. Then the three existing forms of deregulated structure will be described. It is not possible within the scope of this paper to give detailed descriptions of specific implementations, but the basic mechanisms that address transmission management issues are illustrated with simple examples. More detailed information can be found in [6], [7].

II. METHODOLOGY FOR ATC DETERMINATION IN CASE OF MULTI-TRANSACTIONS

A. Dc load flow model

Subsequent are the assumptions when DC model is employed rather than AC model [8]-

- Voltage magnitudes are constant ,
- Only angles of the complex bus voltage vary,
- The variation in angle is small,
- Transmission lines are lossless,

These assumptions create a model that is a reasonable first approximation of the real power system, which is only a little nonlinear in normal steady state function. The model has advantages for speed of computation, and also has some of use properties similar to linearity and superposition. With these assumptions, power flow over transmission lines connecting bus I and bus j is given as:

$$P_{l,m} = \frac{1}{X_{l,m}}\left(\theta_l - \theta_m\right) \tag{1}$$

Where,

$X_{l,m}$ = line inductive reactance in per unit

θ_l = phase angle at bus l

θ_m = phase angle at bus m

$$P_i = \sum_j P_{ij} = \sum_j \frac{1}{x_{ij}}(\theta_i - \theta_j) \tag{2}$$

This can be articulated in matrix form as:

$$\begin{bmatrix} P_1 \\ M \\ P_n \end{bmatrix} = \left[B_X\right] \begin{bmatrix} \theta_1 \\ M \\ \theta_n \end{bmatrix} \tag{3}$$

where, the elements of the susceptance matrix BX are functions of line reactances. 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,

$$\left[X_{init}\right] = \left[B_X, \mathrm{Re}\,duced\right]^{-1} \tag{4}$$

The dimension [Xinit] of obtained is $(n-1 \times n-1)$. Let us augment it by adding zero columns and row corresponding to reference bus. The angles in equation (3) can be found out as

$$\begin{bmatrix} \theta_1 \\ M \\ \theta_n \end{bmatrix} = \left[X\right] \begin{bmatrix} P_1 \\ M \\ P_n \end{bmatrix} \tag{5}$$

B. Power Transfer Distribution Factor (PTDF)

From the power transfer point of view, a transaction is an exact amount of power that is injected into the system at one bus by a generator and drawn at another bus with a load. The coefficient of linear association between the amount of a transaction and flow on a line is represented by PTDF. It is moreover called sensitivity because it relates the amount of one change – transaction amount – to another change – line power flow.

PTDF is the fraction of the amount of a transaction from of one bus to another that flows over a transmission line. $PTDF_{lm,\,ij}$ is the fractions of a transaction from the bus i to bus j that flows over a transmission line connecting buses l and m.

$$PTDF_{lm,ij} = \frac{\Delta P_{lm}}{P_{ij}} \tag{6}$$

C. Calculation of PTDF Using DC Model

Suppose these exists only one transaction in the system. Agree to the transaction be about 1 MW from the bus i to bus j. then, the Corresponding entries in equation (7) will be: P_i = 1and P_j = -1. All other entries will be zero. From equation (5), we get

$$\theta_l = \left[X_{l,1} \quad L \quad X_{l,n-1}\right] \begin{bmatrix} 0 \\ +1 \\ M \\ +1 \\ 0 \end{bmatrix} \tag{7}$$

Similarly,

$$\theta_m = \left[X_{m,1} \quad L \quad X_{m,n-1} \right] \begin{bmatrix} 0 \\ +1 \\ M \\ +1 \\ 0 \end{bmatrix} \tag{8}$$

Thus,

$$\theta_l = X_{li} - X_{lj} \tag{9}$$

$$\theta_m = X_{mi} - X_{mj} \tag{10}$$

Using equations (9), (10), (1), the PTDF can be calculated as

$$PTDF_{lm,ij} = \frac{X_{li} - X_{mi} - X_{lj} + X_{mj}}{x_{lm}} \tag{11}$$

x_{lm} = Reactance of transmission lines connecting buses l and m.

X_{li} = Entry l^{th}row and i^{th}column of the bus reactance matrix X.

D. ATC Determination at the Base Case Condition

ATC in the base case, between bus/zone l and bus/zone m using line flow limit criterion has been calculated as in [9] using DCPTDFs:

$$P_{ij,lm}^{\max} = \frac{P_{lm}^{\max} - P_{lm}^{0}}{PTDF_{lm,ij}} \tag{12}$$

Where

$P_{lm}^{\max}$ =MW power flow limit of a line between bus-l and bus-m.

P_{lm}^{0} = Base case power flow in the line between bus-l and bus-m.

$PTDF_{lm,ij}$ = Power Transfer Distribution Factors for the line between bus-l and bus-m.

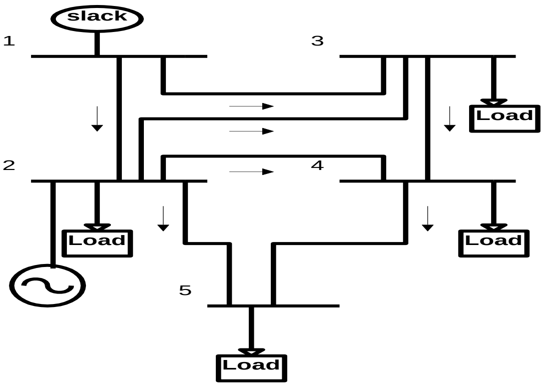
$$ATC_{ij} = \min\left(P_{ij,lm}^{\max}\right) \tag{13}$$

III. RESULT AND DISCUSSION

The results have been determined for IEEE RTS 5 bus system. The results include PTDF calculations in the intact system in case of all transactions. Based on the y-bus PTDF have been calculated for all transaction cases.

The transactions are chosen are:

Bilateral transactions
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.



5-Bus Test System

In Multi-transactions/ Simultaneous Transactions the more than one seller buses are able to flow the power to more than one buyer buses means the power flows simultaneously seller buses to buyer buses and vice-versa. In the bus data table the type column is represented by the bus type means here 1 is represented by slack bus, 2 is represented by p-v bus and 3 is represented by p-q bus.

TABLE-I
Bus data for 5-bus system

Bus	Type	Vm	Pd	Qd	Pg	Qg	Qmn	Qmx
1	1	1.05	0	0	0	0	-1	2
2	2	1.05	0.20	10	1.25	0	-1	2
3	0	1.05	0.45	15	0	0	-1	2
4	0	1	0.40	5	0	0	0	0
5	0	1	0.60	10	0	0	0	0

TABLE-II
Line data for 5-bus system

From bus	To bus	R(p.u.)	X(p.u.)	B(p.u.)	Tap
1	2	0.02	0.06	0.03	1
1	3	0.08	0.24	0.025	1
2	3	0.06	0.18	0.02	1
2	4	0.06	0.18	0.02	1
2	5	0.04	0.12	0.015	1
3	4	0.01	0.03	0.01	1
4	5	0.08	0.24	0.025	1

TABLE-III
X-matrix for 5- bus system

0	0	0	0	0
0	0.0511	0.0383	0.0410	0.0478
0	0.0383	0.0902	0.0799	0.0524
0	0.0410	0.0799	0.0963	0.0596
0	0.0478	0.0524	0.0596	0.1322

TABLE-IV
PTDF for line for different transactions

Lines	PTDF in (p.u.)			
	T1	T2	T3	T4
1-2	0.8509	0.6390	-0.2118	-0.1683
1-3	0.1598	0.3757	0.2159	0.1732
2-3	-0.0706	0.2879	0.3585	0.2871
2-4	-0.0561	0.2310	0.2871	0.3634
2-5	-0.0268	0.1169	0.1437	0.1820
3-4	0.0870	-0.3414	-0.4284	0.4580
4-5	0.0287	-0.1148	-0.1435	-0.1816

TABLE-V
ATC for different transactions

Lines	ATC in (p.u.)			
	T1	T2	T3	T4
1-2	0.1290	0.1718	0.5184	0.6524
1-3	0.4718	0.2006	0.3492	0.4353
2-3	1.9410	0.4762	0.3824	0.4775
2-4	3.1120	0.7558	0.6081	0.4804
2-5	21.7923	4.9972	4.0521	3.2098
3-4	8.9142	2.2706	1.8095	1.6925
4-5	20.5136	2.2706	4.1031	3.2422

We have determined the PTDF for different transaction of the lines. 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 that the PTDF values varied from positive to negative. The same procedure is done for transactions T2, T3 and T4. When the transaction T1 is applied then we see the effect of transaction T1 on the lines with respect to buses.

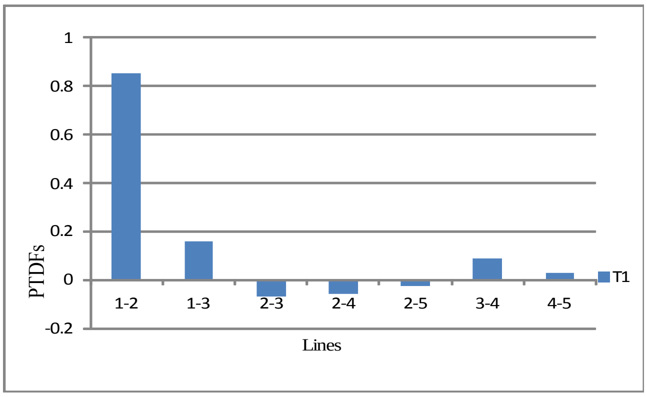


Fig.1 PTDFs for transaction T1

The PTDF values for transaction T1 is shown in the graphical form in the figure1. We can see the maximum positive value of PTDF with respect to line 1-2 and the maximum negative value of PTDF with respect to line 2-3.

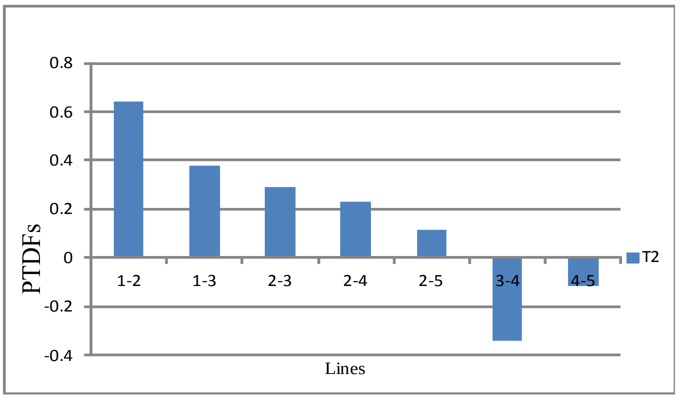


Fig.2 PTDFs for transaction T2

The PTDF values for transaction T2 is shown in the graphical form in the figure2. We can see the maximum negative value of PTDF with respect to line 3-4 and the maximum positive value of PTDF with respect to line 1-2.

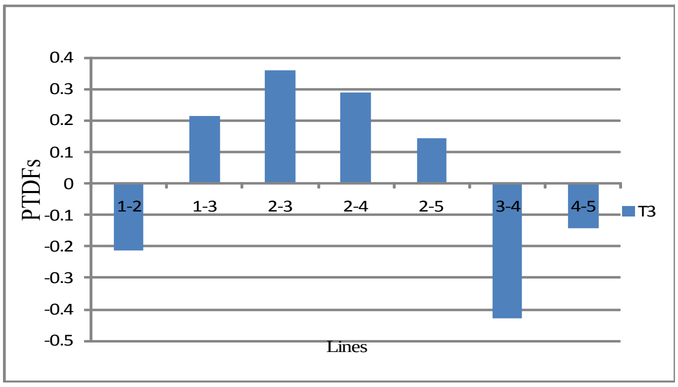


Fig.3 PTDFs for transaction T3

The PTDF values for transaction T3 is shown in the graphical form in the figure3. We can see the maximum negative value of PTDF with respect to line 3-4 and the maximum positive value of PTDF with respect to line 2-3.

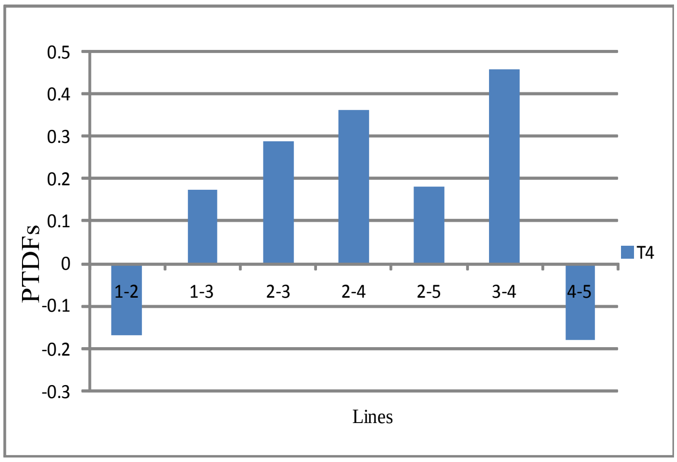


Fig.4 PTDFs for transaction T4

The PTDF values for transaction T4 is shown in the graphical form in the figure4. We can see the maximum negative value of PTDF with respect to line 4-5 and the maximum positive value of PTDF with respect to line 3-4.

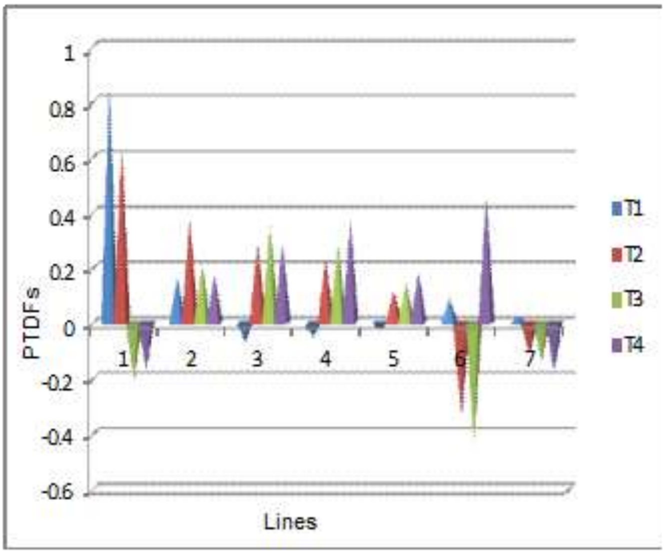


Fig.5 Variation of PTDFs obtained with DC Load flow method.

The Variation of PTDFs for different transactions is shown in the graphical form in the figure 5. 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 and T4 transactions. The lines connected between the buses where slope variation is higher can be observed for all transactions critically. These lines, with higher variation can be taken as potential candidates for the location of FACTS devices as to small changes in the power injection at a particular bus will bring larger change in the power flows. Thus, based on the pattern of PTDFs, the lines between the buses can be identified where power flow sensitivity variations are of lower magnitude but with higher variations. In the above curve transaction T3 has the highest slope with minimum value which is in green color.

IV. Conclusion

The methodology for purpose find out the location of FACTS devices has been suggested for simultaneous/ multi-transactions based on Power Transfer Distribution Factor approach. Results are shown in tabular form and graphical form. Active Power flows changes their patterns for different transactions. Calculation of PTDF of DC load flow is simple and it is less time consuming because this method is a non iterative method. The PTDF obtained varies with simultaneous transaction case as well as multi-transaction case compared to the other transactions. After calculating the PTDF we can find out the ATC means how much power is transferred through the line.

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