ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 1, January 2014

Available Transfer Capability Calculation Methods: A Review

Rajnikant H. Bhesdadiya[1], Dr. Rajesh M. Patel[2]

School of Engineering, RK University, Rajkot, India, PhD Scholar [1], Assistant Professor, L.E. College, Morbi [1]

Principal, HJD Institute of Technical Education and Research, Kera, Kutchh, Member, IEEE, ISTE [2]

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.

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).

I. 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].

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:

$$ATC = TTC - TRM - ETC - CBM$$

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 1, January 2014

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. 1 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.

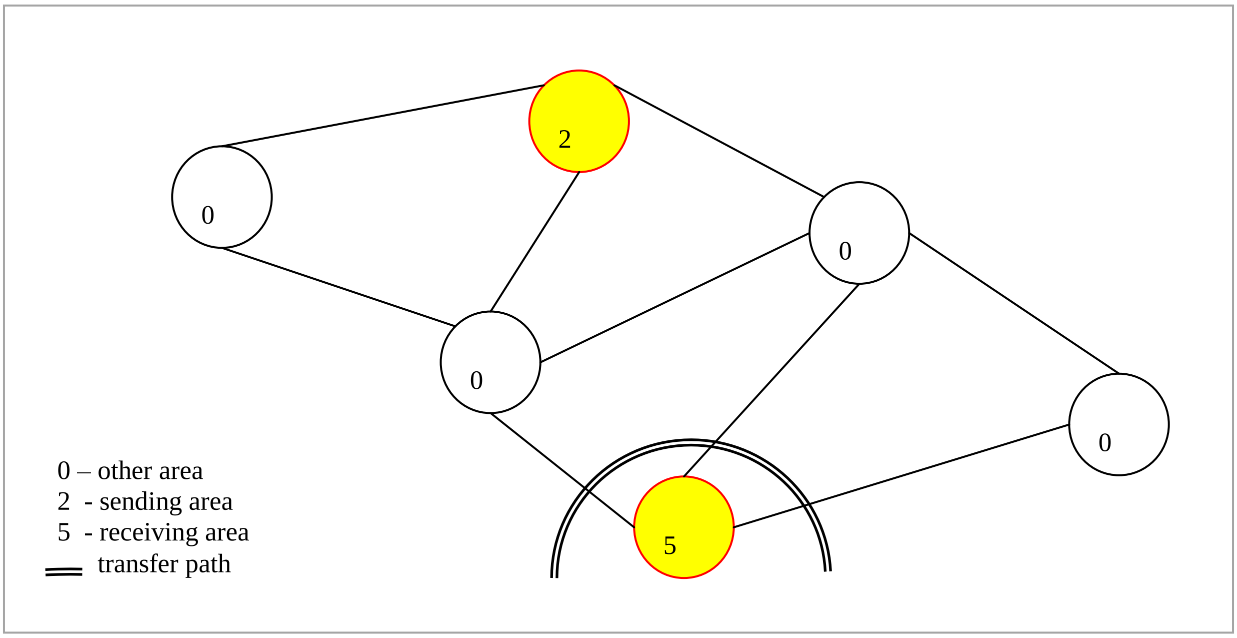

Fig. 1. A Simple Interconnected Power System

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

II. 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

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 1, January 2014

[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.

In reference [32], an approach for power transfer distribution factors based calculation of TCSC reactance for ATC enhancement is presented. Kumar Jitendra and Kumar Ashwani proposed a method of ATC determination in multi-transactions environment using AC power transfer distribution factors is reported in [34].

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 1, January 2014

III. 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.

IV. 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

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 1, January 2014

outages etc. before posting of ATC values as an indication for electrical power bids and hence, are not suitable for on line application.

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.

REFERENCES

[1] https://www.ferc.gov/legal/maj-ord-reg/land-docs/order889.asp. Federal Energy Regulatory Commission. Open Access Same-Time Information System and Standards of Conducts, Docket No. RM 95-9-000, Order 889, April, 1996: [Cited 2013 Jan 8].
[2] http://www.nerc.com/docs/docs/pubs/atcfinal.pdf. Available Transfer Capability Definitions and Determination, A framework for determining available transfer capabilities of the interconnected transmission networks for a commercially viable electricity market prepared by *TTC Task Force*, North American Electric Reliability Council, June 1996: [Cited 2013 Jan 9].
[3] http://www.nerc.com/docs/docs/pubs/TransmissionTransferCapability_May1995.pdf. Transmission Transfer Capability A Reference Document for Calculating and Reporting the Electric Power Transmission Capacity of Interconnected Electric Systems, North American Electric Reliability Council, June 1995: [Cited 2013 Jan 9].
[4] Luo, X., Patton, A. D., and Singh, C., "Real Power Transfer Capability Calculations Using Multi Layer Feed Forward Neural Network", IEEE Transactions on Power Systems, 15(2): 903-908, May 2000.
[5] Mozafari, B., Ranjbar, A. M., Shirani, A. R. and et al. "A Comprehensive method for available transfer capability calculation in a deregulated power system", IEEE International conference on Electric Utility Deregulation, Restructuring and Power Technology, Hong Kong, 680-685, 2004.
[6] Ying-Yi Hong , and Chien-Yang Hsiao, "On-Line ATC estimator using hybrid principal component analysis network", *Journal of the Chinese Institute of Engineers*, Vol. 30, No. 5, pp. 781-789, 2007.
[7] Selvi, K., Ramaraj, N., Bhavani, M., "Total Transfer Capability Evaluation using Genetic Algorithms" *IE(I) Journal* – EL, Vol. 88, pp. 60-64, June 2007.
[8] Ejebe, G. C., Tong, J., Waight, J.G. and et al. "Available Transfer Capability Calculations", IEEE Transactions on Power Systems, Vol. 13(4), pp. 1521-6, November 1998.
[9] Gravener, M. H., Nwankpa, C., Tai-Sim Yeoh, "ATC computational issues [electricity supply]', In: Proceedings of the 32nd annual Hawaii international conference on system sciences, p. 1–6, 1999.
[10] Ou, Y., Singh, C., "Assessment of available transfer capability and margins", IEEE Trans Power System, Vol. 17 (2), pp. 463–8, 2002.
[11] Hamoud, G., "Assessment of available transfer capability of transmission systems", IEEE Transactions on Power Systems, Vol. 15(1), pp. 27-32, February 2000.
[12] Ilic, M. D., Yoon, Y. T., Zobian, A., "Available transmission capacity (ATC) and its value under open access", IEEE Trans Power System, Vol. 12 (2), pp. 636–45, 1997.
[13] Wood, A. J., Wollenberg, B. F., "Power generation, operation and control", New York: Wiley; 1996.
[14] Grijalva, S., Sauer, P. W., Weber, J. D., "Enhancement of linear ATC calculations by the incorporation of reactive power flows", IEEE Trans Power System, Vol. 18 (2), pp. 619–24, 2003.
[15] Kumar, A., Srivastava, S. C., "AC power transfer distribution factors for allocating power transactions in a deregulated market", IEEE Power Eng Rev, Vol. 22 (7), pp. 42–3, 2002.
[16] Venkatesh, P., Gnanadass, R., and Padhy, N. P., "Available Transfer Capability Determination Using Power Transfer Distribution Factors", International Journal of Emerging Electric Power System, Vol. 1(2): Art. 9:1-14, 2004.
[17] Kumar, A., Srivastava, S. C., and Singh S. N., "Available Transfer Capability Assessment in a Competitive Electricity Market Using a Bifurcation Approach", *IEE Proc. on Generation, Transmission and Distribution*, vol. 151, No. 2, pp. 133 – 140, March 2004.
[18] Konrad Purchala,, Daniel Van Dommelen, and Ronnie Belmans," Usefulness of DC Power Flow for Active Power Flow Analysis" IEEE Power Engineering Society General Meeting, vol. 1, pp. 454 – 459, June 2005.
[19] Mohamed, S., Yixin, Ni, Felix, F. W., "Transfer Capability Computations in Deregulated power systems," *Proceedings of the 33rd Hawaii International Conference on System Sciences, – 2000.*
[20] Wasserman, P. D., "*Advanced Methods in Neural Computing*" New York: Van Nostrand Reinhold, 1993.
[21] Hammerstrom, D., "Neural networks at work," *IEEE Spectrum*, vol. 30, pp. 26–32, June 1993.
[22] King, R. L., "Artificial neural networks and computational intelligence," *IEEE Comput. Appl. Power*, vol. 11, pp. 14–25, 1998.
[23] Goldberg, D. E., "*Genetic Algorithms in Search Optimization and Machine Learning*. Reading", MA: Addison-Wesley, 1989.
[24] Haupt, R. L., and Haupt, S. E., "*Practical Genetic Algorithms",* New York: Wiley, 1998.
[25] Davis, L., "*Handbook of Genetic Algorithms",* New York: Van Nostrand Reinhold, 1991.
[26] Vose, M. D., "*The Simple Genetic Algorithm*" Cambridge, U.K.: MIT Press, 1999.
[27] Christie, R. D., Wollenberg, B. F., Wangstien, I., "Transmission management in the deregulated environment", Proc IEEE Vol. 88(2), pp. 170–95, 2000.

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 1, January 2014

[28] Gravener, M. H., Nwankpa, C., "Available transfer capability and first order sensitivity", IEEE Trans Power System, Vol. 14(2), pp. 512–8, 1999.
[29] Ejebe, G. C., Waight, J. G., Santos-Nieto, M., Tinney, W. F., "Fast calculation of linear available transfer capability", IEEE Trans Power System, Vol. 15(3), pp. 1112–6, 2000.
[30] Greene, S., Dobson, I., Alvarado, F. L., "Sensitivity of transfer capability margin with a fast formula", IEEE Trans Power System, Vol. 17(1), 2002.
[31] Grijalva, S., Sauer, P. W., Weber, J. D., "Enhancement of linear ATC calculations by the incorporation of reactive power flows", IEEE Trans Power System, Vol. 18(2), pp. 619–24, 2003.
[32] Ghawghawe, N. D., Thakre, K. L., "Computation of TCSC reactance and suggesting criterion of its location for ATC enhancement", Int J Electric Power Energy System, 31:86–93, 2009.
[33] Kumar, J., and Kumar, A., "Multi-transactions ATC determination using PTDFs based approach in deregulated markets", In: Proc. annual power India conference, (INDICON), pp. 1–6, 2011.
[34] Kumar, J., and Kumar, A., "ACPTDF for multi-transactions and ATC determination in deregulated markets", Int J Electr Comput Eng (IJECE), Vol. 1(1), 71–84, 2011.
[35] Pandey, S. N., Pandey, N. K., and Shashikala Tapaswi, "Neural networkbased approach for ATC estimation using distributed computing", IEEE Transactions on power systems, Vol. 25, No. 3, pp. 1291-1300, August 2010.

BIOGRAPHY

Rajnikant H. Bhesdadiya graduated and mastered in 1999 and 2003 in electrical engineering from Gujarat University Gujarat, India. He has 7 years of experience in field in PGVCL, DISCOM of Gujarat State as a junior engineer. Since, May 2011, he is working as an assistant professor in Electrical Engineering Department of Lakhdhirsinhji Engineering Collage, Morbi, Gujarat. Currently, he is pursuing Ph.D. from R. K. University, Gujarat on ATC indication and congestion management. He is a Life Member of ISTE. He is a member of IEEE. His research interests include congestion management and ATC calculation using artificial intelligence aspects in power systems and electricity markets.

Dr. Rajesh Patel received his BE and ME in Electrical Engineering from Government Engineering College, Modasa in 1998 and L.D. College of Engineering, Ahmedabad, 2000, respectively. He obtained his PhD from IIT Roorkee in 2011. He has 13 years of experience of teaching and research. Since August 2011, he is working as Principal in HJD Institute of Technical Education and Research, Kera, Gujarat. He is a member of IEEE and Life Member of the Indian Society of Technical Education. His research interest includes condition monitoring, vibration analysis, power quality issues and artificial intelligence.