

Study on the Effect of Renewable Energy Power Generation on Available Transfer Capability

Anu Sara Thomas ¹, Dr.S.Padma²

P.G. Student, Department of EEE, Sona College of Technology, Salem, Tamilnadu, India¹

Professor, Department of EEE, Sona College of Technology, Salem, Tamilnadu, India²

ABSTRACT: The rapid utilization of renewable power can help countries to meet their policy goals on secure and reliable energy but the renewable energy often relies on the unpredictable and inconsistent weather for its source of power. Due to this intermittent and stochastic performance, the generation could increase the uncertainties of power system. This has significant effect on Available Transfer Capability (ATC). In this paper, an attempt is made to study the effect of renewable energy power generation on available transfer capability with the solar power generators regarded as PV node. The AC Power Transfer Distribution Factor method is proposed to calculate the available transfer capability under both contingency and non-contingency conditions with the consideration of thermal limits, reactive limit and line flow limits. The simulation results have been carried out on 6-bus system and IEEE-30 bus system.

KEYWORDS: Available Transfer Capability (ATC), Renewable power, AC Power Transfer Distribution Factor method (ACPTDFs).

I. INTRODUCTION

Electric utilities around the world are confronted with restructuring, deregulation and privatization. Hence the identification of power transfer capability must be accurate that it provides vital information for both planning and operation of the bulk power market. Estimates of transfer capabilities must be updated regularly to avoid the causing of any undue risk such as overloads, equipment damage, or blackouts.

With the development of renewable energy power generation technology and increase of power load demand [7], the renewable energy generation can be massively incorporated into the power grid. But when the sources are massively incorporated into the power grid, the intermittent and stochastic output of power generation influences the Available Transfer Capability. This paper deals with the calculation of available transfer capability from sending area to the receiving area through the specified transfer path with the incorporation of a typical new energy power generation, solar power generation. Its variation with load demand under both normal and contingency condition and the impact of Renewable energy power generation on ATC is also studied. The computation of ATC using Power Transfer Distribution Factors has been carried out and the applicability of this method is investigated on a 6-bus system and modified IEEE 30 bus reliability system with the PV node to regard as the solar power generator system.

Available Transfer Capability (ATC) is a measure of the transfer capability remaining in the physical transmission network for further commercial activity over and above already committed uses [11]. Mathematically,

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

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

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Special Issue 6, May 2015

II. MATHEMATICAL MODELLING

In this section, Available Transfer Capability problem is formulated and is solved using AC Power Transfer Distribution Factors method. The objective function is to calculate the measure of the transfer capability remaining in the physical transmission network for further commercial activities over and above already committed uses from a specific set of generators in a source area to loads in a sink area and to study its impact on renewable power generation. The objective function is subjected to the constraints of load flow equations and system operation limits. The static load flow equations can be expressed as:

$$P_i = |V_i| \sum_{k=1}^n |V_k| |Y_{ik}| \cos(\theta_{ik} + \delta_k - \delta_i) \quad (2)$$

$$Q_i = -|V_i|^2 \sum_{k=1}^n |Y_{ik}| \sin(\theta_{ik} + \delta_k - \delta_i) \quad (3)$$

Where P_i and Q_i denotes the real and reactive power generation at bus i . V_i and V_j are the voltage magnitudes at bus i and j respectively. Y_{ik} and θ_{ik} represents the magnitude and angle of element i,k of bus admittance matrix. δ_i and δ_k indicates the voltage angles of bus i and j . P_{gmin} and P_{gmax} are the lower and upper limits of real power generation at bus i . Q_{gmin} and Q_{gmax} are the lower and upper limits of reactive power generation at limits of voltage magnitude at bus i .

III. OVERVIEW OF AC POWER TRANSFER DISTRIBUTION FACTOR METHOD

AC Power Transfer Distribution Factor method is a simple and efficient method for determining the Available transfer capability (ATC) of the system under different system conditions [5]. In this work, the AC load flow program is executed by varying the generation and load on the system. Thus the various transmission line flows can be determined with the limiting factors like thermal limit, real and reactive power limits taken into account.

In order to determine ATC using AC load flow method, the base case load flow program using N-R method is run to calculate the power flow in various transmission lines. Newton-Raphson method is preferred over Gauss-Siedal method owing to its faster convergence rate in less number of iteration [2]. The N-R method solves non-linear algebraic equations and the Jacobian matrix which is formed during every iteration is given as:

$$\begin{pmatrix} \Delta \delta \\ \Delta V \end{pmatrix} = \begin{pmatrix} \frac{\partial P}{\partial \delta} & \frac{\partial P}{\partial V} \\ \frac{\partial Q}{\partial \delta} & \frac{\partial Q}{\partial V} \end{pmatrix}^{-1} \begin{pmatrix} \Delta P \\ \Delta Q \end{pmatrix} = J^{-1} \begin{pmatrix} \Delta P \\ \Delta Q \end{pmatrix} \quad (4)$$

In the above equation (4) the change in active power flow of line $i-j$ with respect to changes in state variables is determined as:

$$\frac{\partial P_{ij}}{\partial \delta_e} = \begin{cases} 0 & \text{for } e \neq i, j \\ -V_i V_j Y_{ij} \sin(\delta_i - \delta_j - \theta_{ij}) & \text{for } e = i \\ V_i V_j Y_{ij} \sin(\delta_i - \delta_j - \theta_{ij}) & \text{for } e = j \end{cases} \quad (5)$$

$$\frac{\partial P_{ij}}{\partial V_e} = \begin{cases} 0 & \text{for } e \neq i, j \\ -2V_i V_j Y_{ij} \cos(\delta_i - \delta_j - \theta_{ij}) & \text{for } e = i \\ V_i V_j Y_{ij} \sin(\delta_i - \delta_j - \theta_{ij}) & \text{for } e = j \end{cases} \quad (6)$$

If any one of the k th bilateral transactions is changed by Δt_k MW, the following two entries in the mismatch vector on right-hand side of Equation (4) will be non zero:

$$\Delta P_i = \Delta t_k, \quad \Delta P_j = -\Delta t_k \quad (7)$$

Hence with these mismatch vector elements, the change in voltage angle and magnitude at all buses can be determined from equation (4) and (7) and hence the new voltage profile can be calculated. These elements can be utilized to obtain all of the transmission quantities q_1 and hence the corresponding change in quantities, Δq_1 from the

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Special Issue 6, May 2015

base case[3]. The PTDFs can be obtained when the change in transmission, Δq_l for all lines corresponding to a change in the transaction Δtk is known. The ACPTDF is given by,

$$ACPTDF_{ij, mn} = \frac{\Delta q_l}{\Delta tk} \tag{8}$$

The linear impact of a transfer on the element of the power system can be determined using these PTDF's[7]. The line flows are deducted from their respective thermal limits and the minimum of the difference between actual line flow and thermal limit of all lines equals ATC of the system.

IV.METHODOLOGY

AC Power Transfer Distribution Method is a simple and efficient method to calculate the ATC from the source area to the sink area for contingency conditions as well. Under normal condition, a base case ac power flow is established, in which the system load is supplied without violating the system constraints. When a line outage occurs in a system, the power flowing on that line is redistributed on to the remaining lines in the system. Then the base case is modified by changing the generation in the source area and the load in sink area simultaneously[2]. This process continues until the limiting factors causes the violation of the system limit considered. The minimal amount of power transferred within the limit for the corresponding power transaction is observed as the ATC. The ATC is the reliable indicator of network congestion where multiple power transactions are carried out over existing transmission network. The Fig.1 shows the flowchart of the proposed method.

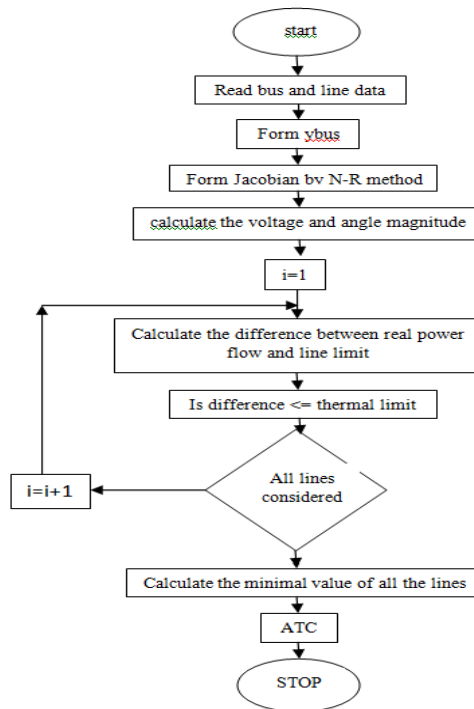


Fig. 1 The flowchart of proposed system

V.CASE STUDY

This section presents a case study to illustrate the basic notion of available transfer capability. The proposed technique is first applied to a 6-bus system with the buses 4, 5 considered as solar PV buses and the ATC values are calculated. For simplicity, only generators and tie-lines contingencies are considered here and the final ATC value is determined from the most limiting contingency case. The single line-diagram of the 6 Bus system taken as case study 1 is shown in the Fig.2.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Special Issue 6, May 2015

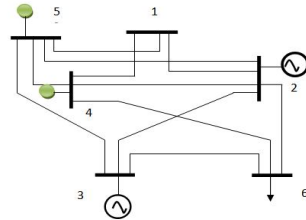


Fig 2: case study 1: 6-bus system

Similarly the same proposed technique is applied to IEEE 30-bus system with the buses 3, 22, 25 considered as solar PV buses and the respective ATC values for normal as well as contingency conditions are calculated. The single line diagram of IEEE 30-bus system is shown in Fig.3 as:

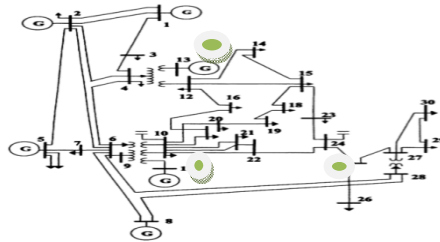


Fig 3: case study 2: IEEE 30 bus system

VI. RESULTS

The ATC values obtained using ACPTDF method with and without contingency for a particular transaction from bus 2 to bus 5 for 6-bus system and transaction between the bus 14 and bus 15 for IEEE -30 bus system are noted down. The table I give the ATC values for both 6-bus and IEEE 30 bus system without solar power generators for both case studies

TABLE I: ATC VALUES WITHOUT SOLAR POWER GENERATION FOR 6-BUS SYSTEM

FROM BUS	TO BUS	WITHOUT CONTINGENCY(MW)	WITH CONTINGENCY(MW) IN THE LINE 2-5
1	2	20.3	14.4
1	4	25.5	35.1
1	5	34.5	50.7
2	3	68.2	52.0
2	4	76.4	96.0
2	5	22.74	18.97
2	6	24.35	25.70
3	5	25.50	27.53
3	6	41.76	32.58
4	5	50.12	50.52

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Special Issue 6, May 2015

Similarly for IEEE 30 bus system, the ATC values under both conditions are calculated. The values for a single line outage in line 14- 15 is shown in table II:

TABLE II: ATC VALUES WITHOUT SOLAR POWER GENERATION FOR IEEE-30 BUS SYSTEM

FROM BUS	TO BUS	WITHOUT CONTIGENCY(MW)	WITH CONTIGENCY(MW) IN THE LINE 14-15
14	15	13.42	44.3456

To study the effect of renewable energy, the solar power generators are incorporated as PV nodes.. The solar turbines are rated at 20MW, which is installed on the node 4 and node in 6 bus system and node 3, 22 and 25 for 30 bus-system. In order to make comparable research, 3 kinds of penetration level of renewable energy power generation are set as:

- a) level 1: There is no solar power in system
- b) level 2: A solar station is added
- c) level 3: 2 solar stations are added. The base case ATC values obtained at each penetration level is noted down as shown in the table I

TABLE II: BASE CASE ATC (MW) VALUE WITH SOLAR POWER GENERATION

BASE CASE ATC VALUES FOR 6- BUS SYSTEM WITH SOLAR POWER GENERATION (MW)	
WITH 0 SOLAR POWER GENERATION OF 20MW.	202.8852
WITH 1 SOLAR POWER GENERATION OF 20MW.	203.9550
WITH 2 SOLAR POWER GENERATION OF 20MW.	209.5165

The ATC value for transaction 1 -2 has been increased from 27.44 to 56.5107 with the penetration of 1 solar power generator and later to 113.2471 as the effect of adding a solar generator at node 5. Similarly the impact of renewable energy generation on ATC for other transaction between bus 1 and bus 4 and transaction between bus 1 and bus 5 is shown in the Fig 4:

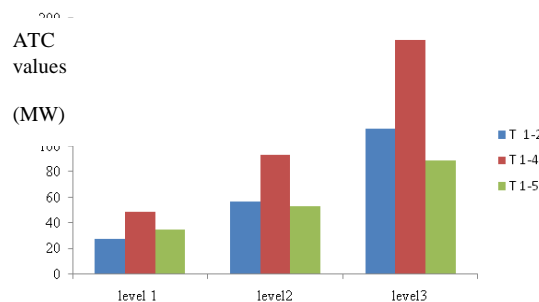


Fig4: Impact of renewable energy source on ATC for 3 transactions.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Special Issue 6, May 2015

Fig. 5 represents the variation of available transfer capability with respect to the change in load as 70, 80, 90, 100, 110 MWs in the system with constant power factor. As the load is increased, the ATC decreased due to decrease in load margin. No contingencies are considered here.

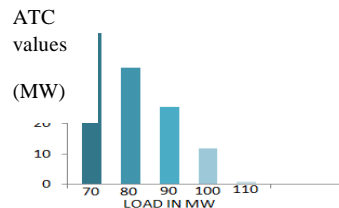


Fig 5 Variation of ATC with change in load

VI. CONCLUSION

An accurate ATC computation is a very important to the transmission system. The transmission of power will not be efficient economically if the computed ATC is less than the ATC of the system and if the computed ATC is more than the ATC of the system, the transmission will be operating in a dangerous state and any power increased will pave a chance to collapse the whole system and may result in disastrous. In this paper, a simple and efficient method for determining the available transfer capability of the system under different system conditions and its impact on renewable energy generation is studied with the solar power generator regarded as PV node. The present work provides platform for ATC determination in deregulated power market. The variation of ATC with load is also studied here. The drawback of this method is that it is not suitable for real time applications. Otherwise, ACPTDF method is very accurate method for ATC determination compared to other methods. There is calculation of ATC value for 6-bus system and IEEE30 bus system defined by MATLAB programming. The insertion of FACTS devices in electrical systems seems to be a promising strategy to enhance ATC. In the future works, the viability and technical merits of boosting ATC using UPFC can be analyzed.

REFERENCES

- [1] Anup Kumar and Mukesh Kumar "Available Transfer Capability Determination Using Power Transfer Distribution Factors", International Journal of Information and Computation Technology, Volume 3,(2013)
- [2] NirmalSolanki , Mr. U. L. Makwana "Calculation of Available Transfer Capability Using AC Load Flow Method", International Journal for Scientific Research & Development Vol. 2, Issue 01, 2014.
- [3] M. Y. Patel and A. A. Girgis "New Iterative Method for Available Transfer Capability Calculation", 978-1-4577-1002-5/11/\$26.00 ©2011 IEEE.
- [4] PoornimaPankajam T, J SrinivasaRao, J Amarnath "ATC Enhancement with FACTS Devices Considering Reactive Power Flows Using PTFDF", International Journal of Electrical and Computer Engineering (IJECE) Vol. 3, No. 6, December 2013, pp. 741~750.
- [5] Rajnikant H. Bhesdadiya, Dr. Rajesh M. Patel "Available Transfer Capability Calculation Methods: A Review", International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, Vol. 3, Issue 1, January 2014.
- [6] Luis Luna, JorgeMartínezCarlos, ValeroPacual and VanesaValiño "impact of wind power generation on the atc value", 17th Power Systems Computation Conference Stockholm Sweden - August 22-26, 2011.
- [7] PoornimaPankajam. T J. SrinivasaRao J. Amarnath "Linear ATC Enhancement with FACTS Devices Considering Reactive Power Flows using PTFDF", International Journal of Computer Applications (0975 – 8887) Volume 76– No.4, August 2013.
- [8] MojganHojabri and HashimHizam "Available Transfer Capability Calculation", Applications of MATLAB in Science and Engineering.
- [9] Yongfu Liu, Jun Harbin, Limei Zhang and DehaoZou "Research on Effect of Renewable Energy Power Generation on Available Transfer Capability", journal of software, vol. 8, no. 4, april 2013.
- [10] G. Hamoud, "Assessment of available transfer capability of transmission systems", IEEE Transactions on Power systems 15 (1) (2000) 27-32.
- [11] A framework for determining available transfer capabilities of the interconnected transmission networks for a commercially viable electricity market, "Available Transfer Capability Definitions and Determination" North American Electric Reliability Council June 1996.
- [12] Yan Ou, Student Member, IEEE, and Chanan Singh, Fellow, IEEE, "Assessment of available transfer capability and margins", IEEE Transactions on power systems, Vol. 17, No. 2, May 2002.
- [13] G.C. Ejebe, J. Tong, J.G. Waight, J.G. Flame, X. Wang, W.F. Tinney, "Available Transfer Capability Calculations", IEEE Transactions on Power Systems, Vol. 13, No. 4, November 1998.
- [14] Ashwanikumar, S.C.Srivastava and S.N.Singh, "ATC determination in a competitive electricity market using AC distribution factors", Electric Power Components and Systems 32 (2004) 927-939.
- [15] "Power System Analysis", by HadiSaadat, Mc GRAW-HILL international editions .