REVIEW ON AVAILABLE TRANSFER CAPABILITY CALCULATION METHODS

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Abstract: Intimation of available transfer capability (ATC) by Independent System Operator is important issue in a deregulated power markets. ATC is the prime important indication for all companies, IPPs, retailers, transmitters, distributors and customers, for participation in the trading of electrical powers. ATC indicates remaining transfer capability over and above already committed use in a competitive electricity markets for its commercial use. This paper review the literature related to ATC calculation in a deregulated electricity markets. 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 (ATC), Artificial Neural Network (ANN), Continuation Power Flow (CPF), DC Load Flow, Genetic Algorithm (GA), Intelligent Methods, Repetitive Power Flow (PRF).

1. INTRODUCTION

Available transfer capability (ATC) calculation has been a research area of exponentially increasing interest particularly in the past two decades. Nowadays electricity market direction is toward the deregulation, very strongly. The foremost center of thought at the back of restructuring electricity market is to bring some form of competition among the market participants, open access to all, to provide options and benefits to the end user customers. In order to bring the competitiveness in electricity industries, the transmission network capability and generation capacity of the power system should be made available to the market participants well in advance before bidding. Independent System Operator (ISO) is responsible for providing commercially viable information of transmission capability. Before allowing transaction ISO should check whether the transmission capability in a transmission network is within limits or not.

The U.S. Federal Energy Regulatory Commission (FERC) issued orders 888 and 889, which established open access non-discriminatory transmission services policy and Open Access Same-time Information System (OASIS) formerly known as Real Time Information System (RIN). Available transfer capability (ATC) is required to be posted on publicly accessible OASIS. This necessitates the calculation of Available Transfer Capability (ATC) of transmission path [1] in deregulated electricity markets. Over calculated ATC will offer more power transactions, which will decrease system's security. Under calculated ATC will offer lesser transactions, ultimately affect market economy. To avoid the undesirable impacts of open access in an energy markets such as heavier line loadings and increased loop flows, a clear indication of system ATC is required [2]. North American Electric Reliability Council (NERC) defines ATC as a "measure of transfer capability remaining in the physical transmission network for further commercial activity over and above already committed uses [2].

Definition- According to NERC Report Available Transfer capability (ATC) is a measure of transfer capability remaining in the physical transmission network for further commercial activity over and above already committed uses "The term capability here refers to the ability of lines(s) to reliably transfer power from one bus/area to another It is different from transfer capacity in the sense that capacity implies rating of specified line(s) and that accounts for the thermal limits only. Capability on the other hand is the function of that line with other elements in the transmission network. Mathematically, ATC is defined as,

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

Where TTC- Total Transfer Capability
TRM-Transmission Reliability Margin
ETC-Existing Transmission Commitments
CBM-Capacity Benefit Margin

In equation (1), other terms except TTC are normally decided by the load serving entities. If TRM and CBM are not considered, TTC represents ATC at the base load flow conditions. The term TTC is variable and changes according to the change in line flows, line limits and the transacting power between the buses. The line limit and transacting power are the known quantities. Hence major part of TTC (or ATC) determination is to compute the change in line flows for a specific transaction. These changes can be determined by taking the difference of line flows obtained before and

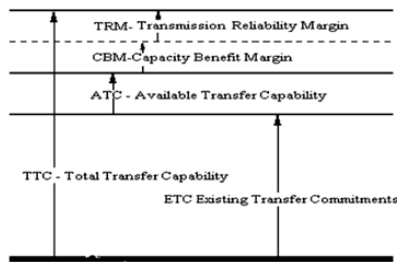after applying the transactions. Graphically these values are represented in Figure 1

Fig. 1: Graphical Representation of ATC and other associated terms

Mathematically, ATC is defined as the Total Transfer Capability (TTC) less the Transmission Reliability Margin (TRM), less the sum of Existing Transmission Commitment (ETC) (which includes retail customer service) and the Capacity benefit Margin (CBM)".
ATC can be expressed as:

ATC = TTC – TRM - ETC –CBM

The report [2] defines the ATC principles under which ATC values are to be calculated. The ATC principles include the following:

- ATC calculations must recognize time-variant power flow conditions and simultaneous transfers and parallel path flows throughout the transmission network.
- ATC calculations must recognize the dependency of ATC on the points of power injection, the directions of power transfers and the points of power extraction.
- ATC calculations must produce commercially viable results and the computed ATC's must give a reasonably accurate and dependable indication of transfer capabilities available to the electric power market.

North America Electric Reliability Council (NERC) defines TTC between any two areas or across particular path or interface as an "amount of electric power that can be transferred over the interconnected transmission network in a reliable manner without violation of thermal limits, voltage limits and dynamic stability limits". TTC is a direction specific and consistent with the First Contingency Total Transfer Capability (FCTTC) as defined by NERC's May 1995 Transmission Transfer Capability reference document [3].

Fig. 2 shows the simple interconnected power system, which can be divided into three kinds of areas: sending area, receiving area and other area. Area may be power pool, individual electric system, sub regions, etc. the objective is to

calculate ATC from sending area to the receiving area through the specified transfer path.
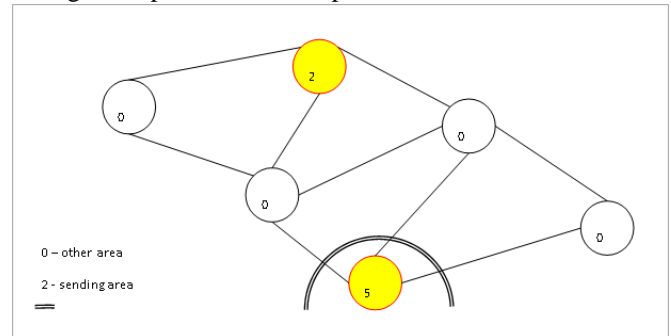

Fig. 2. A Simple Interconnected Power System

Literature survey reveals that ATC calculation methods can be further divided into two main categories as a deterministic methods and intelligent methods.

2. DETERMINISTIC METHODS

There are various deterministic mathematical techniques for available transfer capability (ATC) calculations. They are continuation power flow method (CPF) [8, 9], repeated power flow (RPF) method [10], optimum power flow method [19], dc load flow-based method [11, 12, 27], and power transfer distribution factor (PTDF) methods [8, 13-16, 17, 27-31, 33].

Sensitivity based power flow methods have been proposed by many researchers for fast computation of ATC. This method is based on power transfer distribution factors (PTDFs) or line outage distribution factors (LODFs) using DC load flow approach. In reference [27], using DC power transfer distribution factors (DCPTDF), the DC load flow based method is reported for fast calculation of ATC.

Comprehensive approach for ATC determination in multi-transactions environment using DCPTDF based problem formulation is reported in [33]. G. Hamoud proposed method of ATC assessment using Probabilistic Composite System Evaluation program (PROCOSE) in [11].This program provides a good tool for computing the ATC of a transmission system and identifying the most limiting facilities affecting the available transfer capability. PROCOSE uses a dc power flow model to simulate the operation of the power system, taking into account outages of generating units, economic dispatch, fixed power injections, system load profile, transmission outages and limits imposed on the transmission network. The program first schedules the generating units in each state, one unit at a time, using their incremental fuel costs to meet the load without respecting transmission constraints. The program then checks for the violation of network constraints. If there are violations of transmission constraints, the program reschedules the state generation to remove these violations and curtails loads if the violations persist.

DC load flow method has a poor accuracy when X/R ratio is low due to assumptions involved. This method is very useful due to its simplicity in calculation and speedy outcomes.

The DC load flow based approaches are fast using assumptions for DC load flow. Many researchers have presented more accurate methods considering reactive power flow based on AC load flow formulation for ATC calculation using the sensitivity factors reported in reference [8, 17, 28–31].

G.C.Ejebe et al in reference [8], reported a novel formulation of the ATC problem based on full AC power flow solution to incorporate the effects of reactive power flows, voltage limits and voltage collapse as well as thermal loading effects. An efficient continuation power flow approach with adaptive localization enhances speed in processing a large number of contingencies to determine ATC for each specified transfer. The CPF algorithm effectively increases the controlling parameter in discrete steps and solves the resulting power flow problem at each step. The procedure is continued until a given condition or physical limit preventing further increase is reached. Proposed method use Newton power flow algorithm, requires the calculation of Jacobean matrix once in iteration. Hence, the speed of proposed method is very slow. CPF yields solutions even at voltage collapse points, accurately.

Mohamed Shaban et al presented the calculation of TTC through optimal power flow approach in which the objective functions was to maximize the sum of the sending end generation and receiving load of specified buses in [19].

Ashwani Kumar, S.C. Srivastava and S.N. Singh presented an application of bifurcation criteria for available transfer capability (ATC) determination in a competitive power market having bilateral as well as multilateral transactions in [17]. It is a fast algorithm to calculate the available transfer capability (ATC). The proposed method has been applied for ATC determination on the system having static loads as well as induction motor loads. For ATC determination, the only real power loading at the selected buses has been increased. The real power outputs of generators participating in the transactions have been increased by the amount of load change in the ratio of predefined generation distribution factors. The slack bus generator is assumed to supply the change in system loss. PTDF gives a set of network sensitivity factors to predict flow changes due to bilateral transactions or the post-outage effects after transmission outages. In proposed method, a sequential full ac power flow is not required and hence has a high calculation speed.

3. INTELLIGENT METHODS

ANNs mimic the neural brain structure of humans. ANN structure consists of simple artificial neurons units connected in layer architecture. ANNs are capable of representing any degree of nonlinear functions with suitable selection of numbers of hidden layers and neurons in a hidden layer. ANN learns these complex functions through sets of inputs and targets data using appropriate algorithm for training reported in [20–22].

Many researchers of power system area are hoping solution of complex problems such as ATC calculation using ANN. This increases solution speed and ultimately security. This methodology is favored because it does not require mathematical model and further calculations.

Luo X. Patton A. D. and Singh C. in reference [4], Proposed a real power transfer capability calculations using multi-layer feed forward neural network for computing ATC between two specific area in the transmission network. In this paper, MLP topology based solution methodology is presented. Problem formulation is based on Optimum power flow methodology. This method calculates ATC accurately between single bilateral transactions between the two specified areas. The load variation is between 0.5 to 1.5 times of base case while all lines and generator remains in operation. Load variation is uniform in a particular area. Quick prop algorithm is used to train the neural network.

Ying Yi Hong proposed a method for ATC estimation using multi layered feed forward network in [6]. In this paper, the hybrid principle component analysis network is used to extract the essential bus information for independent system operator (ISO).

Seema N. Pandey, Nirved K. Pandey and Shashikala Tapaswi have proposed a Levenberg- Marquardt algorithm neural network based approach for fast and accurate estimation of system ATC in reference [35],. The system ATC has been estimated for both varying load condition as well as for single line outage condition by employing distributed computing. Principal component analysis has been applied for effective input variable selection. Contingency clusters are formed such that each cluster contains almost similar ATC values. The proposed approach has been examined on 75-bus Indian power system and IEEE 300-bus system and found significantly efficient.

GAs uses the techniques of human genetic evolution. Basic steps involved in GAs are coding, fitness Function, constraints and convergence. Set of random population is generated, which all represents solutions. Coding is a transformation of a real problem into an equivalent coded form. Fitness Function is a problem specific and represents single numerical fitness hence a measure of success. GA Operators choose better individuals and remove worst individuals by using Gas operator reproduction, crossover and mutation. . Convergence is a suitable termination. Generated solution fitness is checked using fitness function. GA Operators choose better individuals and remove worst individuals. GAs may be considered as a multidimensional optimization technique based on a genetically random search such that fittest will survive [23–26].

Mozafari B, Ranjbar AM, Shirani AR and et al [5] proposes a genetic algorithm based method for computing ATC between two specific areas in the transmission network. Problem formulation is based on an OPF model considering AC power flow equations as equality constraints and active power generation costs of generators to dispatch them economically in every operating points of the system. Objective function tries to maximize total generation in one area and consumptions in another area and simultaneously tries to minimize the cost of generation as well.

K. Selvi et al proposed genetic algorithm based problem formulation to estimate total transfer capability (TTC) in [7]. In this paper, main objective function is maximized without system constraint violations and estimates the TTC between the two specific areas through global optimal search.

4. 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].
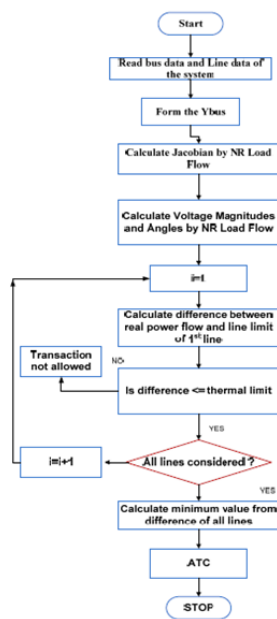

Figure 3: Flow chart for ATC calculation

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.

5. CONCLUSIONS

The CPF and RPF methods provide more accuracy in ATC calculation than the DC load flow but computational time requirement is high due to involvement of much iteration to realize contingencies such as lines outages, generator outages etc. before posting of ATC values as an indication for electrical power bids and hence, are not suitable for on line application. The work proposed in this paper presents a simple and efficient RPF 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.

When X/R ratio is more than 4, DC load flow method is practically suitable for on line application, as it gives solution with reasonable accuracy, but every network is not suitable for DC load flow application. Indeed, mathematical modelling of a system problem and calculations are not required in ANN and also due to its capability of parallel processing and to represents any degrees of nonlinear functions with suitable selection of numbers of hidden layers and simple neurons in a hidden layer, it may be suitable for on line application.

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