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Power flow analysis of Restructured power Market with wheeling transactions for variable loads

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Abstract

This paper deals with the power flow analysis in the restructured power market environment. In this paper, the power flow analysis was carried out for different load conditions such as baseload, increasing load and peakload. The simultaneous bilateral and multilateral wheeling transactions are introduced to make the system as restructured environment. The results were compared for without and with wheeling transactions for all the above said cases. The power flow analysis has been tested using Newton Raphson power flow algorithm. The proposed power flow method has been demonstrated and analyzed on IEEE 30 bus system with and without wheeling transactions.
Keywords: *Power Flow Analysis, Newton Raphson, Simultaneous Wheeling Transaction, Restructured Power Market, Loads.*

1. Introduction

Electricity sector across the world is undergoing a rapid revolutionize in its business and operational mode to create market condition in the power industry. The main intention of this change is to enhance competition and bring consumer's new choices, lower price and economic benefits. "Wheeling is the transmission of power from a seller to a buyer through the network owned by a third party". The wheeling utility is paid for its service and for meeting the losses. The challenge in power system operation lies in bridging the gap between demand and supply in vertical integrated utility, whereas in a restructured power market has a neutral entity called independent system operator (ISO). The main role of ISO is not dispatching or re-dispatching generation, but matching electricity supply with demand to ensure reliability and also monitors and operates the interconnected power system. It maintains the power flow balance throughout the network and includes the transmission losses and permits the feasible transactions. These transactions could be two types, if the transaction involving with one buyer and one seller known as bilateral transaction, or if the transaction between multiple buyers and sellers known as multilateral transaction. If the transaction includes both the above said transactions known as simultaneous wheeling transactions.

William et al, solved an AC power flow problem by newtons method with the help of optimally ordered gaussian elimination and special programming technique. The authors compare the effectiveness of newton's method with conventional Gauss-Seidal method and claim that it is faster, more accurate, and more reliable than any other known method for any size or kind of problem.[1] Mukerji et.al, applied optimal power flow for the evaluation of wheeling and non utility generation (NUG) considering short term marginal wheeling costs. The IEEE 30 bus test case and northeast utilities is used to illustrate the use of OPF for wheeling and non utility generation (NUG).[2]

Ferrero et.al, implemented game theory to simulate the decision making process for defining offered prices for a restructured environment. The outcome of this study can be used by pool coordinators in order to discourage unfair coalitions. A modified IEEE 30 bus system was used as a restructured power pool to illustrate the main features of the proposed method.[3] Lee et.al, reported the power flow between inter areas for the Korean electric power corporation (KEPCO) in South Korea. These power flow data can be utilized when calculating reliable available transfer capabilities between countries, losses of interconnected lines.

The parameters discussed are the major key factors of determining market structures. [4] Kostkova et.al, made an attempt to provide a theoretical description of the main load management goals and methods, to discuss the implementation state and worldwide usage of load management approaches. It provides a comprehensive study with the load management .[5]

Hamada et.al, presented a study of variation of the power flow in the restructured power market due to the wheeling transactions. This paper describes the identification of the transaction paths in restructured power market. Depends upon the direction of power flow the wheeling charge are computed and demonstrated on IEEE 30 bus system.[6] Galiana et.al, proposed a simple and systematic approach for allocating losses to bilateral transactions. This leads to a set of governing differential equations whose solution yields the loss allocation for contracts of any size.[7]

Christie et.al, presented the operation, analysis & management of power flow in restructured power market. It also explores the calculation of capability of the transmission system in the restructured environment. The chances of congestion due to wheeling transaction are explained on the practical utility system.[8] Sood et.al, presented the detailed literature survey about the concept of wheeling and it impacts on the power flow in restructured power market. The methodologies, regulatory issues, future planning of the restructured power market are explained with the supportive papers. This paper also had provided a review on utilities and Independent system operator (ISO).[9]
Galiana et.al, presented a general mathematical framework for the analysis and management of power transactions under open access subject to system security constraints. The framework introduces the notions of a virtual network of transactions and the transactions matrix, both describing virtual power flows among financial entities and also it shows how the transactions selected by the market forces are influenced by the security requirements of the physical network.[10] Gnanadoss et.al, presented an EP based optimal power dispatch model with bilateral wheeling transactions for restructured environment. This paper also proposes ETC of the system which determines the amount of power that can be transferred over the transmission network without affecting the economy of the utilities. Such economic transactions help to reduce the overall cost of electricity customers. The proposed EP-OPF algorithm for the computation of TTC and ETC with bilateral wheeling transactions is demonstrated on the IEEE-30bus system.[11]

Anbazhagan et.al presents a comprehensive model for day ahead electricity price classification using an artificial neural network models for Spain and New-york deregulated environment. The factors considered are historical prices, system load, fuel price, future addition of generation and transmission capacity, regulatory structure and rules, future demand growth, plant operations and climate changes. It is confirmed that the historical price factors is the most important of the variables affecting the electricity prices.[12] Shaaban et.al, presents the calculation of total transfer capability (TTC) through an optimal power flow approach. The method is based on full AC power flow solution which accurately determines reactive power flow, and voltage limits as well as the line flow effect. Sequential quadratic programming (SQP) method is used for the optimization process.[13]

Wu et.al proposed a novel algorithm for contingency ATC computation and a sensitivity analysis for system uncertainties. It incorporates linear distribution factors and AC load flow sensitivity-based method in order to calculate ATC values efficiently and speedily considering line outages.[14] Gnanadoss et.al, proposed the assessment of available transfer capacity with capacity benefit and transmission reliability margins of practical power systems with combined economic emission dispatch (CEED). In the proposed approach, Newton Raphson method and EP algorithm have been used for power flow and combined economic emission dispatch respectively. A modified price penalty factor was proposed to solve the CEED problem. A non linear scaling factor is also included on EP algorithm to improve the convergence performance.[15]

AswaniKumar et.al, presents, a comprehensive bibliographical survey of the literature on transmission congestion management and the related issues were addressed. Information about the congestion management issues worldwide existing in different restructured electricity markets.[16] Sood et.al, presents an optimal model of congestion management with special emphasis for promotion of renewable energy sources in competitive electricity market. This paper also presents a generalized optimal model of congestion management for restructured power sector that dispatches the pool in combination with privately negotiated bilateral and multilateral contracts while maximizing social benefit. This model determines the locational marginal pricing (LMP) based on marginal cost theory. [17]

Gnanadoss et.al, presented an optimal power flow for congestion management with bilateral and multilateral transactions. The preferred schedules of generations of the corresponding scheduling coordinators have been obtained in combined economic emission dispatch environment. An evolutionary programming algorithm was demonstrated to relieve the congestion management by taking into consideration of incremental/decremental bids of generators.[18] Rajasekaran et.al, presented the power flow analysis in the restructured power market due to the wheeling transaction. The results were analysed on specific parameters such as real power flow, system losses and voltage profile after incorporating the wheeling transactions. A daily load curve was assumed and the powerflow analysis was carried out for each hour without and with wheeling transactions and the results were compared.[19]

In this paper the power flow analysis is carried out using newton raphson method in the restructured power market environment with and without wheeling transactions for different load conditions, i.e baseload, increasing load and peakload and also demonstrated on IEEE 30 bus test system. In the 30 bus system the simultaneous bilateral & multilateral wheeling transactions are introduced to make the system as restructured environment. The results were compared for all the above said cases.

2 Problem Formulation:

The objective of the work is to determine the power flow in all the transmission lines, which modelled as:

$$\textit{Objective function} = \sum_{i=1}^{N_i} P_i \qquad (1)$$

Where, N_i - Number of Transmission lines
P_i - Number of generators in MW

For a given power system network, the optimization cost of generation is given by the following equation,

$$F = Min \sum_{i=1}^{N_g} f(FC) \qquad (2)$$

Where, F is the optimal cost of generation, FC is the total fuel cost of generators and N_g represents the number of generators connected in the network.

The system constraint is given as follows,

$$\sum_{i=1}^{Ng} P_{gi} = P_d + P_l \qquad (3)$$

Where P_d is the total load of the system and P_l is the transmission losses of the system.

The power flow equation of the power network

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

Where,

$$g(|v|,\theta) = \begin{vmatrix} P_i(|v|,\theta) - P_i^{net} \\ Q_i(|v|,\theta) - Q_i^{net} \\ P_m(|v|,\theta) - P_m^{net} \end{vmatrix}$$

For eachPQbus i

For each PV bus m, not including the reference bus

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, and

|v| and θ are voltage magnitude and phase angles of different buses.

The inequality constraint on real power generation P_{gi} of each generation i

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

Where,

P_{gi}^{min} and P_{gi}^{max} are minimum and maximum value of real power generation allowed at generator i respectively.The inequality constraint on voltage of each PQ bus(1)

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

Where,

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

Power limit on transmission line

$$MVAf_{p,q} \leq MVAf_{p,q}^{max} \quad (7)$$

Where,

$MVAf_{p,q}^{max}$ is the maximum rating of transmission line connecting bus p and q.

3 Results and Discussion:

The power flow analysis is carried out in the restructured power market environment with wheeling transactions and demonstrated on IEEE 30 bus system. The one line diagram of IEEE 30 bus system is shown in figure 1. The utility system was modified to have wheeling transactions and assumed to be a restructured system. It consists of 06 generators, 41 transmission lines and its base load demand is 283.4 MW. The bus data and line data for the IEEE 30 bus system are taken from [20]. In the 30 bus system the simultaneous bilateral & multilateral wheeling transactions are introduced to make the system as restructured environment. The details of simultaneous bilateral & multilateral wheeling transactions are given in the tables 1 and 2 respectively.

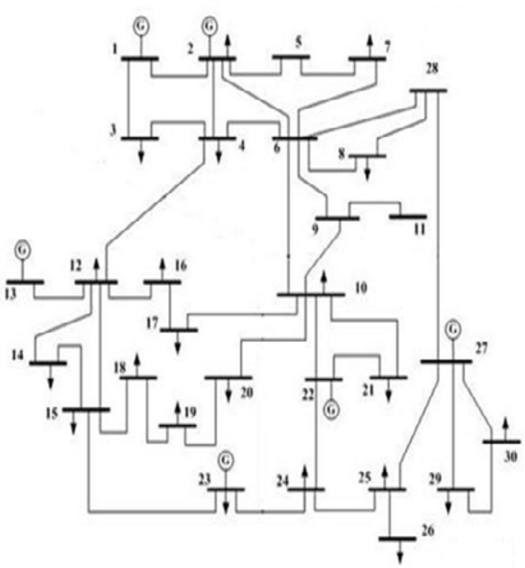

Figure 1: One line diagram of IEEE 30 bus system

Table 4: Details of Multilateral wheeling transaction

Power injected		**Power extracted**	
Bus no.	**Value of Transaction (MW)**	**Bus no.**	**Value of Transaction (MW)**
15	15	07	12
		29	03
Total	**15**	**Total**	**15**

3.1 Details of Simultaneous wheeling Transactions:

a.Increasing Load

Table 1: Details of bilateral wheeling transaction

Table 2: Details of Multilateral wheeling transaction

Power injected		***Power extracted***	
Bus no.	***Value of Transaction (MW)***	***Bus no.***	***Value of Transaction (MW)***
21	10	16	06
		14	04
Total	**10**	**Total**	**10**

b. Peak Load

Table 3: Details of bilateral wheeling transaction

Sl.No.	***Transaction***	***From Bus no.***	***To Bus no.***	***Value of Transaction (MW)***
1	T_1	21	10	7.5
2	T_2	16	03	8.5

Sl.No.	***Transaction***	***From Bus no.***	***To Bus no.***	***Value of Transaction (MW)***
1	T_1	15	23	06
2	T_2	26	29	04

The power flow was carried out using conventional Newton's method for IEEE 30 bus system in the matlab environment for the following cases.

Case 1- Base Load
Case 2- Increasing Load
Case 3 -Peak Load

Case 1: Base Load Analysis

It is the minimum amount of power that a utility or distribution company must make available to its customers, or the amount of power required to meet minumum demands based on reasonable expectations of customer requirements. The base load demand for the IEEE 30 bus system is 283.4 MW. The table 5 shows that the power flow results for without wheeling transaction during base load condition. The power flows on the corresponding lines were tabulated in table 5. It was observed that the power flows in all the lines were satisfied with their thermal ratings.

Table 5: Power flow results without wheeling transactions

Line No	From	To	Magnitude of Real power(MW)	Magnitude of Apparent power (MVA)	Thermal Ratings of Transmission Lines (MVA)
1	1	2	177.77	179.152	300
2	1	3	83.221	83.378	300
3	2	4	45.712	45.792	150
4	3	4	78.012	78.076	300
5	2	5	82.990	83.008	150
6	2	6	61.912	61.920	150
7	4	6	70.126	72.282	200
8	5	7	14.356	18.831	150
9	6	7	37.523	37.570	150
10	6	8	29.528	29.766	150
11	6	9	27.693	28.644	150
12	6	10	15.823	15.836	150
13	9	11	0.000	15.657	150
14	9	10	27.693	28.501	150
15	4	12	44.121	46.489	150
16	12	13	0.000	10.291	150
17	12	14	7.856	8.227	150
18	12	15	17.857	19.161	150
19	12	16	7.208	7.954	150
20	14	15	1.582	1.724	150
21	16	17	3.654	3.932	150
22	15	18	6.014	1.774	150
23	18	19	2.775	2.879	150
24	19	20	6.747	7.259	150
25	10	20	9.027	9.704	150
26	10	17	5.372	6.953	150
27	10	21	15.733	18.558	150

28	10	22	7.583	8.813	150
29	21	22	1.877	2.464	150
30	15	23	5.001	5.810	150
31	22	24	5.654	6.304	150
32	23	24	1.770	2.192	150
33	24	25	1.333	2.073	150
34	25	26	3.545	4.262	150
35	25	27	4.903	4.972	150
36	28	27	18.184	18.987	150
37	27	29	6.189	6.410	150
38	27	30	7.091	7.283	150
39	29	30	3.704	3.753	150
40	8	28	0.575	2.080	150
41	6	28	18.819	21.134	150

Case 2: Increasing in Load Analysis:

The increase in load is the intermediate level between base and peak loading levels of the system. In real time systems the customers always experience momentary variations in load and hence their effect on the system stability, losses, frequency profile and real power flow in the transmission lines is important and becomes mandatory to be accounted for.The increase in load demand was taken for the IEEE 30 bus system is 311.74 MW.

Case 3: Peak Load Analysis:

Peak demand is used to refer to a historically high point in the sales record of a particular product. In terms of energy use, peak demand describes a period of simultaneous, strong consumer demand or a period of highest demand in a billing period. Peak demand, peak load or on peak are terms used in energy demand management describing a period in which eletrical power is expected to be provided for sustainable period at a significantly higher than average supply level. The peak load demand for the IEEE 30 bus system is 354.25 MW. The table 6 shows that the comparison of real power flow in the lines with and without wheeling transactions.

Table 6: Comparison of power flows with and without wheeling transactions

Line No.	***From***	***To***	***Increasing Load***		***Peak Load***	
			Before Wheeling	***After Wheeling***	***Before Wheeling***	***After Wheeling***
1	1	2	199.569	199.372	232.449	231.179

2	1	3	94.997	95.028	112.735	112.988
3	2	4	53.063	53.175	64.930	63.499
4	3	4	88.910	88.398	105.050	96.795
5	2	5	87.136	87.038	93.002	94.624
6	2	6	70.859	70.660	83.580	82.220
7	4	6	76.884	75.556	79.865	80.567
8	5	7	10.534	10.624	5.184	3.693
9	6	7	33.637	33.728	29.069	37.738
10	6	8	30.897	31.023	30.827	30.643
11	6	9	35.400	33.981	47.834	42.46
12	6	10	20.169	19.366	27.104	24.088
13	9	11	0.000	0.000	0.000	0.000
14	9	10	35.400	33.981	47.834	42.46
15	4	12	54.958	56.420	78.716	68.666
16	12	13	0.000	0.000	0.000	0.000
17	12	14	9.981	11.591	17.335	15.908
18	12	15	26.073	24.21	34.206	28.64
19	12	16	7.704	9.417	15.974	12.917
20	14	15	3.664	1.232	0.770	0.603
21	16	17	4.141	0.175	7.827	2.259
22	15	18	9.668	8.741	10.481	13.088
23	18	19	1.369	0.458	2.851	0.301
24	19	20	8.157	9.072	12.406	9.836
25	10	20	15.582	16.521	25.199	22.504
26	10	17	4.887	9.206	16.922	11.302
27	10	21	19.350	13.864	17.969	12.666
28	10	22	9.949	7.956	9.048	6.776
29	21	22	1.695	6.271	0.322	2.578
30	15	23	6.392	9.104	5.501	8.195
31	22	24	11.561	14.166	9.295	9.305
32	23	24	3.142	0.192	7.842	5.134
33	24	25	0.830	0.046	7.497	4.705
34	25	26	11.885	7.667	3.548	3.547
35	25	27	11.200	7.691	11.183	8.329
36	28	27	24.841	25.477	24.482	23.692
37	27	29	6.444	9.411	6.197	7.675
38	27	30	7.196	8.375	7.107	7.688
39	29	30	3.608	2.472	3.706	3.138
40	8	28	0.775	0.901	0.697	0.523
41	6	28	24.167	24.681	23.888	23.266

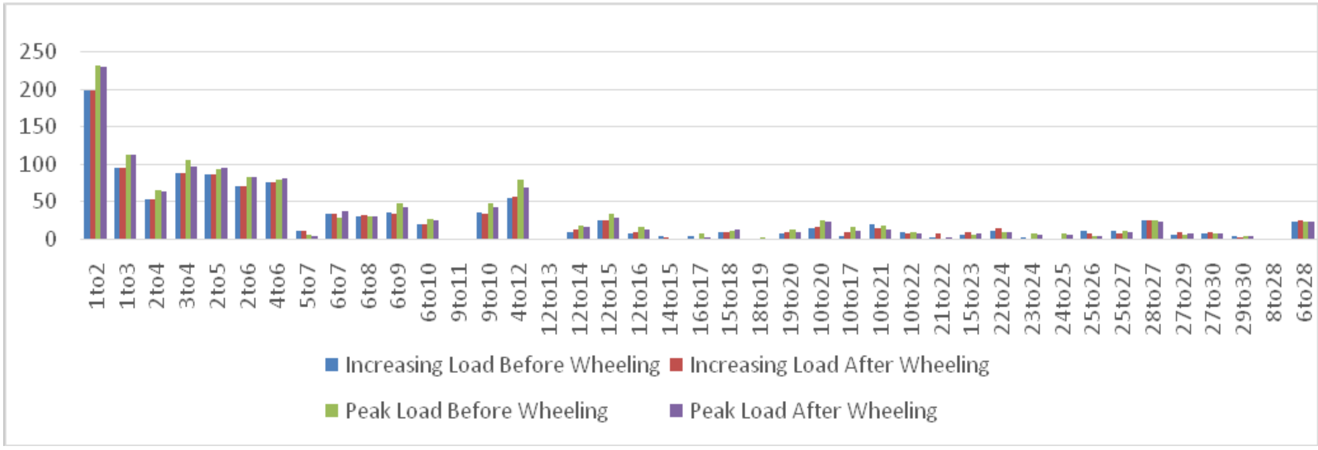

Figure 2: Comparison of power flows with and without wheeling transactions

It was observed that the power flow changes in the most of the lines due to the wheeling transactions and there is no change in few lines.

The figure 3 shows that the system losses in the transmission lines without and with wheeling transactions. It indicates that the losses for the base load condition without wheeling transaction are 17.599 MW. The losses for the increasing load and peak loads are 22.826 and 30.934 respectively. After incorporating the wheeling transactions the losses for increasing load and peak loads are 21.960 & 29.917 respectively. It was observed that the losses are less compared to without wheeling transaction. The reactive power losses also reduced considerably after incorporating the wheeling transaction.

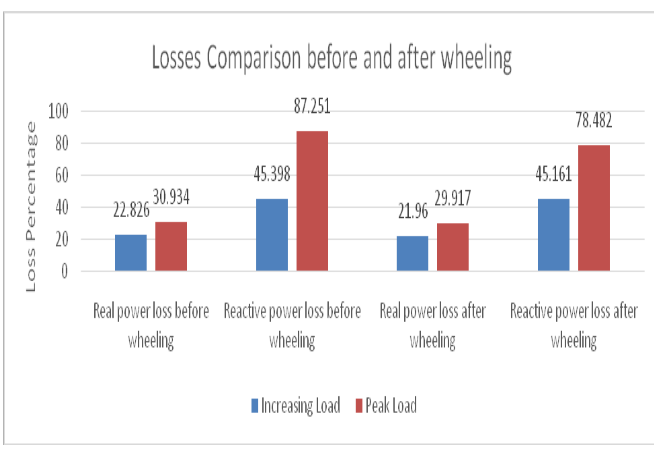

Figure 3: Comparison of losses before and after wheeling

4 CONCLUSION:

This paper presents the power flow analysis for IEEE 30 bus system using without wheeling transaction and simultaneous wheeling transactions for baseload, increasing load and peakload conditions. From the results it was observed that real power flow changed in most of the lines due to the wheeling transactions and there is no change in few lines. After incorporating the wheeling transactions, it was observed that the losses are slightly decreased when compared to without wheeling transaction eventhough the load was increased. The Newton Raphson method was used for the power flow analysis and also the proposed algorithm was illustrated in IEEE 30 bus system with and without wheeling transactions.

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