A Review on FACTS Controller based Total Transmission Capability Computation of a Deregulated Power System

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ABSTRACT:

Available Transmission capability (ATC) from past few decades is approved as the framework to satisfy industrial needs and Federal Energy Regulatory Commission (FERC) requirements. In a Deregulated power system network ATC is the unutilised transmission capability of the transmission network for the transfer of power for further commercial use over and above already committed usage. In practical power markets, there are a wide range of margin determination methodologies, approaches, applications and algorithms to compute ATC. The purpose of the paper is to present a review and better define the margins using different approaches for their determination and application. This paper also focuses on the use, types and location of FACTS Controller in a deregulated power system to maximise the ATC further.

Keywords: *Available Transmission capability, Deregulated power system, Flexible AC transmission systems.*

I.INTRODUCTION:

Deregulation in a power system refers to restructuring of the rules and economic incentives set by the government to control and drive Vertically Integrated Electrical Utility (VIEU) in an electrical power industry. The companies participating in the power transaction activities focus mainly on maximizing the Total Transfer Capacity thereby minimizing load shedding without violating a pre-established reliability level, therefore in a new deregulated environment Available Transfer Capacity planning is very much needed when a new generation/load is added to increase the Power Transfer Capacity[1]. Available Transfer Capability calculation provides the usefulness to transmission customers in their evaluation of transaction bids and purchase of

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transmission rights so that the generating companies or power marketers take a contract of supplying uninterruptible loads [7].

Majority of interruptions in a transmission network takes place due to instability in voltage levels, thereby affecting the total transfer capability. This necessitates the need of installing Flexible AC transmission systems (FACTS) devices which exploits the maximum capability of the electrical power system.

As the power system network over the globe is transformed from regulated service industry to a free trade market with the generators/consumers as the participants, several issues such as optimizing the cost of generation, transmission, voltage instability, thermal instability come into consideration. The purpose of this paper is to review the literature on the Deregulated power systems voltage profile, stability analysis by focusing on the use of different types of FACTS controllers with their ratings, locations minimising the overall cost of the system.

II.AVAILABE TRANSMISSION CAPABILITY:

In general, Available Transfer Capacity (ATC) indicates the increase in the amount of inter-area power transfer without compromising systems security and is continuously updated in real-time and made available to the market participants through Open Access Same Time Information (OASIS) and on the basic of ATC, Independent System Operator (ISO) evaluates the transaction[1].

ATC calculations, defined by North American Electric Reliability Council (NERC) involves parameters such as Total Transfer Capacity (TTC), and two margins[2]:Capacity Benefit Margin(CBM) and Transmission Reliability Margin(TRM)]

$$ATC = TTC-(CBM+TRM)$$

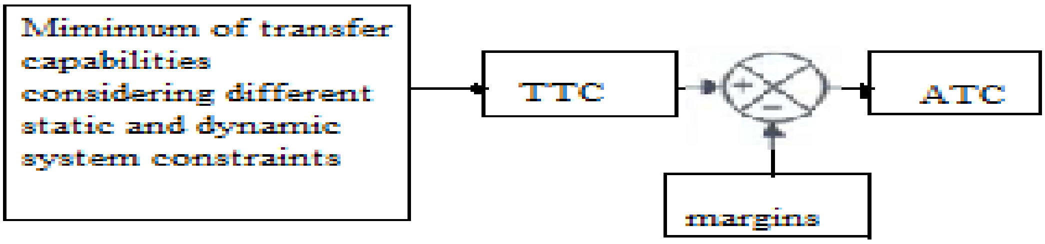

Figure 1: Available transfer capability parameters

If TRM is constant or not considered then,

ATC = TTC-CBM

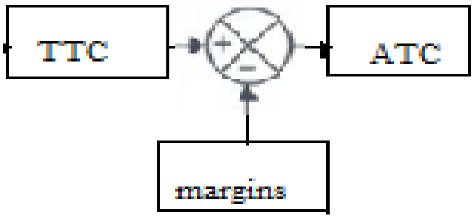

Figure 2: Available transfer capability parameters excluding Transmission Reliability Margin

Total Transfer Capability (TTC) is the amount of electric power that can be transferred over the interconnected transmission network in a reliable manner while meeting all of a specific set of defined pre and post-contingency system conditions[11].

Yan et.al have proposed popular method to calculate TTC and is limited by the physical and electrical characteristics of the systems including thermal, voltage and stability considerations. Once the critical contingencies are identified, their impact on network must be evaluated using any of the following methods[2]:

1. Continuation power flow(CPF)
2. Repeated power flow(RPF)
3. Security constrained optimal power flows(SCOPF)
4. Transfer-based security constrained OPF (TSCOPF)

Both CPF and RPF enable transfers by increasing the complex load with uniform power factor at every laoad bus in the sink area and increasing the injected real power at generator buses in the source area in the incremental steps until limits are incurred.

Conventional Security constrained optimal power flows(SCOPF) methods maximize the transfer capability between two control areas assuming all OPF- optimised parameter, which is much easier and time to convergence is reduced[2].

Capacity Benefit Margin (CBM) [1] is the amount of transmission transfer capability reserved by load serving entities to ensure access to generation from interconnected systems to meet generation reliability requirement.

Probabilistic or deterministic approach using probability density function which results in realistic information, considering all uncertainties in the system equipment can be used to calculate CBM.

The literature of ATC calculation can be divided into different categories, few of them are listed below:

i. **Power flow analysis:**

1. Linear Approximation method
2. Optimal power flow method

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3. Continuation power flow method

ii. Statistical methods:

1. Monte carlo simulation
2. Stochastic programming
3. Bootstrap approach.
4. Sensitivity analysis.
5. Enumeration method.

iii. Artificial Intelligent techniques:

1. Back propagation Algorithm (BPA).
2. Radial Basic function (RBF) Neural networks (NN).
3. Adaptive Neuro Fuzzy Inference system (ANFIS).
4. Quick propagation algorithm to train the NN.
5. Conjugate gradient.
6. Interior point algorithm.

Case I: Power flow analysis:

Linear Approximation method (DC Power flow model computes Thermal limit only), Optimal power flow method (AC Power flow model computes Thermal+ voltage limit) and Continuation power flow method(AC Power flow model computes Thermal+ voltage limit, voltage collapse) are based on power flow computation[2]. For these methods, the steady state constraints can be easily considered but dynamic stability constraints are difficult to be taken into account, and the computation time is longer.

Case II: Statistical method:

Ying et.al have proposed the stochastic programming method for evaluation of ATC; recognizing the uncertainties of power systems, availability of generators and circuits as well as load forecast error are considered as random variables and steady state ATC evaluation of interconnected system is obtained[9]. Kulyos et.al has proposed Sensitivity analysis in [6] can provide results with shorter computation time. References [7] Luo et.al and [8] khairuddin et.al adopt AI methods to deal with uncertainties of power systems with a shorter computer time, but with the system expansion, the validity and effect of the algorithm is still to be verified. These methods all belong to deterministic methods.

Xiao et.al have proposed the probabilistic methods include: stochastic programming in [9] and Xia et.al have proposed enumeration method in [10] which consider uncertainties, but the computation time will increase rapidly when the size of system increases. Tsai et.al have proposed Bootstrap procedure in [12] computes the distribution of ATC value that reflects the recent market activities, while it is hard to deal with uncertainties. Armando et.al have proposed Monte Carlo simulation in [11] can process uncertainties of power systems within a shorter computation time. The steady state constraints and voltage stability and transient stability constraints are taken into account.

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Case III: Artificial Intelligent techniques:

In real time application ATC can be computed using intelligent techniques such as Back propagation Algorithm(BPA),Radial Basic function (RBF) Neural networks(NN), Adaptive Neuro Fuzzy Inference system(ANFIS),Quick propagation algorithm to train the NN[7], Conjugate gradient, Interior point algorithm. Artificial intelligent techniques takes more time for training but once trained requires less computation time.[7] Vinod Kumar et.al focused on artificial neural networks method [24] as it requires a large input vector so that it has to oversimplify determination of ATC and proposed techniques such as Back propagation Algorithm(BPA),Radial Basic function (RBF) Neural networks(NN), Adaptive Neuro Fuzzy Inference system(ANFIS), to reduce the computational burden and to execute ATC in real time differential Artificial intelligence.

Luo.et.al proposed Quick propagation Algorithm [7] model employing Artificial neural networks to calculate transfer capability, which overcomes the slowness of the Back propagation Algorithm. When a neutron with a standard sigmoid function is near its boundary, the slope of the activation function is almost zero and error gradient is near zero. As e result the update weight step will be very small.

III. FACTS CONTROLLERS:

Due to availability of limited energy resources and certain economic constrains, power transmission networks are forced to operate near their stability thresholds at maximum capacity .To achieve this some expensive solutions such as building up of new lines, topological reconfiguration through line switching in or outage, power flow control are generally used . To achieve more flexibility in power system control and management, FACTS devices, are widely used in large power systems networks.

Flexible AC transmission systems (FACTS) devices are the powerful tools for improving the voltage profile of the system. These FACTS devices could be a suitable solution for increasing transmission system capacity with power flow controls. Cai et.al [17] and Nareshacharyan et.al[18] proposed that from the steady-state point of view, by supplying or absorbing reactive power, increasing or decreasing the voltage and controlling series impedance or phase angle, a FACTS device makes it possible to operate transmission lines close to their thermal limits, thus reducing line losses. However, the effects of the FACTS devices are highly dependent on their type, size, number and location on the transmission system [18].

Wang et.al have proposed that Thyristor Controlled Series Compensator (TCSC) [15] can help increase power transfer capability in heavily loaded network because of its capability to control power flow fliexibly.Genetic Algorithm is used as the optimization tool to determine the location as well as the parameters of TCSC simultaneously.

Devices such as Unified Power Flow Controller (UPFC), Thyristor Controlled Series Compensator (TCSC), Static Var Compensator (SVC), Thyristor control phase shift transformer (TCPST) can be placed in a power system network at different locations to minimize the overall cost of the system including the FACTS

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controllers investing costs. FACTS controllers also minimize the total congestion rent and maximize the quality of welfare to the society.

IV.PROBLEM FORMULATION:

A power system may have 'n' number of buses. India is having IEEE 14 bus system so generally IEEE 14 bus system is designed for simplification.

The flow chart represents the work to be carried out further.

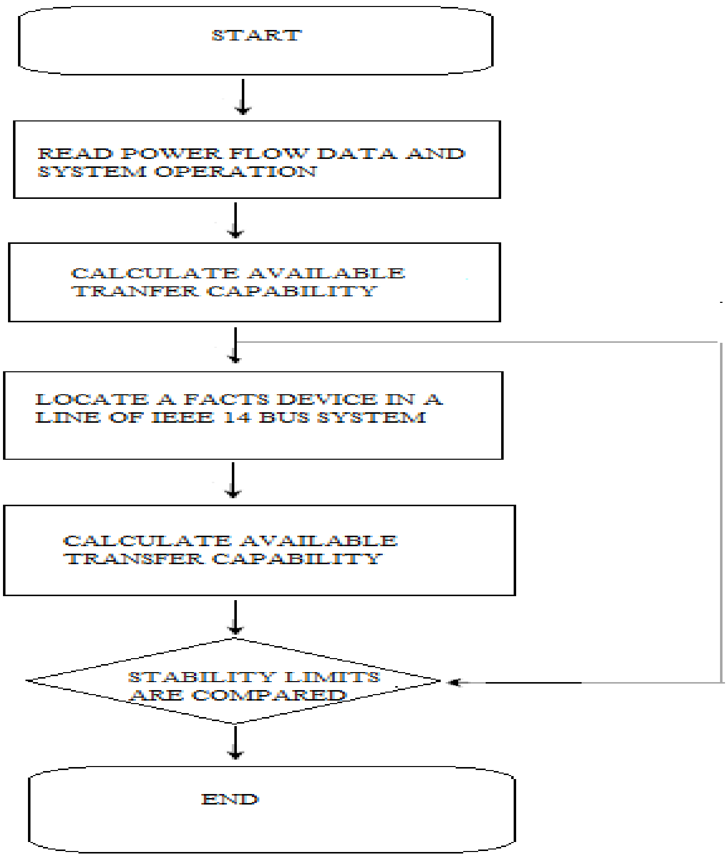

Figure 3: Flow chart of IEEE 14 bus system stability improvement

The flow chart represents the work to be carried out further.

1. Take a IEEE 14 bus system with all the parameters (Voltage magnitude, phase angle, active and reactive power) of load flows specified.
2. This system is continuously monitored and computed using ATC technique.
3. A FACTS Device with a FACTS controller is located in in a line of IEEE 14 bus system to improve the power flow and dynamic stability.

4. The FACTS based IEEE 14 bus system s is continuously monitored and computed using ATC technique.
5. IEEE 14 bus system with and without FACTS Device is compared and the voltage,thermal and stability limits are obtained.

V.CONCLUSION:

This paper mainly studies two margins of ATC:TRM and CBM and presents the review on some methods suitable for calculating ATC and are a measure of accuracy from which the risk of curtailment of each transfer level can be determined. As in practical power markets, the load and trading scheme continuously changes with large number of uncertainties which has impact on all the participants in the decision making and evaluation about the risk of different trading is also worth of consideration. The location of FACTS Device decides the maximum ATC.

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