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Available Transfer Capability Determination Using Power Transfer Distribution Factors

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Abstract

Electric power industries throughout the world have been restructured to introduce competition among the market participants and bring several competitive opportunities. Open access to the transmission system places an emphasis on the intensive use of the interconnected network reliably, which requires knowledge of the network capability. Available Transfer Capability (ATC) is a measure of the remaining power transfer capability of the transmission network for further transactions. This paper describes the assessment of ATC using AC Power transfer distribution factors (ACPTDFs) in combined economic emission dispatch (CEED) environment. The ACPTDFs are derived using sensitivity based approach for the system intact case and utilized to check the line flow limits during ATC determination. The obtained ATC results are compared with Newton Raphson Load Flow method (NRLF) to justify its accuracy. Simultaneous bilateral and multilateral wheeling transactions have been carried out on IEEE 6 and 30 bus systems for the assessment of ATC.

Keywords: Available Transfer Capability, Restructuring, Wheeling transactions, A.C. Powertransfer distribution factors, Combined Economic Emission Dispatch.

1. Introduction

Restructuring process of the electrical industry throughout the world aims at creating competitive markets to trade electricity [1-5]. In order to have open access in the restructured power market, a transparent knowledge about the generation capacity and the transmission capability of the system has to be determined. Since many utilities provide transaction services for wholesale customers, they must know about the post information on ATC of their transmission networks. Such information will help power marketers, sellers and buyers in reserving transmission services. The computation of ATC has been carried out by the various researchers. Yan-Ou and Chanansingh demonstrated on IEEE 24 bus reliability test system [11]. However this method has a poor accuracy due to the assumption involved in the DC power flow model. Researchers have proposed the computation of ATC using AC Power Transfer Distribution Factors (ACPTDF) [13-15]. Before computing the ATC, the basic optimal power flow solution has to be determined. Nanda et.al made an attempt to explore the feasibility ofdeveloping a classical technique based on coordination equations to solve the combined economic emission load dispatch with line flow constraints [16]. ATC is computed using ACPTDF also in CEED environment for IEEE test systems. CEED problem is formulated as a multiobjective problem by considering both economy and emission simultaneously.

2. Available Transfer Capability

Available transfer capability (ATC) is a measure of the transfer capability remaining in the physical transmission network for further commercial activity over and above committed uses [21]. ATC can be expressed as:

$$\text{ATC} = \text{TTC} - \text{existing transmission commitments} \qquad (1)$$

Where, Total Transfer Capability (TTC) is defined as the amount of electric power that can be transferred over the interconnected transmission network or particular path or interface in a reliable manner while meeting all of a specific set of defined pre and post contingency conditions.

ATC at base case, between bus m and bus n using line flow limit (thermal limit) criterion is mathematically formulated using PTDF as

$$P_{ij-rs}^{max} = \left\{ \begin{array}{c} \frac{Limit_{ij}^{max} - P_{ij}}{ACPTDF_{ij,rs}} \; ; \; ACPTDF > 0 \\ \infty(infinite) \; ; \; ACPTDF = 0 \\ \frac{-Limit_{ij}^{max} - Pij_{max}}{ACPTDF_{ij,rs}} \; ; ACPTDF < 0 \end{array} \right\} \qquad (2)$$

Where P_{ij} is the real power flow through any line i-j.

$Limit_{ij}^{max}$is the thermal limit of any line i-j. $P_{ij,rs}^{max}$is the maximum allowable transaction amount from bus r to bus s constrained by the line flow limit from bus i to bus j.

2.1 CEED problem formulation

Optimisation of CEED problem has been mathematically formulated and is given by the following equation:

$$\sum_{i=1}^{Ng} Pg = Pd + Pi \qquad (3)$$

Where

P_d is the total load of the system and

P_i is the transmission losses of the system.

The power flow equation of the power network

$$g\ (|v|, \theta) = 0 \qquad (4)$$

The inequality constraint on real power generation Pgi on real power generation of each generation i

$$P_{gi}^{min} < P_{gi} < P_{gi}^{max} \qquad (5)$$

Where P_{gi}^{min} and P_{gi}^{max} are respectively minimum and maximum value of realpower allowed at generator I, respectively.

The inequality constraint on voltage of each PQ bus

$$V_i^{min} < V_i < V_i^{max} \qquad (6)$$

Where V_i^{min} and V_i^{max} are respectively minimum and maximum voltage at bus i.

Power limit on transmission line

$$\text{MVAfpq} < \text{MVAfpqmax} \qquad (7)$$

Where MVA fpq max is the maximum rating of transmission line connects bus p and q.

The bi-objective combined economic emission dispatch problem is converted into single optimization problem by introducing price penalty factor h [18] as follows.

$$\text{Minimise } \emptyset = FC + h * EC \qquad (8)$$

Subject to the power flow constraints of Eqs. (4) – (8). The price penalty factor h blends the emission costs with fuel costs and φ is the total operating cost in US$/h. The price penalty factor hi (US$/lb) is the ratio between the maximum fuel cost and maximum emission of corresponding generator.

$$h_i = \frac{FC(P_{gi}^{max})}{EC(P_{gi}^{max}} \quad \text{i= } 1,2,\ldots,N_g \qquad (9)$$

3. Simulation results and Discussion

The assessment of ATC using ACPTDF has been conducted on IEEE 6 and 30 bus systems, slightly modified to represent simultaneous wheeling transaction in a restructured market.

a) IEEE 6 bus system

The bus data and line data for the sample system is taken from [22]. TheCEED base case values of the generator settings are taken from [20]. Two bilateral wheeling transactions T1 and T2 are carried on the IEEE 6 bus system to determine the ATC. Transactions were carried out between buses 3 and 6 and buses 2 and 5 respectively. The obtained ATC values for bilateral transaction T1 and T2 using DCPTDF and ACPTDF are given in Table 1.. NRLF method is practically inefficient and time consuming. So this method is not suited for deregulation environment.

Table 1: ATC (MW) – IEEE 6 bus system.

Transaction	DCPTDF method	ACPTDF method	NRLF method
T1 (3-6)	40.3331	41.0374	41.00
T2 (2-5)	43.6850	43.2484	43.00

b) IEEE 30 bus system

The bus data, line data and CEED base case values is taken from [20].Four simultaneous bilateral transactions and two multilateral transactions have been carried out to determine the ATC. It is inferred that ACPTDF is giving exact result from previous test system study, so the comparison is carried out only with that method. The obtained results for four bilateral transactions T_1 to T_4 using ACPTDF are given in Table 2. Further the results are justified with Repetitive AC Load Flow (NRLF) method and the power world simulator.

Table 2: ATC (MW) - IEEE 30 bus system.

Transaction	ACPTDF method	NRLF method
T1 (8-25)	25.00	25.20
T2 (5-30)	11.45	13.93
T3(11-26)	9.18	11.80
T4(2-8)	21.94	23.555

The calculated ACPTDF values are listed in table 3 for the abovetransactions. The ACPTDF having the highest value for each transaction is represented with bold case.

ATC value of each transaction is matching with bold case value of the particular line. For example ACPTDF value of line 6-8 is represented in bold case because of highest value in the transaction T1. This gives the indication of ATC lies in that line and similarly it is observed for all the transactions (lines 27-30, 25-26& 6-28). The determination of ATC under CEED environment for the multilateral transaction is carried out between seller buses 2 &11 and buyer buses 28 & 26.

Table 3: Execution time in seconds for ATC determination of two test systems

Test systems	ACPTDF method	NRLF method
IEEE 6 bus	7.7	10.7
IEEE 30 bus	55.89	64.01

4. Conclusion

To have open access non-discriminatory operation in a restructuredmarket, a transparent knowledge of the system capability is beneficial. This paves the way for the determination of ATC in a restructured power system. The ATC value serves as an important indicator of system performance. It is useful in making power transaction contracts in the system. This paper made an attempt forthe calculation of ATC using AC power transfer distribution factors in combined economic and emission environment. The accuracy of the proposed method has been justified by comparing the obtained results with standard NRLF and Power world simulator results.

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