# Calculation of Available Transfer Capability Using AC Load Flow Method

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*Abstract*— The need for calculation of Available transfer Capability (ATC) is very much important in deregulated power system environment as correct estimation of ATC yields economically efficient operation of the restructured 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 6-bus system using MATLAB programming.

*Key words:* Available transfer capability (ATC), total transfer capability (TTC).

## 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

Where, TTC=Total transfer capability, TRM=Transmission reliability margin, CBM=Capacity benefit margin, ETC=Existing transmission commitments etc.

### *A. TTC*

It is defined as the amount of electric power that can be transferred over the interconnected transmission network in a reliable manner.

### *B. TRM*

It is defined as the amount of transmission transfer capability that interconnected transmission network is secure under a reasonable range of uncertainty in system conditions.

### *C. CBM*

It is defined as the amount of transmission transfer capability reserved by load serving entities to generation from interconnected systems to meet generation reliability requirements.

### *D. ETC*

It is defined as that including retail customer services between the same two points.

The restructuring of the electric industry throughout the world aims to create competitive markets to trade electricity and generates a host of new technical challenges to market participants and power system researchers [8]. There are main three parts of restructuring of electrical power system: Generation, transmission and distribution. Generation Company GENCO are using for generation. The GENCO would try to minimize cost of production and maximize profits by reducing operating and maintaining costs. Transmission Company TRANSCO are using for transmission facilities. TRANSCO would reduce transmission losses and operate efficiently to justify delivery fees. Distribution Company DISTCO are using to supply power to consumers. DISCO would also similarly reduce costs. [7].

## II. ATC CALCULATION USING AC LOAD FLOW METHOD

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 expressed as:

Pi (Real power) = $|Vi| \sum_{k=1}^{n} |Vk|\,|Yik| \cos(\theta ik + \delta k - \delta i)$

Qi (Reactive power) $= -|Vi| \sum_{k=1}^{n} |Vk|\,|Yik| \sin(\theta ik + \delta k - \delta i)$

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 little iteration. 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:

$J11=\frac{\partial P}{\partial \delta}$

$J12=\frac{\partial P}{\partial |V|}$

$J21=\frac{\partial Q}{\partial \delta}$

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$J22=\frac{\partial Q}{\partial |V|}$

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

AC Load Flow method is a simple and efficient for determining the Available transfer capability (ATC) of the system under different system conditions. 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]. There is the flow chart of AC Load Flow method is shown in figure 1.

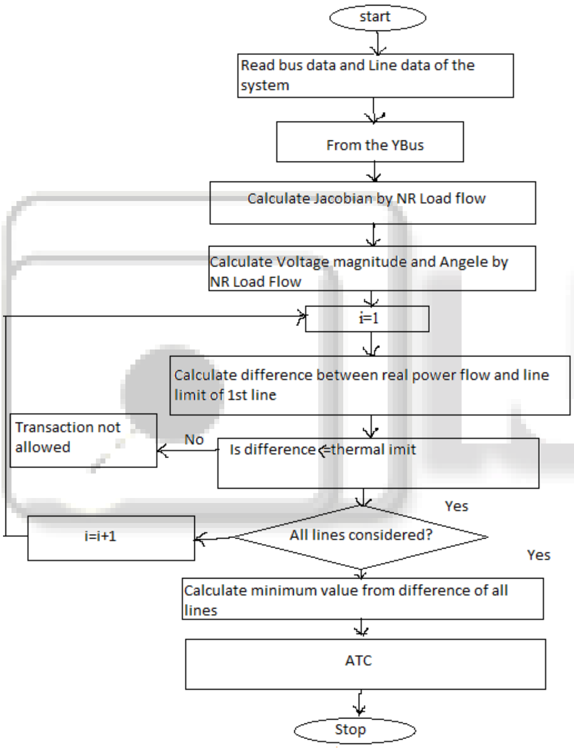


Fig. 1: Flow chart for ATC calculation

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 AND RESULTS

The 6-bus test system is considered here to demonstrate the calculations of ATC using proposed method. 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 figure 4.2 and Table 1.

| Line no. | From | To | R(pu) | X(pu) |
|---|---|---|---|---|
| 1 | 1 | 2 | 0.04 | 0.08 |
| 2 | 1 | 5 | 0.04 | 0.08 |
| 3 | 2 | 4 | 0.04 | 0.08 |
| 4 | 3 | 5 | 0.04 | 0.08 |
| 5 | 3 | 6 | 0.04 | 0.08 |
| 6 | 4 | 5 | 0.04 | 0.08 |
| 7 | 4 | 6 | 0.04 | 0.08 |

Table. 1: Line data for 6-bus system

| Bus no. | Bus type | Voltage (pu) | Angle | Load MW | Load MVAR | GenMW |
|---|---|---|---|---|---|---|
| 1 | 1 | 1.1 | 0 | 70 | 10 | 18 |
| 2 | 2 | 0.9 | 0 | 45 | 10 | 100 |
| 3 | 2 | 1 | 0 | 50 | 10 | 86 |
| 4 | 2 | 1 | 0 | 30 | 10 | 130 |
| 5 | 0 | 1 | 0 | 35 | 10 | 0 |
| 6 | 0 | 1 | 0 | 100 | 10 | 0 |

Table. 2: Bus data for 6-bus system

| Line no. | From | To | ATC |
|---|---|---|---|
| 1 | 1 | 2 | -143.5370 |
| 2 | 1 | 5 | 54.2580 |
| 3 | 2 | 1 | -93.7320 |
| 4 | 2 | 4 | 33.6660 |
| 5 | 3 | 5 | 113.6540 |
| 6 | 3 | 6 | 113.1610 |
| ***7*** | ***4*** | ***2*** | ***24.5360*** |
| 8 | 4 | 5 | 88.0120 |
| 9 | 4 | 6 | 82.8030 |
| 10 | 5 | 1 | 56.2210 |
| 11 | 5 | 3 | 116.8270 |

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| | | | |
|---|---|---|---|
| 12 | 5 | 4 | 89.8110 |
| 13 | 6 | 3 | 112.7880 |
| 14 | 6 | 4 | 84.6180 |

Table. 3: ATC value for 6-bus system

## V. CONCLUSION

In this paper, a simple and efficient method for determining the available transfer capability of the system under different system conditions. 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. There is calculation of ATC value for 6-bus system defined by MATLAB programming.

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