Comparative Analysis of ATC Probabilistic Methods

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Abstract - The price of power transfer between two areas is a key issue between buyers and sellers in the power market which is directly related to the ATC deal and security. ATC deal is computed by Deterministic methods and ATC security presented by probabilistic methods. Since the ATC is used for operation or planning of power system, ATC can be determined by Deterministic or Probabilistic methods. In this paper, existing probabilistic methods which could predict ATC for power system planning are reviewed and compared. [Journal of American Science 2010;6(9):1-4]. (ISSN: 1545-1003).

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1. Introduction

ATC is an evaluation of the remaining energy in the physical transmission network for future commercial activity over and above already committed utilities (NERC, 1996). ATC should represent accurate and practical knowledge information on the ability of interconnected networks to reliably increase the transfer of power between two sites, and it is a function of increase in power transfers between different sites in the interconnected network (Cornière et al., 2000; Tsai and Lu, 2001). Mathematically, ATC is defined as the total transfer capability (TTC) less the transmission reliability margin (TRM) the sum of the capacity benefit margin (CBM) and existing transmission commitments (ETC), which includes pre-transfer base case flows without contracts and the flows caused by existing contracts. In other words, ATC can be expressed as:

$$ATC = TTC - TRM - CBM - ETC \qquad (1)$$

Transfer capability essential necessary to secure that the interconnected transmission network is certain under a reasonable range of uncertainties in system situation determine the transmission reliability margin (TRM). Capacity benefit margin is specified as that quantity of total transfer capability reserved by load serving entities to certain access to generation from interconnected systems to meet generation reliability necessities.

TRM accounts for the intrinsic uncertainty in system situations and the necessity for operating flexibility to certain reliable system operation as system conditions change. There are several approaches proposed to achieve this (Sauer, 1997):

1) Repeated computation of TTC using variations in the base case data
2) A single repeat computation of TTC using limitations reduced by a fixed percentage (i.e., 4%).
3) TTC reduced by a fixed percentage (i.e., 5%).
4) Probabilistic approach using statistical or other systematic reliability concepts.
5) First order sensitivity method to take the effect of changes in load and simultaneous transfer on ATC Gravener and Nwankpa , 1999).

Utilities would have to determine sufficiently their ATCs to certain that system reliability is maintained while serving a wide range of transmission transactions. ATC would be continuously calculated and updated in planned power transfers between or among the areas.

The ATC principles are stated as follows:

1) Give a reasonable and dependable indication of transfer capabilities.
2) Recognize time-variant conditions, simultaneous transfers, and parallel flows.
3) Recognize the dependence on points of injection / extraction.
4) Reflect regional coordination to include the interconnected network.
5) Conform to NERC and other organizational system reliability criteria and guides.
6) Accommodate reasonable uncertainties in system conditions and provide flexibility (Sauer and Grijalva, 1999).

In the most case, determination of transfer capability and other related margins has been coordinated by the North American Electric Reliability Council (Ejebe et al., 2000; NERC, 1999). And operating studies commonly seek to determine limitations due to the following types of problems:

1) Thermal overloads Limitation
2) Voltage stability Limitation
3) Voltage limitation
4) Power generated Limitation
5) Reactive power generated Limitation
6) Load Power Limitation

Based on market demands ATC is computed hourly, daily or monthly. In ATC calculations definite factors such as contingencies that would represent most serious disturbances, unit commitment, accuracy of load forecast and distribution, system topology and configuration, and maintenance scheduling should be taken into account. System control devices such as voltage regulators and reactive power control devices also have a direct impact on ATC values. The literatures on ATC calculation can be divided into Deterministic and Probabilistic methods. This paper revises and expands several papers of probabilistic ATC computations. General conclusion is given in section 3.

2. Probabilistic Methods

Since the need of ATC appears only after the electrical industry started deregulation and open access, not many fast ATC calculation algorithms are available nowadays. From the investigations which have been performed on the ATC evaluation, the adopted algorithm may be mainly classified into two categories which are probabilistic and deterministic methods. The former can give comprehensive information during the operational planning stage which is off-line executed shortly before the real-time operation, while the latter may provide timely relevant data to on-line operational performance.

For on-line calculation, i.e. in an operations environment where ATC values are posted on a short-term (usually one to several hours or even shorter) basis, calculation of ATC may be performed for most limiting constraints. The methods of on-line ATC calculation are based on deterministic model, and they may be solved by several methods, such as: DC Power Flow (DCPF), Power Transfer Distribution Factor (PTDF), Generation Shifting Factor (GSF), Repeated Power Flow (RPF), Load Open Distribution Factor (LODF), Continuation Power Flow (CPF), and Optimal Power Flow (OPF) methods.

All of these methods mentioned are deterministic methods. These methods calculate ATC at determined time and system state perfectly. In other words, the steady state constrains can be easily considered but dynamic stability constraints are difficult to be taken into account.

Because of the necessity of considering several limitations in ATC computations, different optimization methods are used. The important constraints that must be applied in determinations are: Voltage (V), Thermal (P_{max}), Voltage Stability, Power generated (P_g), Reactive power generated (Q_g) and Load Power (P_l) Limitation .And most important of them are voltage, thermal and satiability limitations which are considered in most of ATC computations.

In addition, for off-line calculation, uncertainties and time- varying in load demand and state transition of components should be taken into account. The uncertainties that have great influence on power system operation include: weather factors, load forecast and fault of generators, lines and transformers (Yajing et al., 2006).

Generally, the impact of system uncertainties on the ATC has been assessed using probabilistic methods (Yuan, 2007; Audomvongseree and Yokoyama, 2004; Shaaban et al., 2003; Leite da Silva et al., 2002). The probabilistic assessment of power transfers consists basically of two main steps: system state definition and power transfer estimation for it. Up to now, a lot of methods are used for probabilistic calculation of ATC. Some of the important ones are artificial methods (Deqiang et al., 2003; Marangon et al., 2002), Cubic Spline, Stochastic programming and Monte Carlo.

3. Comparing the above Methods

Artificial Neural Network (ANN) method requires a large input vector so that it has to oversimplify determination of ATC (Khairuddin, 2004). A real time ATC calculation using three different techniques: Back propagation Algorithm, Radial Basis Function Neural Network and Adaptive Neuro Fuzzy inference system were proposed in (Kumar et al., 2006). All of these methods follow all the paths between the transfer buses of the ATC. The path with the least impedance is chosen as a basis of sample generation in the intelligent programs .They applied these methods on a 24 bus system considering only line thermal ratings and a few selected line outages. A cubic spline interpolation curve fitting that reduces the computation time of the power flow computations (Othman et al., 2004). The ATC limited by voltage and power flow limits. The results show that this method is accurate and faster than an iterative AC power flow.

The Monte Carlo method is a known method used to obtain the solution of the stochastic power flow problem. This method utilizes repeated distributions of the nodal powers, line flows and losses. Since the accuracy of the probability distribution of line flows, voltages and losses is assumed to be better when modeling all stochastic inputs over a large number of trials, the Monte Carlo method is often characterized by a large computation time. Nonetheless, the Monte Carlo has been used in many general engineering applications (Yajing et al., 2005; Huang and Yan, 2002; Chun, 2004). This method has an appeal that a wide range of stochastic phenomena can be modeled, thus proposing “accuracy “in the results. Monte Carlo approach does not rely on any required system characteristics: e.g. nonlinear systems are just as readily studied as linear systems. But computational burden is a disadvantage of the Monte

Carlo approach and researchers have sought faster methods to calculate the probability distributions. The Monte Carlo method can be used to verify and validate these faster methods. Sequential Monte Carlo Simulation utilized with considering the time-varying load and the fault and repair of equipments (generator, transformers and lines). This method employed with the load forecast error and equipment availability uncertainty (Anselmo , 2007).

A stochastic-algebraic method employed for the first time by assuming that the system is linear with applying just thermal limitation (Stahlhut et al., 2005). Stochastic - algebraic method with voltage and thermal constraints ,improved by considering two uncertainties, Bus loading and Transmission element status (Jonathan and Stahlhut,2007) .

Table 1. Performance comparison of probabilistic methods

Constraints & Uncertainties	Methods			
	Stochastic Programming	Monte Carlo	Cubic Spline	Artificial Methods
V	√	√	√	√
Pmax	√	√	√	√
Pg		√		√
Qg		√		√
Pl		√		√
voltage stability	√			
component outages	√	√	√	√
load variation	√	√		

Some of the important probabilistic methods with their performance and limitation are listed in Table 1. Because of some limitations in the methodology of these methods, considering all constraints are not possible. This table shows that most of the constraints mentioned in the first paragraph of this section are applied to Monte Carlo and Artificial methods.

Based on Table 1 and author's literature review, Monte Carlo method is better than the other methods since it considers more constraints. Despite the fact that the probabilistic ATC is more commercially important in the deregulated environment, all methods used before that for probabilistic ATC calculation are extremely time-consuming and can not be implemented for online power systems. Therefore more efficient method is the method which:

1) Can consider almost of constraints
2) It is possible for predicting ATC by the effect of uncertainties
3) Its computational time is low

4. Conclusion

ATC computations method separate in two groups, Deterministic and Probabilistic. Deterministic methods are faster than Probabilistic methods and they have good performance for using in online system (operation). But their accuracy is low and the uncertainties couldn't take to account. The important uncertainties are Generation dispatch, weather factors, load forecast, and fault of unplanned generators, lines and transformers.

Compared to the deterministic methods, probabilistic approach is not only more accurate but can also provide more information, such as the expected value and variance of ATC, which will be illustrated in the case study. Probabilistic methods such as cubic Spline, Monte Carlo, stochastic programming and intelligent methods are used for calculating ATC with considering uncertainties. According to the result of ATC Probabilistic methods speed and accuracy comparison, the accuracy of Monte Carlo is better than other methods. However Monte Carlo, stochastic algebraic programming and some artificial method's accuracy are good but computational time of them is not acceptable for using this method on-line.

The optimizations are big influence on ATC probabilistic calculations performance. This computation can be improved by using fast and accurate optimization method. This optimization method must be able to use for big system by considering all constraints. The algebraic equations and iterations must be short and simple. In addition, for prediction of ATC for planning system, several statistic methods are available that choosing them requires more consideration.

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