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Feasibility assessment of simultaneous bilateral and multilateral transactions

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ABSTRACT

The main aim in this paper is to develop algorithm for assessment of the feasibility of simultaneous bilateral and multilateral transactions and if they are not feasible then to find out the minimum amount of transacted power to be curtailed in order to make them feasible. This analysis will be a great help for the generations-loads pairs to decide whether to withdraw the unfeasible transaction completely or to make it feasible by reducing its size optimally. The proposed algorithm can also be used for determining the transfer capability and hence feasibility of a single bilateral transaction at a time. In addition to above algorithm an efficient, repeated Newton–Raphson power flow based algorithm is also developed to determine transfer capability and hence feasibility for single bilateral transaction. The results of the proposed algorithm have been compared with a method proposed by Hamoud in his paper [6]. In this paper, based on the proposed algorithm and with the extension of Hamoud's method, different feasibility evaluation procedures for simultaneous bilateral and multilateral transactions are suggested, analyzed and applied.

1. Introduction

All the transactions need to be evaluated ahead of their scheduling time to check their feasibility with regard to the system conditions at the time of scheduling. ISO would have to honor and execute only those proposed transactions as far as the system design and operating conditions permit. So before we go for cost analysis, it is important to analyze the feasibility of all proposed firm transactions for a particular transmission network under prevailing system constraints. Only after passing the feasibility test the proposed firm transactions are scheduled for dispatch. This analysis will be required not only by ISO, but also by the end users of the systems to make proper decisions regarding the generations and loads to be connected at different buses of the power system.

A transaction is deemed to be feasible if it can be accommodated without violating any of the system operating constraints such as equipment ratings, transmission interface limits, voltage limits etc. The feasibility of a single bilateral transaction can easily be determined from the available transfer capability (ATC) of the network between the buses where a transaction power enters and leaves the network. ATC is a measure of the transfer capability remaining in the physical transmission network for future commercial activity over and above already committed uses [1]. Transfer capability evaluation is a very wide area of research. Extensive work has already been carried out in this direction and more research is in progress in this field in order to increase its accuracy considering various factors and margins [1–4]. The transfer capability has been defined in the literature [1,5,6] in many ways depending upon the requirements and accuracy required for a particular analysis. It may be defined as amount of power, incremental above normal base power transfers that can be transferred over the transmission network, with all facility loading are within normal ratings and all voltages are within normal limits [5].

The literature survey [7] reveals that most of the work has been done related with determination of ATC. Ou and Singh [8] have presented a probabilistic based method to assess various factors and procedures to incorporate them into ATC. Christie et al. [9] have suggested power transfer distribution factor and line outage distribution factor for determination of transfer capability from one bus to another bus of the power system. But this method provided only the approximate results. The Information Technology applications for determination of ATC have also been given in some research papers [10]. Application software [11] is also available for ATC calculations. To render the ATC as a more realistic measure of transmission availability, a stochastic calculation of ATC has also been explained in the literature [12,13]. But most of calculation procedures reported in the literature for ATC will be useful for feasibility assessment of only bilateral transactions. But in this paper methods are proposed for feasibility assessment of simultaneous bilateral as well as simultaneous multilateral transactions.

Available transfer capability is required to be posted on Open Access Same-time Information System (OASIS). The generation-load pair can make reservation for the bilateral transaction whose size should be less than ATC between the points where transaction power enters and leaves the system. After including one transaction in the system, ATC between all the buses changes and reevaluated. Same procedure is repeated for second transaction. Similarly all the feasible bilateral transactions are added to the system one

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by one. But this procedure cannot be applied directly to simultaneous bilateral and multilateral transactions. Because the transfer capability of a transaction in a group of simultaneous transactions will depend upon the order in which the transactions are considered to be added to the transmission network.

2. Proposed algorithm for assessment of feasibility

Generalized formulation of the proposed algorithm is given in this section. This algorithm can be used directly to determine the feasibility of simultaneous bilateral and multilateral transactions. In case these transactions turned out to be not feasible, then this algorithm provides an answer to the question that how much minimum amount of power has to be curtailed, in order to make them feasible.

2.1. Mathematical Formulation

Let there be *nbt* number of bilateral transactions and a transaction t is from bus i to bus j.

Let Pg_i^t be generation (in addition to base case) at bus i and Pd_j^t is load (in addition to base case) at bus j for a transaction t. Base case means already committed generations, loads and transactions on transmission network.

Let Ts^t be size of each proposed bilateral transaction t.

So Ts^t is equal to Pd_j^t which is also equal to Pg_i^t, considering transmission losses for the transaction being provided by the utility or pool.

Let there are *nmt* number of groups of multilateral transactions.

Let PMT^k be the size of k th group of multilateral transaction.

Let there be *ngk* number of generation points and *ndk* number of demand points for a group k. It may be noted that '*ngk*' may or may not equal to *ndk*.

Let Pgm_i^k be the generation at a generation bus i of multilateral transaction k.

Let Pdm_i^k be the load at a load bus i of multilateral transaction k.

The objective is to maximize total power transfer PT.

$$PT = \sum_{t=1}^{nbt} Ts^t + \sum_{k=1}^{nmt} PMT^k \tag{1}$$

Subject to the following constraints.

The bilateral transaction constraint

$$Pg_i^t = Pd_j^t \quad \text{for all bilateral transactions} \tag{2}$$

Bilateral transaction size constraints

$$Ts^t \leqslant Ts_m^t \quad \text{for all bilateral transactions} \tag{3}$$

where, Ts_m^t is maximum proposed size of transaction t.

Multilateral transaction constraints

$$\sum_{j=1}^{ndk} Pdm_j^k = \sum_{i=1}^{ngk} Pgm_i^k = PMT^k \tag{4}$$

Multilateral transaction generation and load constraints

$$Pgm_i^k \leqslant Pgmp_i^k \tag{5}$$

$$Pdm_j^k \leqslant Pdmp_j^k \tag{6}$$

where, $Pgmp_i^k$ is the proposed generation at generation point i of group k of multilateral transaction. $Pdmp_j^k$ is the proposed load at load point j of group k of multilateral transaction.

The power flow equation of the power network

$$g(V, \phi) = 0 \tag{7}$$

where

$$g(V,\phi) = \begin{cases} P_i(V,\phi) - P_i^{net}\} & \\ Q_i(V,\phi) - Q_i^{net}\} & \leftarrow \text{For each PQ bus } i \\ P_m(V,\phi) - P_m^{net}\} & \leftarrow \text{For each PV bus } m, \text{not including ref. bus.} \end{cases} \tag{8}$$

where P_i and Q_i are respectively calculated real and reactive power for PQ bus i. P_i^{net} and Q_i^{net} are respectively specified real and reactive power for PQ bus i. P_m and P_m^{net} are respectively calculated and specified real power for PV bus m. V and ϕ are voltage magnitude and phase angles of different buses.

The inequality constraint on reactive power generation Qg_i at PV buses

$$Qg_i^{\min} \leqslant Qg_i \leqslant Qg_i^{\max} \tag{9}$$

where $Qg_i^{\min}$ and $Qg_i^{\max}$ are respectively minimum and maximum value of reactive power generation at PV bus i.

The inequality constraint on voltage magnitude V of each PQ bus

$$V_i^{\min} \leqslant V_i \leqslant V_i^{\max} \tag{10}$$

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

The inequality constraint on phase angle ϕ_i of voltage at all the buses i

$$\phi_i^{\min} \leqslant \phi_i \leqslant \phi_i^{\max} \tag{11}$$

where $\phi_i^{\min}$ and $\phi_i^{\max}$ are respectively minimum and maximum allowed value of voltage phase angle at bus i.

Power limit on transmission line

$$MVAf_{ij} \leqslant MVAf_{ij}^{\max} \tag{12}$$

where $MVAf_{ij}^{\max}$ is the maximum rating of transmission line connecting bus i and j.

Some of these constraints are based on the anticipation of the transmission contingencies and may be due to thermal, voltage and stability problems.

This optimization problem has been solved by using optimization tools explained in reference [14].

3. Assessment of available transfer capability

The feasibility of a single bilateral transaction can easily be determined from the ATC of the transmission network between the buses, where the transaction power enters and leaves the network. Hamoud [6] has also used the same ATC for determination of feasibility of simultaneous bilateral transactions, without considering various margins like transmission reliability margin, capacity benefit margin etc. for ATC evaluation. In that case ATC is approximately equal to total transfer capability, which is a key component for ATC assessment. In order to compare the results of the proposed algorithm with the method proposed by Hamoud and for extension of his method, these margins are not considered in this analysis.

In this paper two independent methods have been proposed for assessment of ATC, first method is based on optimization algorithm proposed in above Section 2 and second is based on Newton–Raphson repeated power flow (RPF) method.

3.1. By proposed algorithm

The proposed algorithm described in Section 2 has been used for assessment of available transfer capability for single bilateral transaction by putting number of transaction $nbt = 1$, number of