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Power Transfer Capability Recognition in Deregulated System under Line Outage Condition Using Power World Simulator

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Abstract

The major challenges in deregulated system are determination of available transfer capability on the interconnected transmission lines. Electricity industry deregulation is the required for creating a competitive market throughout the world, which instigate new technical issues to market participants and Power System Operators (PSO). Power transfer capability is a crucial parameter to decide the power flow in the lines for further transactions and the estimation of Transfer Capability decides the power transactions based on the safety and ability of the system. This parameter will decide if an interconnected network could be reliable for the transfer of bulk power between two different areas of the network without causing risk to system consistency. The Power Transfer Distribution Factor (PTDF) is the sensitivity index, which decides the transfer capability in the interconnected network under deregulated power systems. This experiment is conducted on IEEE-6 bus system using Power World Simulator to determine the transfer capability in deregulated system under line outage condition.

Keywords: Deregulated system, PTDF, Transfer Capacity, Transfer Limit, Power World Simulator

1. Introduction

The bulk power transfers between two areas have to be done steadily and economically. Transmission capability in the lines indicates that inter area power transfer increases with no compromise in the system security. Pin point identification of transfer capability delivers vital information which helps the planning and operating engineers. Regular estimation of transfer capabilities are required to ensure the effects of power transfers, thereby avoiding chronic

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damage of the power system. Power transfers can be increased both in amount and in diversity as deregulations proceed. Certainly, such power transfers are essential for the competitive market [1,2]. There are many techniques to calculate the power transfer capability, out of which Power Transfer Distribution Factor (PTDF) method is fast and best to determine the transfer capability in the interconnected lines at any time. The following procedure has to be followed to determine the PTDF value [3].

1. Run the base case load flow simulation in the power world simulator maintaining the power system operating conditions. The results show the PTDF and power flow values in the lines.

2. Sensitivity factor PTDF can be identified by changing the power injections at different buses in the network. This sets new PTDF values in the lines.

3. The PTDF value decides the next power flow transactions in the lines. It is essential to know the transfer capability in the interconnected lines, when there is a change in base case.

4. This is a simple and fast technique to determine the transfer capability in the lines by simply changing the base case parameter [4,5].

In deregulated system available transfer capability plays a major role in both the operation and planning of the power system networks, in the view of system security. The usefulness of interconnected power systems is the increased reliability. In deregulated interconnected system, need of power requirement in one area, can be satisfied by the other area. Thus, power can be easily transferred between the areas whenever there is a need. Transfer capability in the lines is the required parameter to transfer the power in the lines. Hence, it increases interconnected system reliability and reduces the power generation cost [6,11].

The determination of available transfer capability is very much needed in electric power deregulation. This parameter decides the amount of bulk power transmission between inter areas that can be increased without compromising the system security. Moreover, market participants can have contradictory interests in knowing the increasing and decreasing available transfer capability in the interconnected system [7]. The power world simulator is the software tool which is very useful to determine the power transfer capability recognition in the deregulated power system. This is the key factor in the power market for further transaction in the lines.

2. Methodology

PTDF is a sensitive index that regulates the percentage of change in power flow in the interconnected line (p-q), due to the change in power flow in X & Y buses.

$$\mathrm{PTDF} = \frac{\begin{array}{c}\text{(change in power flow through branch p} - \text{q} \\ \text{due to the change in power flow from X to Y)}\end{array}}{\text{(Power flow between X to Y)}}$$

It gives continual change of active power flow in lines caused by an continual change of addition of power sources at any node in the network. This factor depends on the power flow in the lines and other network parameters, but they are independent new power sources added in the system. PTDF of the line depends on active power flow change ΔP due to the change of injection of power source at any node. [8-10].

The power transfer limit on the lines depends on the PTDF value. Since PTDF is positive, the increase of the power flow is in the positive direction. If PTDF value is very small, it means that the transfer has a very small impact on the limiting element. If PTDF is negative, there is a decrease of power flow in the lines. The Transmission Limit (TM) in the lines depends on the following equations [12-15].

$$\mathrm{TM} = \frac{\text{Limit M – MW flow}}{\mathrm{PTDF}} \quad ; \mathrm{PTDF} > 0 - - - - (1)$$

$$\mathrm{PTDF} = 0 - - - - - (2)$$

$$\mathrm{TM} = \frac{-\text{Limit M – MW flow}}{\mathrm{PTDF}} \quad ; \mathrm{PTDF} < 0 - - - - (3)$$

Figure 1. Shows the single line diagram of the deregulated system. It comprises of three generating units and three loads and 6 bus system with 11 lines. Table 1. indicates the line parameters and capacity of the lines. Table 2. indicates generator and load details on each bus.

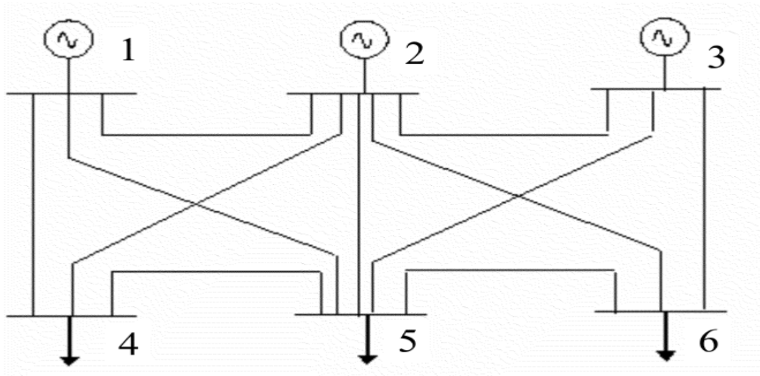

Figure 1. IEEE- 6 bus system

Table 1. Line data of IEEE-6 bus system

No. of lines	Line between buses	Impedance of line	Maximum capacity of line
1	1-2	0.10+ j0.20	100 MVA
2	1-4	0.05+ j0.02	100 MVA
3	1-5	0.08+ j0.30	100 MVA
4	2-3	0.05+ j0.25	100 MVA
5	2-4	0.05+ j0.10	100 MVA
6	2-5	0.10+ j0.30	100 MVA
7	2-6	0.70+ j0.02	100 MVA
8	3-5	0.12+ j0.26	100 MVA
9	3-6	0.020+ j0.10	100 MVA
10	4-5	0.20+ j0.40	100 MVA
11	5-6	0.10+ j0.30	100 MVA

Table 2. Generator and Load details of IEEE-6 bus system

Buses	Generator		Load	
	MW	MVAR	MW	MVAR
1 (slack bus)	100	0	---	--
2	50	0	---	---
3	60	0	---	---
4	--	---	110	50

5	--	--	80	40
6			80	30

3. Simulation Results and Discussions

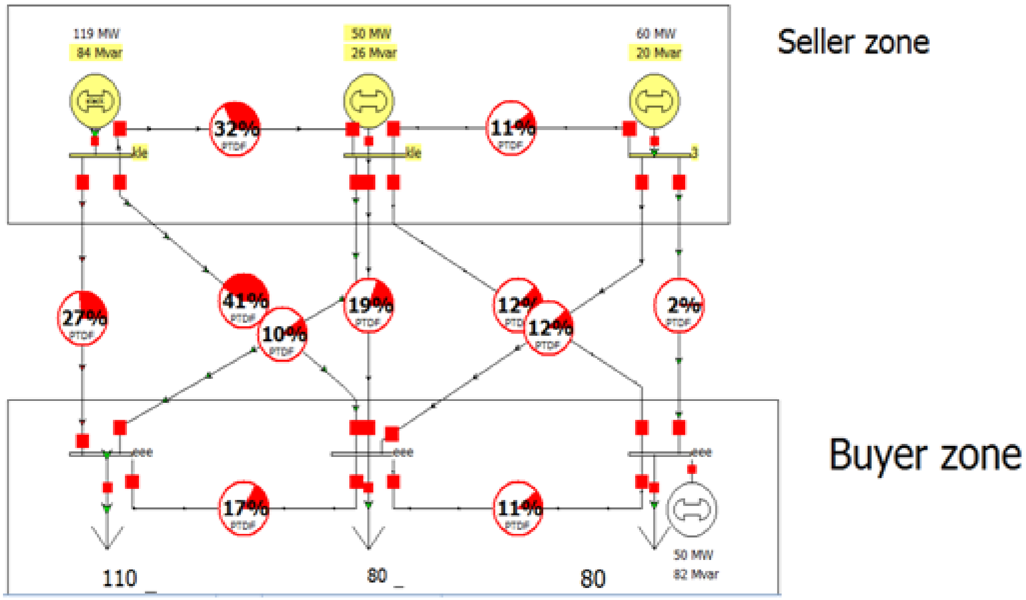

Figure 2. Normal load power flow in the system

Figure 2 shows simulation normal load flow, PTDF/OTDF values of simulations are indicated in Table 3. The transfer limit is inversely promotional to the PTDF value. The lines which have less PTDF, have more transfer capacity. The lines which have more PTDF value, these lines have less power transfer capacity. Table 4 indicates the power flow and power losses in MW in the lines.

Table 3. Normal load flow with normal PTDF values

All Limiters | Branch Limiters | Interface Limiters | Nomogram Interface Limiters

	Init Value	MVA Used	Trans Lim	Limiting Element	% PTDF	Limiting CTG	% OTDF	Pre-Trans Est	Limit Used
1	55.07	50.00	-18.72	Line kle (1) TO eee (4) CKT 1 [	27.11	Base Case	27.11	55.07	50.00
2	34.55	100.00	160.75	Line kle (1) TO eee (5) CKT 1 [	40.72	Base Case	40.72	34.55	100.00
3	29.40	100.00	219.45	Line kle (1) TO kle (2) CKT 1 [1	32.17	Base Case	32.17	29.40	100.00
4	16.10	100.00	435.44	Line kle (2) TO eee (5) CKT 1 [	19.27	Base Case	19.27	16.10	100.00
5	-1.71	100.00	598.90	Line eee (4) TO eee (5) CKT 1	16.98	Base Case	16.98	-1.71	100.00

Table 4. Maximum line flow in MW and line losses in MW

All Limiters | Branch Limiters | Interface Limiters | Nomogram Interface Limiters

	% PTDF	MW Loss	Max MW	Trans Lim Last Iteration	Trans Lim	From Number	To Number	Circuit	Limiting CTG	% OTDF	Pre-Trans Est	Limit Used
1	27.1	2.37	55.07	-18.72	-18.72	1	4	1	Base Case	27.11	55.07	50.00
2	40.7	1.49	34.55	160.75	160.75	1	5	1	Base Case	40.72	34.55	100.00
3	32.2	0.92	29.40	219.45	219.45	1	2	1	Base Case	32.17	29.40	100.00
4	19.3	0.45	16.10	435.44	435.44	2	5	1	Base Case	19.27	16.10	100.00
5	17.0	0.01	1.72	598.90	598.90	4	5	1	Base Case	16.98	-1.71	100.00

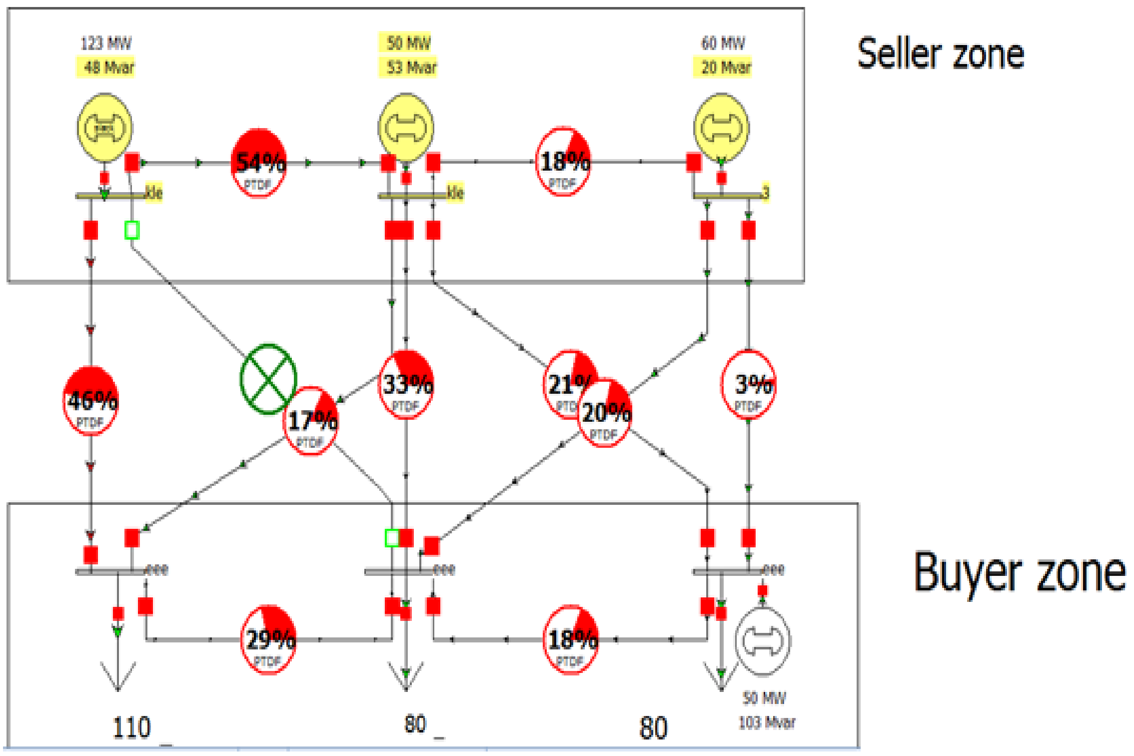

Figure 3. Load flow under line outage condition between bus 1& 5

Figure 3 shows the simulation of the system under line outage between bus 1 & 5, which changes the PTDF values in all the lines and hence transfer capacity also changes which is shown in the Table 5. The Table 6 shows increase in line flow in and line losses in MW in the lines.

Table 5. Line outage between bus 1 & 5 with PTDF values

All Limiters | Branch Limiters | Interface Limiters | Nomogram Interface Limiters

	Init Value	MVA Used	Trans Lim	Limiting Element	% PTDF	Limiting CTG	% OTDF	Pre-Trans Est	Limit Used
1	72.63	50.00	-49.50	Line kle (1) TO eee (4) CKT 1 [	45.73	Base Case	45.73	72.63	50.00
2	49.92	100.00	92.27	Line kle (1) TO kle (2) CKT 1 [1	54.27	Base Case	54.27	49.92	100.00
3	27.42	100.00	223.30	Line kle (2) TO eee (5) CKT 1 [	32.50	Base Case	32.50	27.42	100.00
4	8.26	100.00	320.23	Line eee (4) TO eee (5) CKT 1	28.65	Base Case	28.65	8.26	100.00
5	31.59	100.00	335.99	Line 3 (3) TO eee (5) CKT 1 [1	20.36	Base Case	20.36	31.59	100.00

Table 6. Increase in line flow in MW and line losses in MW

All Limiters | Branch Limiters | Interface Limiters | Nomogram Interface Limiters

	% PTDF	MW Loss	Max MW	Trans Lim Last Iteration	Trans Lim	From Number	To Number	Circuit	Limiting CTG	% OTDF	Pre-Trans Est	Limit Used
1	45.7	3.38	72.63	-49.50	-49.50	1	4	1	Base Case	45.73	72.63	50.00
2	54.3	2.27	49.92	92.27	92.27	1	2	1	Base Case	54.27	49.92	100.00
3	32.5	1.30	27.42	223.30	223.30	2	5	1	Base Case	32.50	27.42	100.00
4	28.6	0.18	8.26	320.23	320.23	4	5	1	Base Case	28.65	8.26	100.00
5	20.4	1.88	31.59	335.99	335.99	3	5	1	Base Case	20.36	31.59	100.00

Based on the above simulation results on IEEE-6 bus system under deregulated scenario, power world simulator is very simple and fast method of determining the transfer capacity of the line under line outage condition. Using power world simulator tool and PTDF sensitivity index, the power transfer capacity, actual power flow and power losses in all the inter-connected lines are determined.

4. Conclusion

The Power World Simulator is the powerful tool for the determination of transfer capacity in the deregulated system. In the system that has many power flow paths, this tool is very useful to calculate the transfer capacity, transfer limit, power flow and power losses in the inter-connected lines during normal and line outage conditions. The PTDF is the sensitivity index that decides the transfer capacity of the lines for further power transactions in the lines.

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