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Graph Theory Algorithm to Find Minimum Cost Power Flow Path in Deregulated Scenario under Line Outage Contingency

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Abstract

Deregulation of the electricity industry throughout the world aims at creating a competitive market to trade electricity, which generates a host of new technical challenges to market participants and power system researchers. In the view of this electric power industry is undergoing vast changes in many parts of the world. Restructuring of the industry involves a transition from centralized planning to decentralize that is subject to competition in the power market. In deregulation system the electricity price segregated into price of electricity energy, energy delivery charges (wheeling charges) and service charges. In a deregulated environment, there are many wheeling transactions in addition to power pool demand. Therefore it is very much important for sellers and buyers of electricity, to find the cost allocation to their wheeling transactions. The proposed method uses minimum cost power flow and avoiding power wheeling charges and power loss reduction method based on minimum impedance path for power flow. The aim of this work is to find minimum cost path under normal condition and alternative path under line outage contingency condition using Dijkstra's Shortest Path Algorithm. This implemented on IEEE-6 bus system. The simulation is carryout using Power World Simulator and MATLAB software.

Keywords: Deregulated Power System, Dijkstra’s Algorithm, line outage contingency, ATC, PTDF

INTRODUCTION

However, it can be safely said that deregulation of the electric power industry has come to stay and the way the power industry is operated will never be the same again. This raises a whole new set of problems and issues which will be both a challenge and an experience for the power engineers of the coming years. In the earlier vertically integrated power system, the mechanism of competitive transmission pricing did not exist because of circumscribed utilization of power within a territory. But in the present deregulated environment, generation and transmission businesses have been separated and bilateral power contracts between them become a major outlay. (Kankar Bhattacharya et.al, 2001). In a competitive electricity market, the seller and buyers submit bids for energy buy and sell. The bids are generally in the form of price and quantity quotation and specify how much seller or buyer is willing buy or sell and at what price. After the bids are available to market operator or independent system operator (ISO) will decide how the path of power flow, through which line power has to flow so that it has less losses in the lines and it should be minimum cost for power wheeling. He will consider all the circumstance of power system like system reliability, security and cost of power flow, ATC, contingencies than he decides the way of power flow. (Naveen.G et.al, 2015).

Independent System Operator (ISO), a supreme entity for the control of transmission system, also needs to know such costs in order to make correct economic and engineering decisions on upgrading the transmission facilities. So wheeling is currently a high priority problem in both regulated and deregulated power industries. In this work, the power transfer is modeled and & carried out with bilateral and multilateral wheeling transactions. The independent system operator (ISO) is the central entity to have emerged in all deregulated markets with the responsibility of ensuring system security and reliability, fair and equitable transmission tariffs and providing for other system services. .(Kankar Bhattacharya et.al, 2001). With differing market structure evolving in various countries, it has been noticed that based on the responsibility assigned to them and their functional differences, ISOs could be placed in two categories. The first and most common one is the pool structure in which ISO is responsible for both market settlement including scheduling and dispatching, ad transmission system management including transmission pricing and security aspects here ISO is also known as Poolco operator. The other structure is that of open access, one dominated by bilateral contacts. In this term bulk the energy traction are directly oganizd between the generator and the customer, and the ISO has no role in generation schduling or dispatch and is only resposible for the system opetaion the role of ISO is minimal and limited to maintiance of system security ad reliability functions. (Subramanian & Devarajan, 2016) (Satyavir Singh , 2016).

NETWROK CONGESTION

when the producer and consuserms of electric enrgy desire to produce and consume in amount that would cause the trasmission system to operate at or beyond one or more trafer limit, the system is said to be congestd. Congstion is a consequence of netwrok constains charecterizing a finite netwrok capacity that precldeds the simulteoues delivery of power from an associted set of owner transctions. Line outage of higher load demands are the caused of congestion in the trasmission netwrok. In deregulated power system transmission networks are available for third party access to allow power wheeling, and spot markets for electricity they been developed in many countries. In such a environment, the ancillary services are no longer treated as an integral part of electric supply. They are unbundled and priced separately and system operator has to purchase ancillary services from ancillary service providers. The methods of tackling transmission congestion differ depending on the network congestion. There are three different ways mainly adopted to tackle the network congestion are as follows (Yousefi et.al, 2012)

1. Price area congestion management
2. Available transfer capability (ATC) based
3. Optimal path power flow based

METHODOLOGY

The proposed methodology in this paper ATC and optimal path power flow based congestion management. This is implemented on IEEE-6 bus system to prove its fairness. The system consists of 3 generators, 3loads and 11 connecting lines as shown in fig 1. The line data and load details are given in the table-1 and table-2 respectively. (Hota,& Naik, 2017)

Standard IEEE- 6 bus system

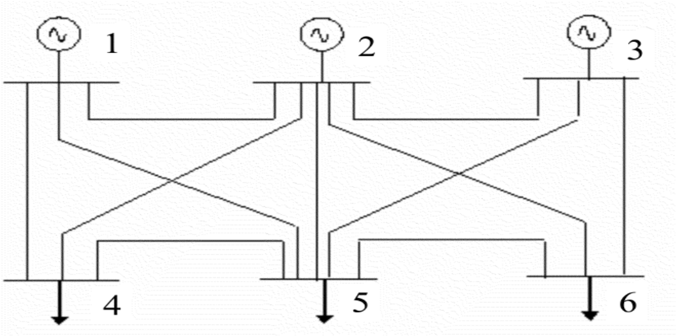


Figure 1. IEEE- 6 bus system

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

SIMULATION RESULTS

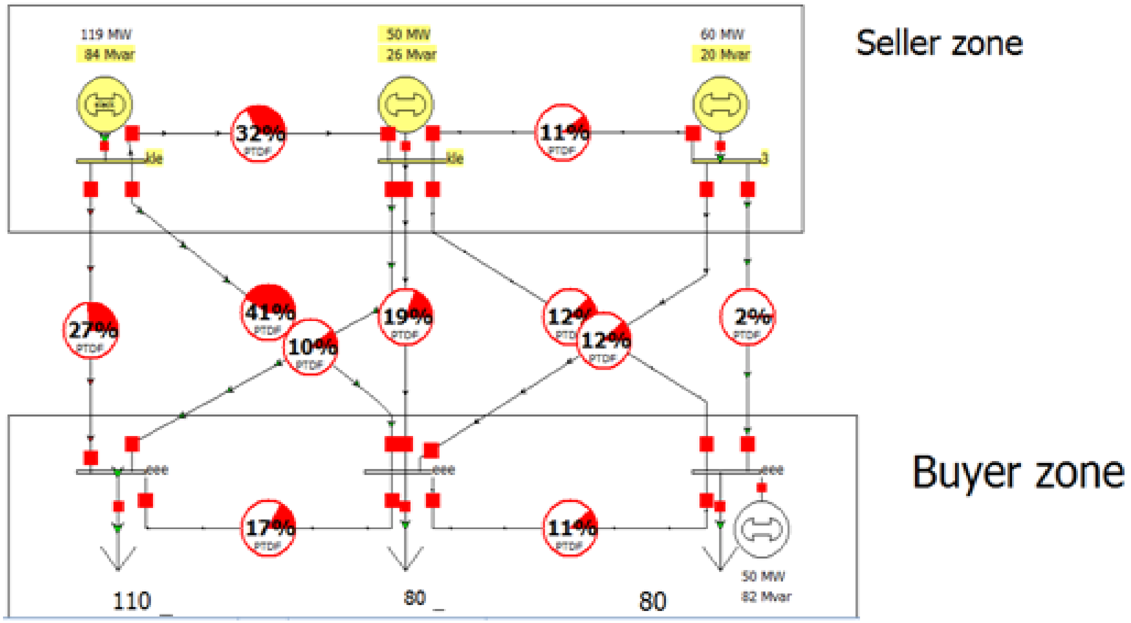
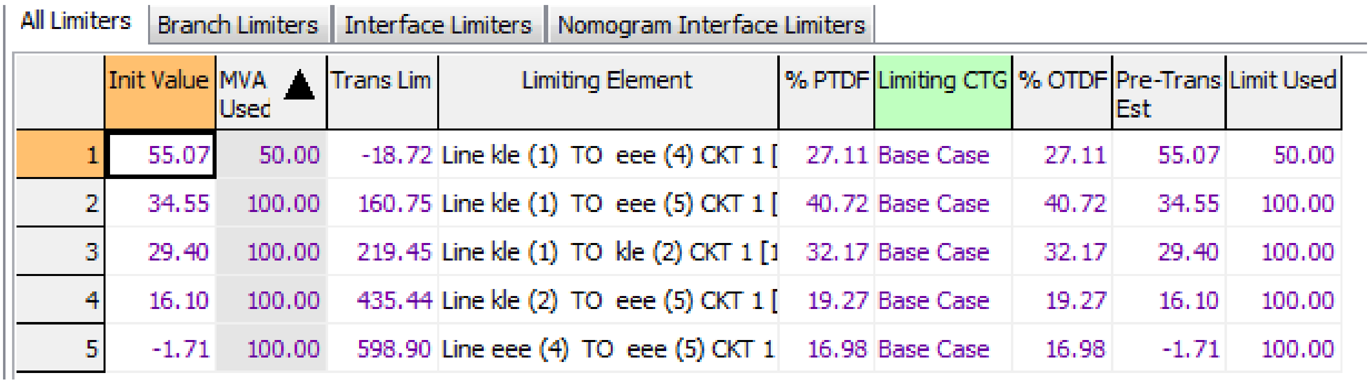


Figure 2. Normal loadflow in the system transction between bus 1& 5

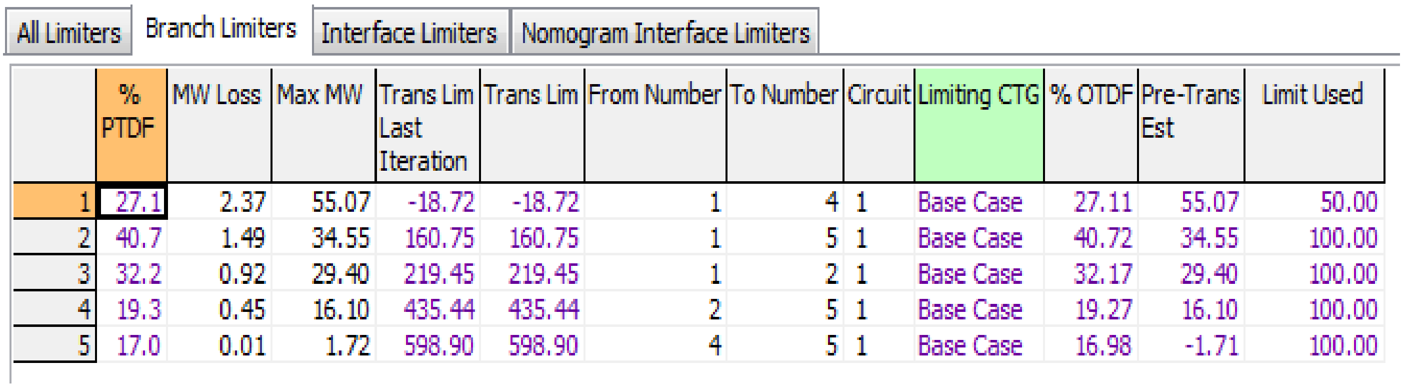
Under normal load flow, transaction between bus 1 and bus 5 the PTDF values are as shown in table-1. The transfer limit is inversely promotional to PTDF value. The line which is having less PTDF, that has more ATC. The line which is having more PTDF value that line carries more power transfer compared to other lines. (Olatunji et.al 2019) (M. Sivasatyanarayana .al 2014), (Manikandan et.al, 2008). The transmission limit in MVA and MW loss are indicated in table-3.

Table-3. Normal load flow between bus 1 & 5 with normal PTDF values



	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.2. Maximum line flow in MW and line losses in MW



	% 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

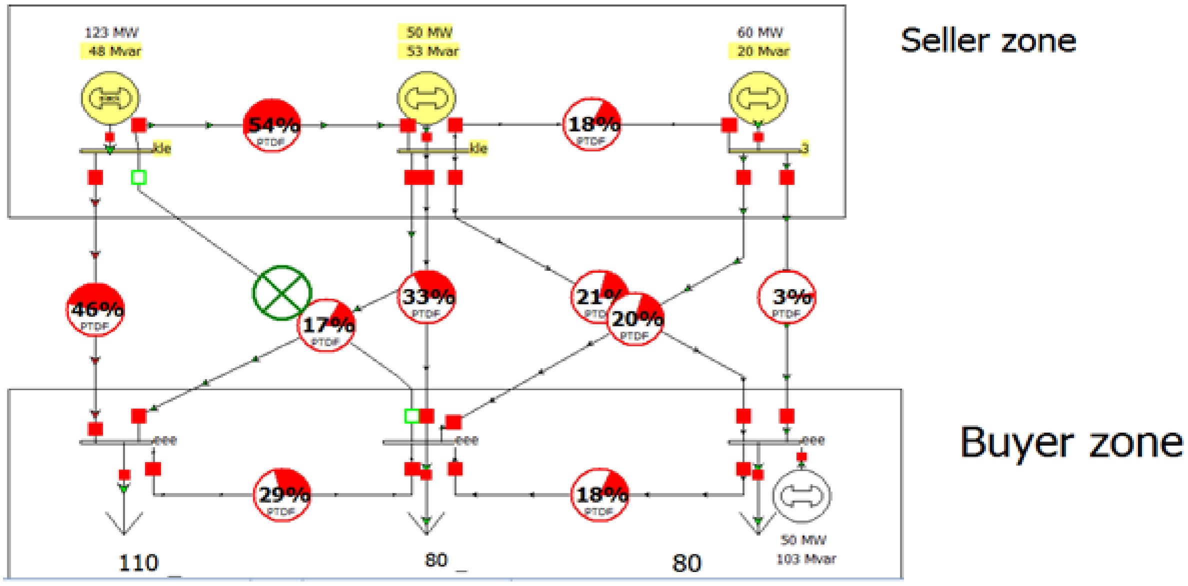
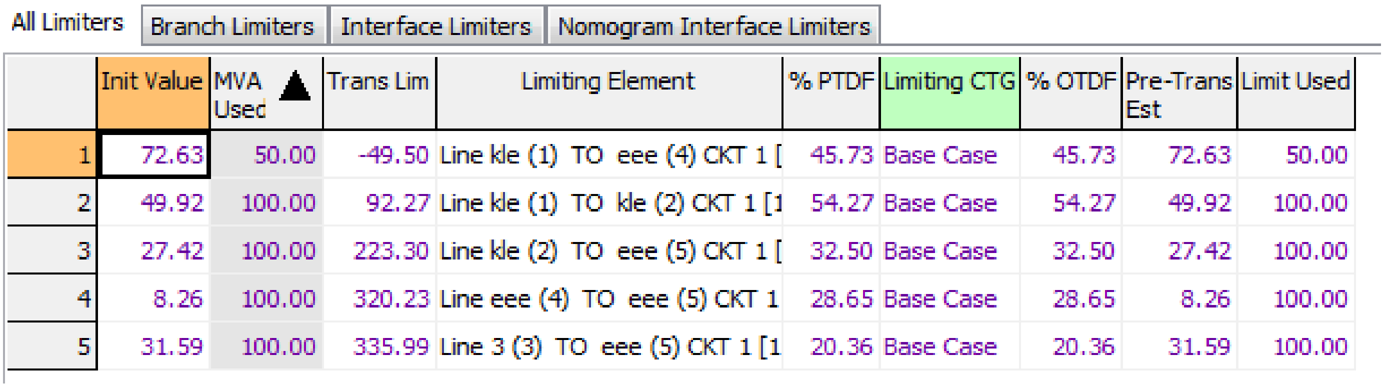


Figure. 3. Load flow under line outage condition between bus 1& 5

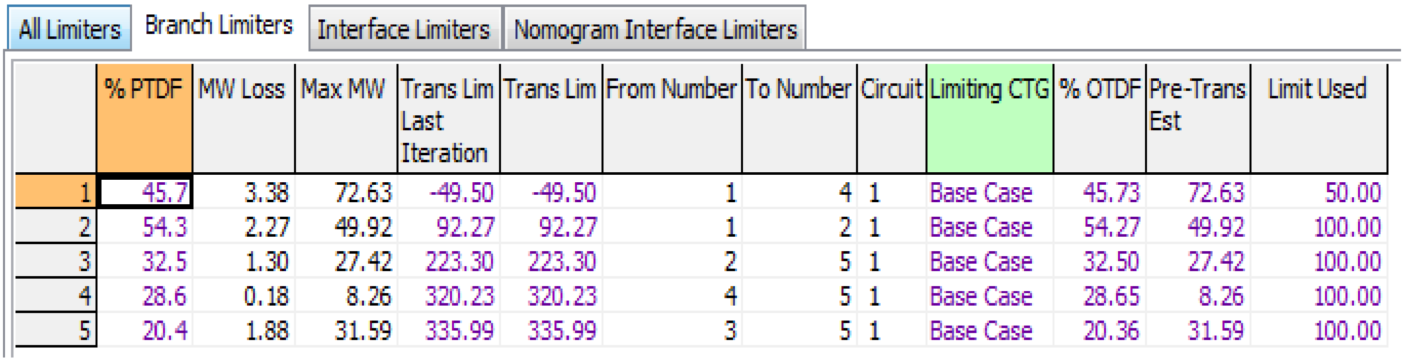
The line outage between bus 1 & 5 which loaded more. Than PTDF values are changes in all lines and hence ATC also changes. That is recorded in the table 5. Maximum line flow in MW and line losses in MW are indicated with line outage between 1 and 5, which shown in table 6.

Table 3. Line out between bus 1 & 5 with PTDF values with transction between 1 & 5



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



	% 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

The competitive electricity market thereby offers customers and industry participants a range of benefits. Most of the benefits accrue from the downward pressure on electricity prices as industry participants compete to secure purchase of their electricity and services more choice: Customers have more choice in a competitive market, as retailers vie for their business by offering a range of options for buying electricity. Better service to Retailers has to be competitive in terms of price and service.

Minimum Cost Path

In IEEE-6 bus system under normal operation condition, the line which carries more power, if that line become outage due some maintenance or repair work, the alternative minimum cost path can be determined by the Shortest Path Algorithm (Subramanian& Devarajan, 2016). The simulation is done in the MATLAB graph theory. The simulation results are as shown in fig.4 & 5 and fig 6 & 7.

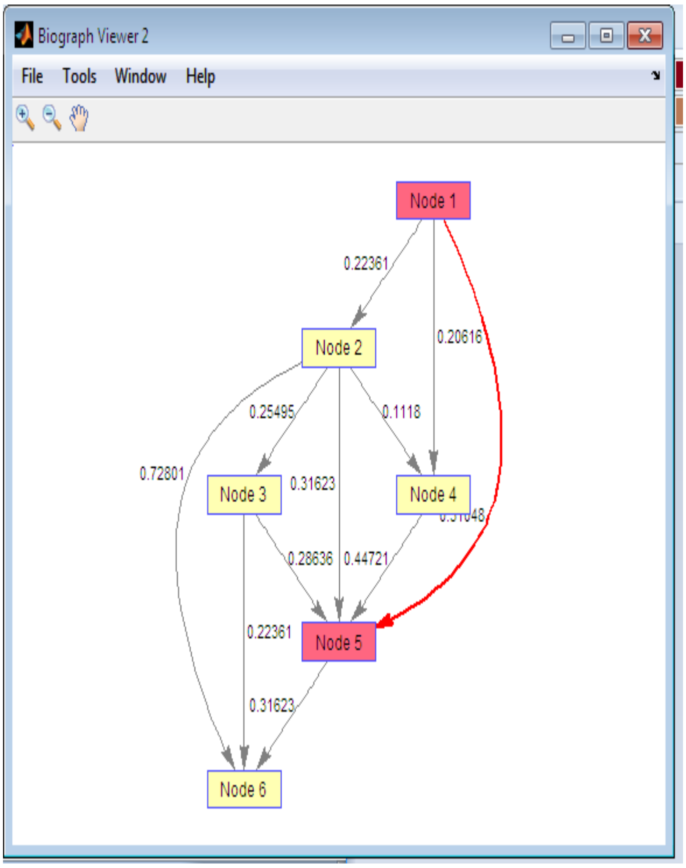


Figure 4. Transaction between bus 1 &5
outage between 1- 5

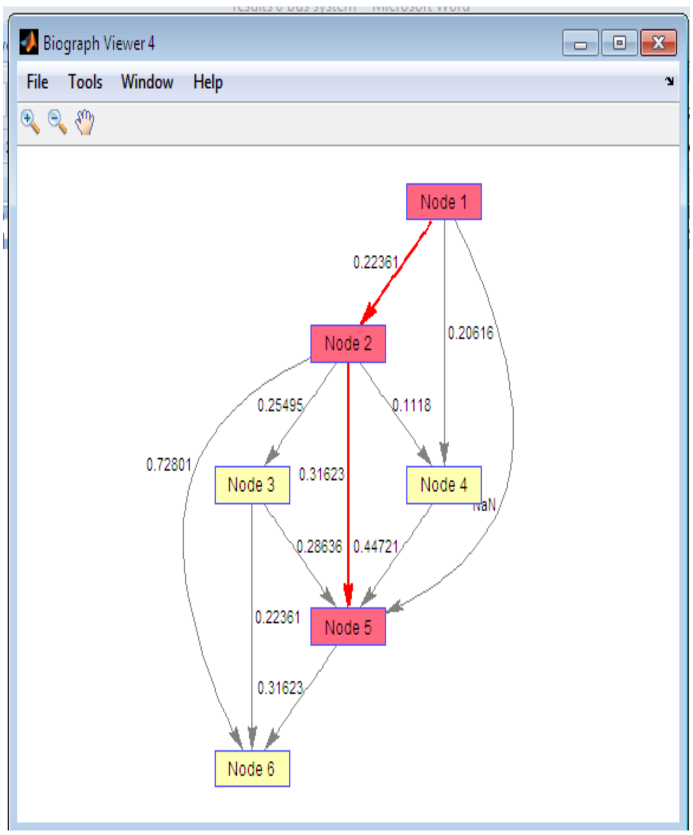


Figure 5. Transaction between bus 1 & 5
an alternative minimum path

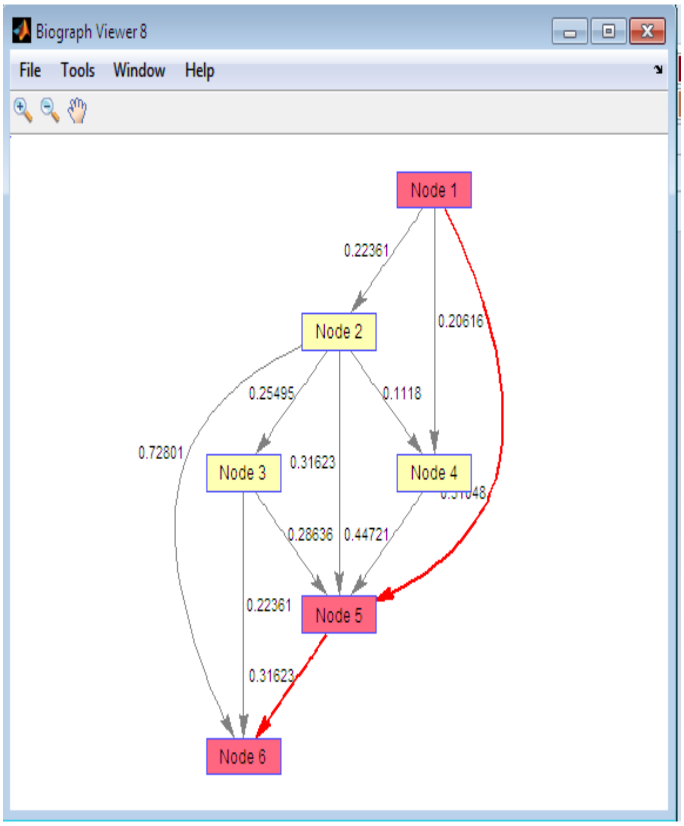


Figure 6. Transaction between bus 1 &6 an alternative minimum path

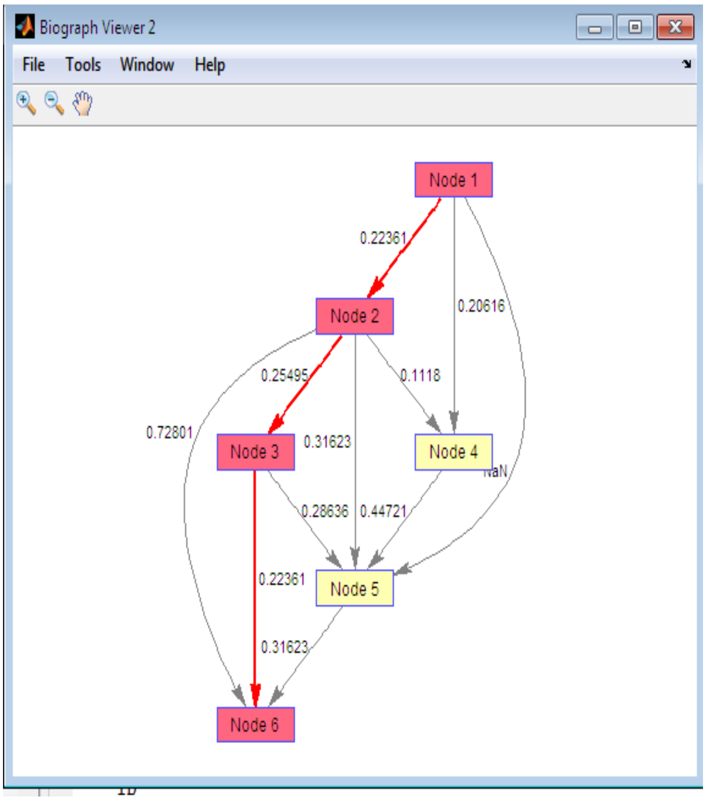


Figure 7. Transaction between bus 1 & 6 when line Outage between 1- 5

Table-5. Minimum cost path under normal power flow and line outage condition

S.no.	Transaction Buses	Minimum Path under Normal power flow	Impedance (Z) / Distance	Alternative minimum Path under line outage condition (1-5 line out)	Impedance (Z) / Distance
1	Bus 1to 5	1-5	0.3104	1-2-5	0.4785
2	Bus 1to 6	1-5-6	0.6266	1-2-3-6	0.7646
3	----	---	---	---	---

The table.5 shows the impedance of path /distance between the power producers and consumers under normal load flow condition and alternative path under line outage conditions.

CONCLUSION

The work presented here to determine the minimum cost power flow path in deregulated power system using the determination of ATC and optimal path power flow based congestion management. The ATC is determined using ACPTDF method to schedule the power flow in the lines using power world simulator and minimum cost path power flow using graph theory algorithm in MATLAB. These two parameters decide the transmission pricing based on least and fair loss allocation predominates in fixing the power contracts. The simulation is carried out on IEEE-6 bus system and found satisfactory results.

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