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DETERMINATION OF AVAILABLE TRANSFER CAPABILITY USING DC OPTIMAL POWER FLOW IN RESTRUCTURED POWER SYSTEM

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ABSTRACT

The electrical industry has been continuously in the process of restructuring in the recent years. The open and competitive market demands the calculation of Available Transfer Capability(ATC).

The ATC between source and sink node indicates maximum additional MW that can be transferred without violating the operating and security constraints. [1]

The ATC needs to be computed and updated on hourly and daily basis and made available on an open access.

This paper utilizes the DC power flow model and linear optimization technique using MATLAB to determine ATC for bilateral transactions.

The DC load flow analysis can be utilized as a first level study as it is an approximate but fast method. An IEEE 24 bus RTS [2] is studied and the results are presented.

KEYWORDS

ATC, DCOPF, TTC, CPF, RPF, SCOPF, SATC,NSATC

INTRODUCTION

Restructuring is a complex process involving national policies, economic strategies and its implementation varies from one country to another.

A well regulated energy market works within a regulatory framework.

Deregulation of electrical industry aims at improved competition in the market leading to reduction in tariffs and providing power quality choice to consumers.

Restructured Power System unbundles the traditional structure of Generation, Transmission and Distribution to various segments like Generating Companies (Gencos) , distribution companies (Discos), scheduling coordinators (Scs), transmission owners (TOs), an independent system operator (ISO) and a power Exchange (PX). Dependency and coordination among these segments vary from one country to another.

The electricity as a commodity is complex to handle as it cannot be stored and utilized on a real time basis. The electricity market is characterized by the uncertainties in the demand. The optimization problem apart from the demand constraints should also cater to the stability limits.

The electric power in a deregulated power market is traded to maximize the profit with minimal losses.

The mathematical definition of ATC is the ability of transmission system to transmit power reliably from one area to another over and above the committed uses.

ATC is the amount of transfer capacity available for sale or purchase at a given time in electric power market under various system conditions.ATC is a dynamic quantity being a function of system parameters and network conditions.ATC needs to be periodically updated. Moreover, ATC must satisfy both commercial and technical issues.

ATC=TTC-base case transfer

Total Transfer Capability or TTC is the maximum real power between the nodes without violating the various stability limits (bus voltage limit, thermal limit, angular stability, line overloads, security constraints.).

The ATC data reflects the generation dispatch, demand level, contingencies and network paradigm.

NSATC or Non-Simultaneous ATC refers to the transfer capabilities between two areas independently while SATC or Simultaneous ATC reflects simultaneous transfers concurrently.

In calculation of SATC interdependency among the areas are taken into consideration.

Various mathematical techniques and algorithm have been applied like Continuous Power Flow (CPF), Repeated Power Flow (RPF), Security Constrained Optimal Power Flow (SCOPF), Sensitivity factors to calculate ATC.The Neural Network and Genetic Algorithm have also recently been experimented to solve power flow contingencies and calculate ATC.The ATC calculation using RPF method involves the increment in supply and demand in steps unless it does not violate the permissible voltage limits or maximum current in a branch or power rating of any line. Optimal power flow maximizes a single quantity that is power generation at supply side. Recently Genetic Algorithm based on Darwin’s theory is experimented to simplify calculation of ATC.

DC Power Flow Model

An iterative procedure is followed in the AC load flow which provides the bus voltage magnitudes and phase angle. Then the MW and MVAR flows for all the transactions are computed. Such an iterative solution requires considerable computational time.

The approximation of AC load flow is the linearized DCOPF model. But it provides only the MW flows on transmission lines. It is a linear and non-iterative power flow algorithm. [3]

DC power flow can thus provide a first level study as it is an approximate but faster method.

Assumptions in DC load flow Model are: -

(i) $Vi = Vj = 1$

(ii) $rij << xij;\ rij \cong 0$

(iii) $gij = \frac{r_{ij}}{{r_{ij}}^2 + {x_{ij}}^2} = 0$

(iv) $Bij = \frac{-x_{ij}}{{r_{ij}}^2 + {x_{ij}}^2} = \frac{-1}{x_{ij}}$

The MW flow between node i-j

$$p_{ij=\frac{\delta_i - \delta_j}{x_{ij}}}$$

In matrix form

P = [B] δ

where

P = (P_1, P_2, ...P_{NB}) = Bus power injection vector in p.u.

δ = (δ_1, δ_2, ...δ_{NB}) = Bus phase angle vector, in radians

[B] = DC load flow matrix or negative bus susceptance matrix.

PROBLEM FORMULATION FOR ATC USING DCOPF MODEL

Objective function:

Max :$\sum_{i=1}^{NT} w_i\, T_i$ (objective function)

Subject to:

P = [B] δ (load flow constraint)

$\Psi^L \leq \Psi \leq \Psi^U$(thermal limit of lines) [4]

Ti ≥0; i=1…...NT

where

$w_{i=}$ weightage given for the i_{th} transfer

T_i =i_{th} transfer capability; i=1 …...NT

NT=Total number of transfer capability

[B]= DC load flow matrix

δ=Bus Phase angle vector

P=Bus Power Injection Vector p.u. MW

Ψ =Line Phase angle vector in radian

Ψ^L, Ψ^U = Line Thermal Limit Vector in radian

Ψ_{a-b}=P_{a-b}(p.u)*x_{a-b}(p.u) (line connected between a and b)

$\Delta\Psi^L$=[A]$\Delta\delta$

where

[A] = Bus incidence matrix with dimension NL x (N-1)

NL = Total Number of Lines

(N-1) = Total Number of buses except the slack bus

The j^{th} element of ΔP, ΔP_j is given as

$$\Delta P_j = \sum_{i\varepsilon\beta j} T_i - \sum_{i\varepsilon\gamma j} T_i$$

where

β_j = Set of transfers which have j^th node as source node

γ_j = Set of transfers which have j^th node as sink node

$$\Delta\Psi_p^L \le \sum_{j=\mathbf{\alpha_G}}(X_{aj}-X_{bj})\sum_{i\varepsilon\beta j}T_i - \sum_{j\in\alpha D}(X_{aj}-X_{bj}\sum_{i\varepsilon\gamma j}T_i) \le \Delta\Psi_p^U;\text{p=1….NL}$$

$\boldsymbol{\alpha_G}$ = Set of source buses of various transfers

$\boldsymbol{\alpha_D}$ = Set of sink buses of various transfers

ALGORITHM FOR ATC DETERMINATION USING DCOPF MODEL

1.Create an input data file which includes power generation and power demand data Pg and Pd (MW) and line data.

2.Get the [B]matrix to run the base case using DC power flow.

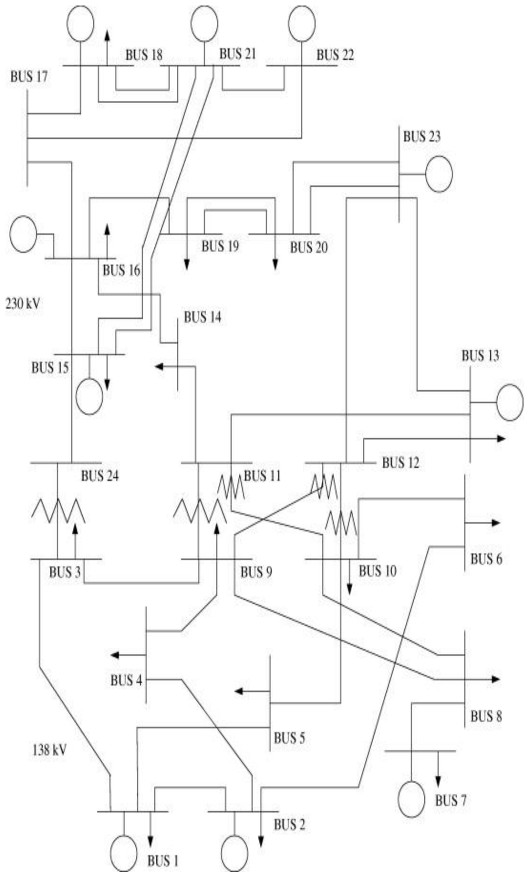
3.Apply 'linprog' in MATLAB to perform LP routine.

4.Update the transfers till there is violation of operating constraints.

5 Display the maximum ATC between given transfers.

Sample system

A 24 bus Reliability Test System is used for verifying the validity of the program developed in MATLAB for assessing ATC using DC load flow model.



IEEE 24 bus reliability test system

NSATC for IEEE 24 Bus reliability test system

ATC is computed for a particular hour of day-ahead-market. Table1 shows the bus data [5]. Table 2 shows results of non–simultaneous ATC for 24 bus IEEE Reliability Test System (RTS) computed over and above the existing transmission commitments in the base case for four different bilateral transfers namely 2-6,14-24,21-5,23-3.

Non Simultaneous ATC is obtained for each of the four transactions taking one transactions at a time and it is given in column 3 of table2. This is the maximum value of power that can be transferred from source bus to sink bus. Column

4 shows the critical lines obtained. Column 5 shows the corresponding rating of critical lines hitting the MW limit. Table 3 shows base case line flows using DCOP.

Table 1 Bus Data

Buses	**PG**	**PD**
1	127	108
2	167	97
3	0	180
4	0	74
5	0	71
6	0	136
7	264	125
8	0	171
9	0	175
10	0	195
11	0	0
12	0	0
13	400	265
14	0	194
15	274	317
16	245	100
17	0	0
18	544	333
19	0	181
20	0	128
21	294	0
22	150	0
23	400	0
24	0	0

Table 2 NSATC using DCOPF for IEEE 24 Bus Reliability Test System

TRANSFER NO.	TRANSFER SOURCE	SINK	NSATC (MW)	CRITICAL LINES	RATING (MW)
T1	2	6	136.23	10-6	175
T2	14	24	393.23	15-24	500
T3	21	5	245.04	5-10	175
T4	23	3	422.34	3-24	400

no	sb	eb	prat(MW)	px(MW)
1	1	2	157.500000	-13.158489
2	1	3	157.500000	-23.157922
3	1	5	157.500000	40.316411
4	2	4	157.500000	20.769120
5	2	6	157.500000	36.072391
6	3	9	157.500000	15.289541
7	3	24	360.000000	-218.447463
8	4	9	157.500000	-53.230880
9	5	10	157.500000	-30.683589
10	6	10	157.500000	-99.927609
11	7	8	157.500000	139.000000
22	13	23	450.000000	-117.747762
23	14	16	450.000000	-345.748316
24	15	16	450.000000	102.228506
25	15	21	450.000000	-181.837985
26	15	21	450.000000	-181.837985
27	15	24	450.000000	218.447463
28	16	17	450.000000	-291.324031
29	16	19	450.000000	192.804222
30	17	18	450.000000	-214.470640
31	17	22	450.000000	-76.853391
32	18	21	450.000000	-1.735320
33	18	21	450.000000	-1.735320

12	8	9	157.500000	-27.413911	34	19	20	450.000000	5.902111
13	8	10	157.500000	-4.586089	35	19	20	450.000000	5.902111
14	9	11	360.000000	-118.276264	36	20	23	450.000000	-58.097889
15	9	12	360.000000	-122.078986	37	20	23	450.000000	-58.097889
16	10	11	360.000000	-163.197282	38	21	22	450.000000	-73.146609
17	10	12	360.000000	-167.000005					
18	11	13	450.000000	-129.725230					
19	11	14	450.000000	-151.748316					
20	12	13	450.000000	-123.022532					
21	12	23	450.000000	-166.056459					

Table 3 shows the Base Case line flow results

where

Sb=source bus

eb=end bus

prat =Power rating of line between sb and eb

px=line flow

CONCLUSION

A 24 bus system is considered to run an optimal power flow program based on DCOPF method. The Non Simultaneous ATC transfers are taken into account. A linear programming technique is applied to increase the transfers in steps after the base case is run. The ATC obtained is validated as the program displays the critical lines as check. The critical lines are those whose power flow exceeds the thermal rating(MW).

The ATC found using DCOPF model requires lesser time compared to AC model. The AC models are based on repeated flow and constraints considered are larger. DC model can be a good approximation where the results need to be faster.

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BIOGRAPHY

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