DETERMINATION OF ATC IN DEREGULATED POWER SYSTEM USING AC LOAD FLOW METHOD

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***ABSTRACT**: In the present deregulated scenario of power system, multiple power transactions are being carried out over existing interconnected transmission network which may lead to overloading of transmission lines in a network, which in turn, challenges the reliability of the power system. Assessment of Available Transfer Capability (ATC) and to display it on Open Access Same-time Information System (OASIS) is of great importance for the secured operation of the power network. This work describes the evaluation of ATC using AC Load flow method. The results are tested on standard IEEE 6-bus system.*

Keywords—Available transfer capability, deregulation, total transfer capability, ISO, OASIS

I: INTRODUCTION

ATC is nothing but the remaining energy in the physical transmission network for future commercial activity over and above already committed uses [1]. Therefore, assessment of ATC gives valuable information to the system operator regarding the ability of an interconnected network to reliably transfer bulk power between two nodes or between different areas of the network without causing threat to system reliability. Mathematically, ATC equals the total transfer capability (TTC) less the transmission reliability margin (TRM) less the capacity benefit margin (CBM) and existing transmission commitments (ETC) [2].

ATC = TTC – TRM –CBM - ETC**…..** (1)

In the present deregulated scenario, the consumer is free to purchase power directly from generating companies (GENCOs), therefore it is mandatory to check the viability of power transaction for particular deal between buyer and the seller. For this purpose, based on market demands, ATC is calculated hourly, daily or monthly and it is displayed on a website named Open Access Simultaneous Information System (OASIS). It is mandatory to check ATC before carrying out any commercial power transaction. In case, the amount of power to be transacted is more than ATC, the transaction is denied or it is limited to ATC of the network. ATC can be computed using deterministic or probabilistic methods.

II: AC LOAD FLOW APPROACH FOR ATC DETERMINATION

To obtain magnitudes and phase angles of voltages at different buses and to obtain transmission line flows, AC load flow program which solves static load flow equations, is run at different instances for different system conditions.

The static load flow equations can be stated as :

P_i (Real Power) =

$$|V_i|\sum_{k=1}^{n} |V_k||Y_{ik}|\cos(\theta_{ik} + \delta_k - \delta_i)$$

Q_i (Reactive Power) =

$$-|V_i|\sum_{k=1}^{n} |V_k||Y_{ik}|\sin(\theta_{ik} + \delta_k - \delta_i)$$

The static load flow equations can be solved using Gauss-Seidel method or Newton-Raphson method. For larger power system, N-R method is preferred over G-S method owing to its faster convergence rate in few iterations. In the present work, N-R method has been used to obtain voltage magnitudes and phase angles at all buses in the network. The N-R method solves non-linear algebraic equations and the jacobian which is formed during each iteration is given as :

$$\begin{bmatrix} \Delta P \\ \Delta Q \end{bmatrix} = \begin{bmatrix} J11 & J12 \\ J21 & J22 \end{bmatrix} \begin{bmatrix} \Delta\delta \\ \Delta V \end{bmatrix}$$

The various elements of jacobian matrix are calculated as:

$$J_{11} = \frac{\partial P}{\partial \delta}$$

$$J_{12} = \frac{\partial P}{\partial |V|}$$

$$J_{21} = \frac{\partial Q}{\partial \delta}$$

$$J_{22} = \frac{\partial Q}{\partial |V|}$$

In order to determine ATC using AC load flow method, the base case load flow program using N-R method is run to determine power flow in various transmission lines. The line flows are deducted from their respective thermal limits. The minimum of the difference between actual line flow and thermal limit of all lines equals ATC of the system.

III: METHODOLOGY

In this work, the generation and load on the system is varied and load flow program is run to determine various transmission line flows. There are several limiting factors including thermal limit, voltage limit, real and reactive power limits and stability limit [2].

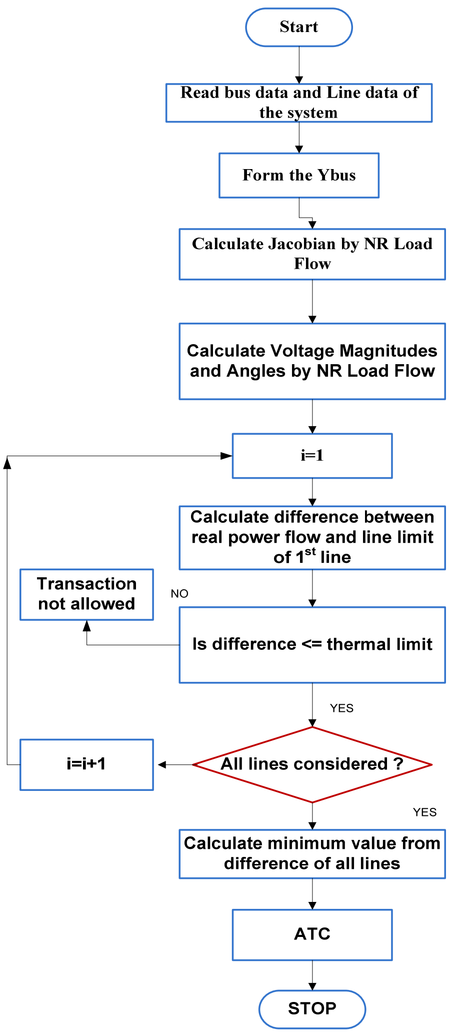

Fig.1: Flow chart for ATC calculation

In the present work, thermal limit is considered as the limiting factor to ATC. The line flows are deducted from their respective thermal limits and minimum value out of the difference equals the ATC of the system for given conditions. In the present scenario of deregulated power system where multiple power transactions are carried out over existing transmission network, the ATC is the reliable indicator of network congestion. Therefore it is mandatory to refer to website named OASIS before carrying out any commercial power transaction, the transaction is allowed only if it is equal to or less than ATC of the system. In case power to be transacted is greater than ATC, the transaction is rejected or limited to ATC.

IV: CASE STUDY

The standard IEEE 6-bus test system is considered here to demonstrate the calculations of ATC using proposed method. The diagram of the system is shown in Fig. 2.

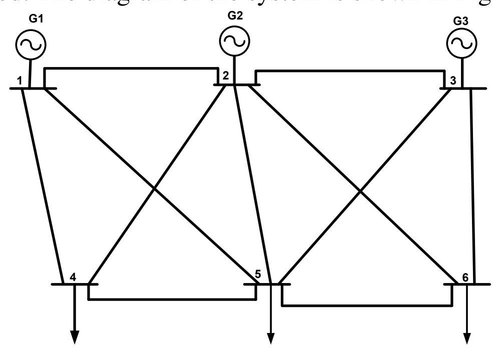

Fig.2 Standard IEEE 6- bus test system [7].

The 6 bus system under consideration has 3 generators and 3 load buses. Bus 1 is the swing bus, bus 2 and 3 are generator buses whereas bus 4, 5 and 6 are load buses. The bus data and line data of the system has been shown in table 1 and 2.

Bus No.	Bus Type	Voltage (pu)	Angle degree	Load MW	Load MVA R	Generati -on MW
1	1	1.05	0	0	0	0
2	2	1.05	0	0	0	50
3	2	1.07	0	0	0	60
4	0	1	0	70	70	0
5	0	1	0	70	70	0
6	0	1	0	70	70	0

Table 1. Bus data of the system [7].

From bus	To bus	Resistance (pu)	Reactance (pu)	Susceptance ½ B (pu)
1	2	0.10	0.20	0.02
1	4	0.05	0.20	0.02
1	5	0.08	0.30	0.03
2	3	0.05	0.25	0.03
2	4	0.05	0.10	0.01
2	5	0.10	0.30	0.02
2	6	0.07	0.20	0.025
3	5	0.12	0.26	0.025
3	6	0.02	0.10	0.01
4	5	0.20	0.40	0.04
5	6	0.10	0.30	0.03

Table 2. Line data of the system [7].

When the system is operating under the normal operating conditions, the line flows are simulated and this gives the results for base case power flow. It is taken care that the power flow solution does not have any limit violation.

V: RESULTS AND DISCUSSION

The standard IEEE 6- bus test system is considered to obtain the results. The simulation is performed considering various generation and loading conditions on the system.

The power flow is solved for base case condition to obtain line flows under base case condition and thermal limit violation if any, is checked. If real power flow in various lines does not exceed their respective thermal limits, the minimum of the difference of real power flow of all the lines from their thermal limits gives ATC of the system under base case conditions. In present work, the ATC is limited to 76.22 MW due to thermal limit violation of the line connected between buses 3 and 6 having thermal limit of 120 MW. The difference between various line flows in base condition and their thermal limits has been shown in Fig. 3.

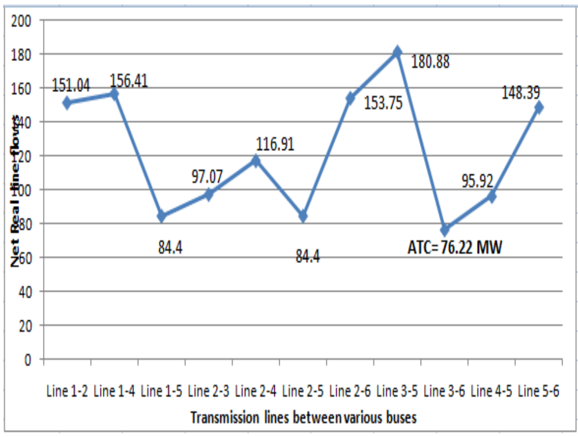

Fig. 3 ATC in base case condition

ATC of the system changes with the system conditions. The value of ATC is different from that of base case value when generation and load on the system changes as changes in load- generation patterns would change line flows in all the lines of the system.

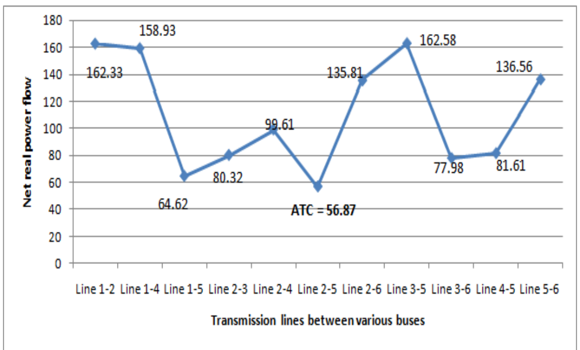

Fig. 4 ATC under varying system conditions

When generation on bus 2 is increased to 140 MW and load on bus 5 is increased to 160 MW, the ATC of the system under such condition is 56.87 MW owing to thermal limit violation of line between bus pair 2 and 5 as shown in Fig. 4. Also, the ATC is 43.16 MW when generation and load on buses 3 and 4 are 150 MW and 160 MW respectively. The ATC of the system under different system conditions is shown in table 3.

System conditions	ATC MW	Limiting Factor
Base Case	76.22	Line 3-6
Increasing generation and load to 100 and 120 MW on buses 2 and 4 respectively.	76.42	Line 3-6
Increasing generation and load to 90 and 110 MW on buses 2 and 5 respectively	72.29	Line 2-5
Increasing generation and load to 140 and 160 MW on buses 2 and 5 respectively	56.87	Line 2-5
Increasing generation and load to 150 and 160 MW on buses 3 and 4 respectively	43.16	Line 3-6

Table 3. ATC under various system conditions

VI: CONCLUSION

This paper presents a simple and efficient method for determining the available transfer capability of the system under different system conditions. The problem of network congestion is one of the issues ahead of power system operators arising due to deregulation. Determination of ATC of the network serves as one tool for congestion management of the transmission network. In order to avoid network congestion, it is mandatory to refer website named OASIS before carrying out any commercial power transaction between seller and buyer. The transaction is rejected or limited to ATC in case the amount of power to be transacted is more than ATC value. The present work provides platform for ATC determination in deregulated power market. Although the proposed method is computationally expensive and hence is not suitable for real time applications. Otherwise, it is very accurate method for ATC determination compared to other methods.

REFERENCES

[1] A.R.Abhyankar, S.A.Khaparde, "Introduction to deregulation in power industry", IIT Bombay, pp. 1-28.

[2] North American Electric Reliability Council (NERC), "Available Transfer Capability Definitions and Determination", NERC Report, June 1996

[3] Bongkoj Sookananta, "The transmission transfer capability: terms, definitions, calculations and applications", KKU Engineering Journal, July- September 2012, 39(3): 311-320.

[4] Sarika Khushalani, S.A. Khaparde Senior Member IEEE, S.A. Soman,"Congestion Management In The Emerging Energy Market Structures", IIT Bombay.

[5] Yan Ou, Student Member, IEEE, and Chanan Singh, Fellow,IEEE, "Assessment of available transfer capability and margins", IEEE Transactions on power systems, Vol. 17, No. 2, May 2002

[6] G.C. Ejebe, J. Tong, J.G. Waight, J.G. Flame, X. Wang, W.F. Tinney, "Available Transfer Capability Calculations", IEEE Transactions on Power Systems, Vol. 13, No. 4, November 1998.

[7] A.J. Wood and B.F. Woolenberg, " *power generation, Operation and Control*", USA, Wiley & sons, 2012.