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COMPUTATION OF AVAILABLE TRANSFER CAPABILITY BY CHANGING GENERATOR PARTICIPATION FACTOR IN ELECTRICAL POWER SYSTEM

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Abstract— Now a day's all our basic needs are relates with electricity. The demand for electricity is tremendously increasing day by day. Due to insufficient transmission capacity one or more transmission lines may operate beyond their limits thereby causing the network congestion. It can be detected by evaluation of Available Transfer Capability (ATC) of the network for various applied power transactions**.** Major challenge in electrical power system is to rigorously compute the transfer capability remaining in the system for further transaction which is describe as Available Transfer capability. This paper reports the appraisal of ATC using participation factor and power transfer distribution factor. The participation factor is a measure of how the real power output of the generator changes in response to load demand. In this paper, by choosing different participation factor, its effect of ATC is observed by MATLAB. The solutions obtained are useful in the present restructuring environment.

Keywords— Generator participation factor, Power Transfer distribution, Available transfer capability, Network Congestion, MATLAB

I. INTRODUCTION

Creating a competitive market to trade electricity is one of the power system restructuring. A deregulated framework has been replacing the traditional vertically integrated structure of power system [8]. Now a day's all our basic needs are relates with electricity. The demand for electricity is tremendously increasing day by day. Every link in the transmission system has a limit on the amount of power it can transfer at a given time. Several phenomena can impose these transfer limits, including thermal limits, voltage limits, and stability limits. The increased power demand has forced the power system to operate very closer to its stability limits and their by may causing congestion and further threatening the security of the network. Available transfer capability is the measure of remaining transmission capability of the network. Congestion free market operation can be ensured by knowing the ATC of the network [2],[3]. Continuation Power flow (CPFLOW) [4] is a tool available for the determination of TTC (or ATC). It utilizes a continuation power flow algorithm for the calculation of maximum load ability of electric power system. Accuracy of results is obtained with negligible computational time. Power transfer distribution factor (PTDF) method is used by many utilities for determination of ATC .The methods of Power Transfer Distribution Factor (PTDF) using DC power flow and AC power flow are derived to calculate ATC. In DCPTDF method[5] , DC load flow i.e. a linear model, is considered. This method is fast but does not provide the accuracy. In [6]ACPTDF method is proposed for determination of ATC of a practical system case. The determination of power transfer distribution factors, computed at a base case load flow using conventional properties of FDLF method [7]. In[1] Sensitivity analysis and power transfer distribution factor are used for the determination of ATC for individual transaction. The participation factor is a measure of how the real power output of the generator changes in response to demand when the generator is available for AGC and the area is on participation factor control. In this paper, the method of ATC computation from the aspect of changes in load is proposed. Generator participation factors are used to split the total change in load into various bilateral transactions. By choosing different generator participation factors, ATC has been found to be changed. The variable load is considered as data to calculate ATC of network ,considering various sets of generator participation factors.

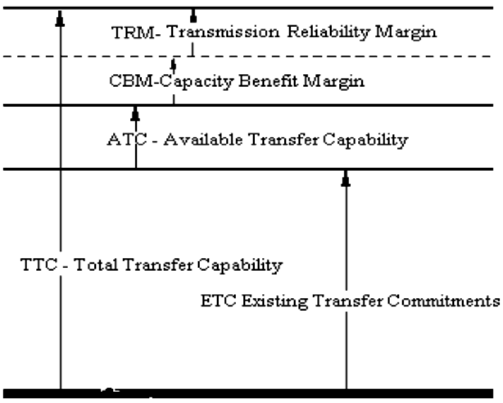
II. AVAILABLE TRANSFER CAPABILITY (ATC)

Definition:- According to NERC Report-ATC is a measure of the transfer capability remaining in the physical transmission network for further commercial activity over and above already committed use. The term capability here refer to the ability of the line(s) to reliability transfer power from one bus/area to another. It is different from the transfer capacity in the sense that capacity implies the rating of specified lines(s) and that account for the thermal limit only. Mathematically, ATC is defined as:

$$ATC = TTC - TRM - \{ETC + CBM\} \quad (1)$$

Where TTC refers to total transfer capability, TRM refers to transmission reliability margin, ETC stands for existing transfer commitments and CBM indicates capacity benefit margin.

The ATC between two specific areas/buses gives the upper limit of additional power flow between them for a specified time period under given condition the term associated with definition of ATC are described below in fig(1)



"Figure 1Basic definition of ATC"

Total transfer capability (TTC):- It is the amount of electric power that can be transferred over the interconnected transmission network in a reliable manner under reasonable range of uncertainties and contingencies. In the process of determining TTC, system conditions, system limits, contingencies parallel path flows and effects of non-simultaneous and simultaneous transfer to be considered.

Transmission reliability margin (TRM):- it is defined as the amount of transmission transfer capability necessary to ensure that the system conditions.

Capability Margin:- It is the amount of transmission transfer capability reserved by the load serving entitles to ensure access to generation from the interconnected system to meet generation reliability requirements. It is also helps to reduce the installed capacity of the plant.

Existing transfer commitments (ETC):- It refers to power transfer capability that must be reserved for already committed transactions.

A. POWER TRANSFER DIDTRIBUTION FACTOR (PTDF):- PTDF are the sensitivity factor Power transfer distribution factor for line x-y with the real power transaction between the buses m and n. they are defined as the power flow sensitivities of various element to the applied power transaction and given as

$$PTDF)_{XY(mn)} = \frac{\Delta P_{xy}}{\Delta T_{mn}} \quad (2)$$

Where

ΔT_{mn} = Power transaction between m and n

ΔP_{xy} = change in real power flow of line x-y for transaction between m and n, obtained .

Within ATC computation, a source and a sink are specified for each transaction. Active power will then flow from source to sink in a direction. For each direction, the ATC value is the maximum megawatt source injection that can be transferred to the sink without violating any of the operating limits such as Line thermal limits, voltage limits and system stability limits. In order to investigate how far the system is from an insecure condition, and how a transaction of active power can affect the loading of the transmission system, it is necessary to analyze the sensitivities of line flows with respect to bus injections. These sensitivities are termed as Power Transfer Distribution Factors. These values provide a linearized approximation of how the flow on the transmission lines and interfaces change in response to transaction between the seller and buyer. For multi-area ATC, the transaction will be between two areas. The PTDFs are operating point dependent.

B. Participation Factor:- When different generator are assumed to share the load.ATC of the network refers to the maximum load that can be applied to the load bus with the specified participation of various generator. To compute ATC from this aspect, generator participation factors are required to be defined. Generator participation factor of ith generator to change in load it can be given as,

$$x_i = \frac{\Delta T_{ik}}{\Delta P_k} \quad (3)$$

Where x_i is Generator participation factor,

ΔT_{ik} is change in generator power at i^{th} bus due to change in load at k^{th} bus,

ΔP_k Change in load at k^{th} bus.

For the purpose of calculating ATC, buyer and seller transactions are to be specified. This can be slack, a single bus, injection groups, areas etc. When multiple generators exist in the transaction, such as the case of areas or injection groups, participation factors needed to be assigned. so as to know the participation of generators or loads, the load flow solution must be known.

C. Principles of ATC Determination: - The basic objective behind the ATC determination is to tell market entities about the system limitations, beforehand, in terms of additional amount of power that can be transferred from one area to another. Since private parties are interested only in commercial aspects, it is the responsibility of SO to determine, update a post the current value of ATC. Following are the governing principles for ATC determination.

1. ATC calculation must produce commercially viable result. ATC provided by the calculations must give a reasonable and dependable indication of transfer capabilities available to the power market.
2. ATC calculation must recognize time-variant power flow conditions on the entire power inter-connected transmission network.
3. ATC calculations must recognize the dependency of ATC on points of electric power injection, the direction of transfer across the interconnected transmission network, and the points of power extraction.
4. Regional and wide-area co-ordination is necessary to develop and post the information that reflects the ATC of the inter-connected transmission network.
5. ATC calculations must conforms to regulatory guidelines in the specific country (Such as NERC in the US), regional, sub regional, power pool, and individual system reliability and operating policies, criteria or guidelines.
6. The determination of ATC must accommodate reasonable uncertainties in the system conditions and operating flexibility to ensure the secure operation of interconnected network.

D. Computation of ATC:- Congestion Management is the most important issue to be tackled in deregulated power system. To have congestion free transmission system knowledge of Available Transfer Capability (ATC) of the network is very important. Available transfer capability is the measure of remaining transmission capability of the network. The usual method of calculating ATC is by Fast decoupled method. In which bilateral transaction is only considered and then, whether the transaction is feasible for the network or not is concluded.

For calculating ATC, Changes in line flow are obtained, considering all the transactions individually. After that PTDF and ATC of all the transactions are obtained separately using Fast de-coupled Method. PTDF is the coefficient of linear relationship between the amount of a transaction and the flow on a line**.** The change in line flow (ΔP_{ij}^{New}) associated with a new transaction (ΔP_{ij}^{New}) given by following equation,

$$\Delta P_{ij}^{New} = DCPTDF_{ij,mn} P_{mn}^{New} \tag{4}$$

Since, the PTDFs define a linear relationship multilateral transaction case, the new real power flows in the lines can be determined by superimposing those corresponding to the individual transaction.

$$P_{mn,ij}^{Max} \leq \frac{P_{ij}^{Max} - P_{ij}^{0}}{PTDF_{ij,mn}} \tag{5}$$

$p_{mn,ij}^{Max}$ is the maximum allowable transaction amount from zone m to zone n.
ATC of the network is constrained by the minimum of the allowable transaction over all lines.

$$ATC_{mn} = \min_{ij} P_{mn,ij}^{Max} \tag{6}$$

After ATC computation, network condition for congestion can be known To remove congestion in case of known ATC, a proper strategy for its improvement must be applied. Here ATC computation by changing the participation factor is carried out .

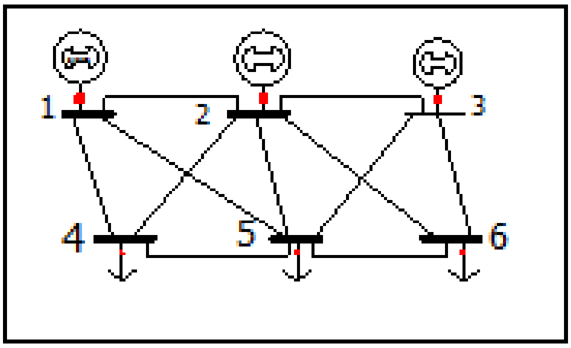
If ATC_i represents the ATC for this transaction, then ATC of the network for change in load at bus "k" will be

$$ATC_k = \min(\frac{ATC_i}{x_i}) \tag{7}$$

Here ATC_k represents the capability of the network to apply the load at bus "k". In this paper ATC computation by varying the load is made.

III. CASE STUDY

Effect of change of Generator Participation Factor on ATC of network by varying the load has been carried out on a 6 Bus System.(Fig 2)



"Figure 2 A 6-bus system"

In this six bus system bus 1 is slack bus, bus 2 and 3 are generator buses whereas bus 4, 5 and 6 are load buses. It is assumed that the load sharing by generator buses are x_i times the change in load. For example, if 0.4 and 0.4 are the participation factors of generator 2 and 3 respectively, for Change in load of 10 MW at bus 6, generator 2 and 3 will contribute 4 and 4MW respectively. Generator 1 being a slack bus generator will contribute the remaining power of 2 MW and the change in losses. The bilateral transaction to meet the change in load will be,

1 – 6 = 2 MW
2 – 6 = 4MW
3 – 6 = 4 MW

A. Algortithm

i) Set the generator participation factor for the hours of ATC computation
ii) Compute initial system condition (base, case) such as bus voltage, bus angles, power flows and current flows using fast decoupled method (FDLF).
iii) Apply change in real power at a load bus k and compute the bilateral transaction which are the product of the generator participation factor and change in load.
iv) Apply the first power transaction between bus i and k.
v) Conduct the load flow using fast decoupled load flow.
vi) Calculate change in transmission line power flow.
vii) Obtain the line PTDF and ATCs for that transaction.
viii) Apply the next transaction and repeat the step (v,vi&vii)
ix) After determining ATCs for all transaction, compute ATC_k of the network using equation $ATC_k = Min\left(\frac{ATC_i}{x_i}\right)$, which refers to the capability of network to apply change in real power at load bus K.
x) By selecting different generator participation factor repeat the step from (i to ix)

"Table 1 Available Transfer Capability with consideration of individual bilateral transactions and changes in load at bus six (participation factor of x1 =0.2, x2=0.4, x3=0.4 initial load at bus six = 70 MW)"

Sr.No	Applied Change in Load at bus 6 (MW)	Generator and Load Bus Pair	Transacting power MW x1=0.2 x2=0.4 x3=0.4	N/W ATC when Individual Transactions are of concern (MW)	N/W ATC (MW) for Simultaneous Power Transaction from all Generators to Bus 6
1	4	1---6	0.8	19.690	98.450
		2---6	1.6	39.420	
		3---6	1.6	39.420	
2	-6	1---6	-1.2	58.100	294.050
		2---6	-2.4	117.639	
		3---6	-2.4	117.639	
3	8	1---6	-1.6	26.290	131.450
		2---6	-3.2	52.612	
		3---6	-3.2	52.612	
4	10	1---6	2	12.289	61.445
		2---6	4	24.610	
		3---6	4	24.610	
5	10	1---6	2	7.430	37.150
		2---6	4	15.126	
		3---6	4	15.126	
6	12	1---6	2.4	6.100	30.500
		2---6	4.8	12.403	
		3---6	4.8	12.403	
7	15	1---6	3	5.349	26.745
		2---6	6	11.098	
		3---6	6	11.098	
8	10	1---6	2	3.079	15.390
		2---6	4	6.218	
		3---6	4	6.218	
9	10	1---6	2	2.580	12.900
		2---6	4	5.360	
		3---6	4	5.360	
10	-5	1---6	-0.1	3.179	15.895
		2---6	-0.4	6.558	
		3---6	-0.4	6.558	
11	-5	1---6	-0.1	3.443	17.215
		2---6	-0.2	7.086	
		3---6	-0.2	7.086	
12	-10	1---6	-2	8.402	42.010
		2---6	-4	16.884	
		3---6	-4	16.884	

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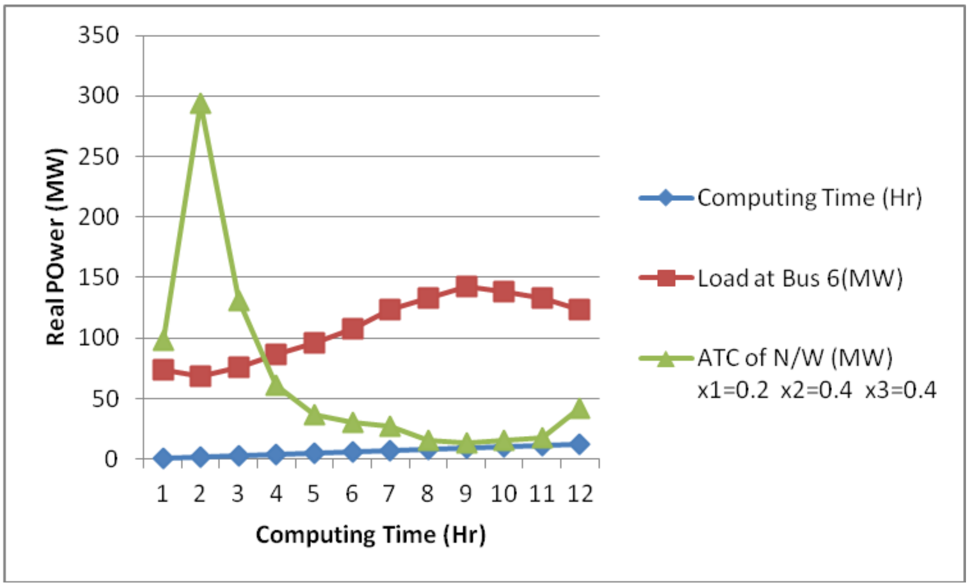
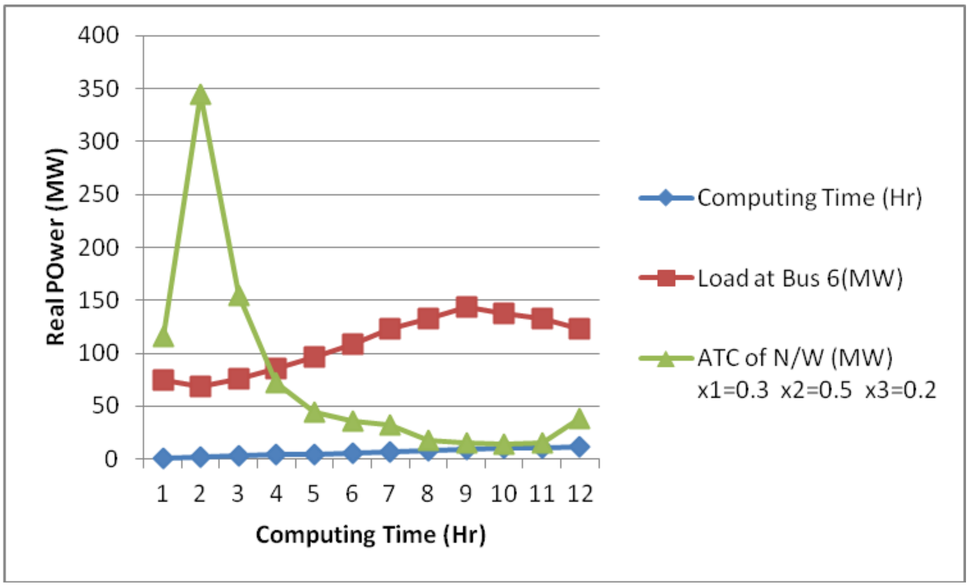
" Table 2. ATC With Examination of changes in load at bus 6 and different participation factors (initial load at bus 6 = 70 MW)"

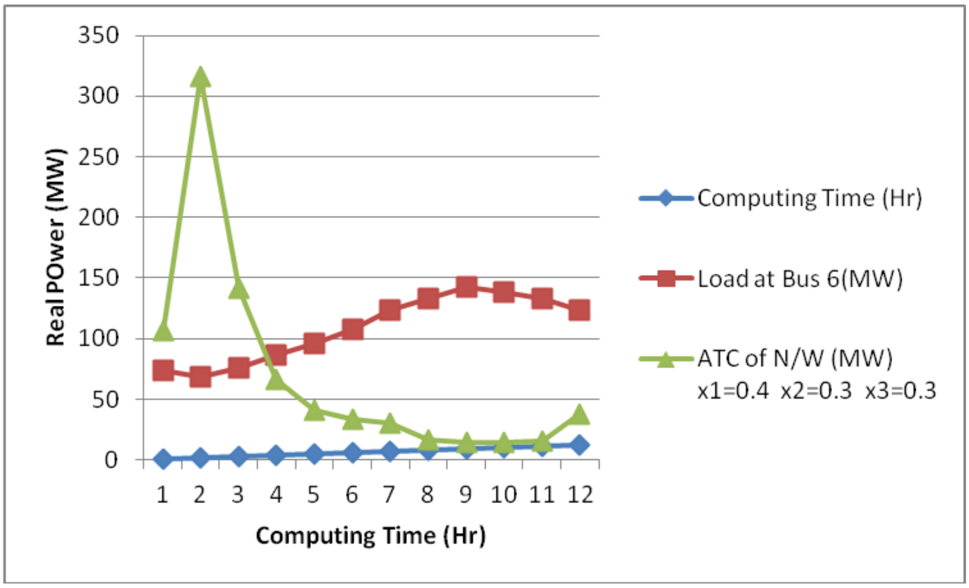
Computing Time (Hr)	Load at Bus 6(MW)	ATC of N/W (MW) x1=0.2 x2=0.4 x3=0.4	ATC of N/W (MW) x1=0.3 x2=0.5 x3=0.2	ATC of N/W (MW) x1=0.4 x2=0.3 x3=0.3
1	74	98.45	115.332	106.110
2	68	294.05	343.912	316.544
3	76	131.45	153.947	141.628
4	86	61.445	71.976	66.235
5	96	37.15	44.223	40.705
6	108	30.5	36.246	33.371
7	123	26.745	32.415	29.853
8	133	15.39	18.154	16.723
9	143	12.9	15.645	14.517
10	138	15.895	14.653	14.759
11	133	17.215	15.834	15.947
12	123	42.01	37.727	37.994



"Figure 3 Graphical Representation of ATC & Load variations for participation factor $X_1 = 0.2$, $X_2 = 0.4$, $X_3 = 0.4$ "



"Figure 4 Graphical Representation of ATC & Load variations for participation factor $X_1 = 0.3$, $X_2 = 0.5$, $X_3 = 0.2$ "



"Figure 5 Graphical Representation of ATC & Load variations for participation factor $X_1 = 0.4$, $X_2 = 0.3$, $X_3 = 0.3$ "

B Observations

It is observed that when load at bus-6 is decreased at 2nd computing hour ATC of network is increased. From 3rd computing hour as the load is increased, the ATC of network decreases and again increases from 10th computing hour when load at bus 6 is decreased. It is observed that ATC of network changes when the generator participation factor is changed. Figure.3 to figure 5 shows the graphical representation the variation of load and network ATC for a set of generator participation factor when same load cycle at bus-6 is considered. ATC Values are obtained by MATLB.

IV. CONCLUSIONS

The ATC value provide as an important indicator of system performance. The ATC values are determined by conventional Fast De-coupled method. It can be observed form Table-I and II that as the load increases, ATC of the network decreases. The decrease in the load increases the network

ATC, which was obtained in earlier hour. When load at a bus is to be shared by different generators, the ATC must be computed from the aspect of maximum allowable load at that bus. By selecting a set of participation factors of the generators, network ATC is computed in the previous hour. This value appear for the maximum load that can be connected to the load bus, in the next hour. From Fig 3 it is very much clear that ATC of network can be changed by changing the generator participation factor. In multiple transactions when simultaneous power flows from all generators to meet the load demand, generator with higher participation factor mainly decides the network ATC. Generator with larger participation factor can have a more positive effect on improving the system power transfer capability. The method is suitable for hour- ahead market.

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