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Evaluation of Transmission Pricing Methodologies for Power Trading Markets

Mrs. Archana Shirbhate*, Mr. V.K.Chandrakar, Mr.R.M.Mohril
Department of Electrical Engineering, RTM Nagpur University, Nagpur, Maharashtra, India

ABSTRACT

The paper evaluates transmission pricing methods under liberalized market conditions. Several concepts are being discussed, whereas three main categories can be distinguished: rolled-in transmission pricing, incremental transmission pricing and embedded/incremental transmission pricing. In order to clarify the general framework in which electricity trading and therefore transmission takes place, the basic principles of electricity markets. The electricity markets and liberalization it becomes obvious, that the question is no longer if competition should be introduced but how to organize markets in order to achieve an optimum performance. Power delivery is nowadays a bundle of many services including mainly generation, transmission and distribution. While the former vertically integrated utilities charged one price for power delivery today every single service has to be priced separately

Keywords: OPF, Power Market, Transmission Pricing, IEEE bus

I. INTRODUCTION

That a countries' electricity market has been liberalized is a very common but likewise unspecific proposition. "Delivered power is a bundle of many services. These include transmission, distribution, frequency control and voltage support, as well as generation Each service requires a separate market, and some require several markets. Liberalization does not necessarily mean perfect competition and it does not necessarily include all markets reaching from generation to ancillary services. It is obvious, that in reality a clear distinction between the different markets does not exist. But, in order to clarify structures, this report mainly follows the theoretical approach of distinguishing and analyzing single markets. Perfect Competition is stated that the theory of perfect competition is well developed but not applicable to the "real" world. The concept is claimed to be an idealized fiction, useful mainly for the conceptual development of ideas.

In this paper the theory of perfect competition is used to evaluate the different electricity markets in order to work out how 'close' the real markets are to the optimal (theoretical) structure. The estimation forms the baseline of the further market assessments Perfectly competitive markets are referred to be efficient, where "efficiency means

(1) the output is produced by the cheapest suppliers,

(2) it is consumed by those most willing to pay for it, and
(3) the right amount is produced.

Another formulation of efficiency is, that the social welfare has been maximized. A basic example should be suitable to discuss this assertion in more detail. Elementary microeconomics state that the intersection of the supply and demand curve determine a stable equilibrium in perfectly competitive markets (see figure 1). The demand curve represents the aggregated preferences of the consumers. It defines how much the consumers are willing to consume at a certain price. In contrast, the supply curve shows how much output the suppliers are willing to produce at a given price. From the crossing of both curves the competitive price (or market price) and the competitive quantity can be read.

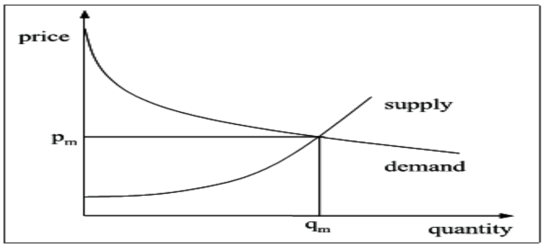

Figure 1. Equilibrium price and quantity in competitive markets

II. METHODS OF CONGESTION MANAGEMENT

The power flow Pij through the transmission line i – j is a function of the line reactance Xij, the voltage magnitude Vi, Vj and the phase angle between the sending and receiving end voltages δi – δj as shown in equation

$$P_{ij} = \frac{V_i V_j}{X_{ij}} \sin(\delta_i - \delta_j) \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (1)$$

From the 2.1, one can see that the power flow can be affected by changing the voltage magnitudes, the reactance of the transmission lines or the power angle (δi –δj). Voltage magnitudes can be controlled through VAR support. The reactance of the line can be reduced through series compensation and the power angle can be varied via power injection changes at either bus, e.g. generation or load changes[3].

In this thesis, voltage magnitudes and power angle are considered for congestion management. The three methods of congestion management provided in the tool are:

1. TLR Sensitivities Based Load Curtailment
2. Economic Load Management for Congestion Relief
3. VAR Support and these are discussed next

2.1 MATLAB

MATLAB is a high-performance language for technical computing. The name MATLAB stands for matrix laboratory. It integrates computation, visualization, and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation.

2.1.1 MATPOWER

MATPOWER is a collection of packages of MATLAB M-files to solve power flow and optimal power flow problems. It is intended as a simulation tool for researchers and educators that are easy to use and modify. MATPOWER is designed in such a way to give the best possible performance with simple code to understand and modify [4].

2.2 Concept of Optimal Power Flow

The main objective of an OPF problem is to determine the optimal setting of control variables in a power system network to optimize an objective function while respecting a set of physical and operating constraints such as generation and load balance, bus voltage limits, power flow equations, and active and reactive power limits. Generally, an OPF Problem can be formulated as ..

III. RESULTS OF TRANSMISSION PRICING PARAMETERS FOR IEEE 14 BUS CASE STUDY

The single line diagram of IEEE-14 bus test system is shown in Figure 2. The system consists of 5 synchronous generators. Associated flow results along with Transmission Pricing are given in Figures and Table as shown below. Table 1 and 2 gives the idea about initial dispatch and re-dispatch value. which is given in Figure10 it also gives their differences.

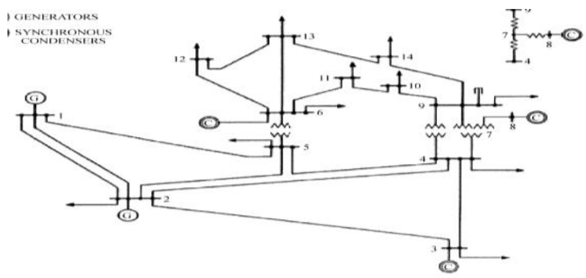

Figure 2. Single Line Diagram of IEEE 14 bus test system

Table 1. Congested lines for Initial Dispatch

Line	Maximum Capacity	Expected line flow capacity	Actual Line flow
1	90	81	84.1196
2	50	45	45.0642

Table 2. Re-Dispatch (MW)

Line	1	2
OPF	112.5	62.5

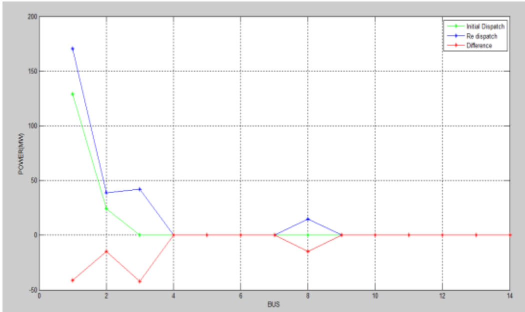

Figure 3. Difference in Initial power flow and Re-Dispatched Power at All Buses in Power System

Result indicates that the difference in load demands at generator bus, whereas difference at other buses are zero. Table 3 provides the contribution of each generator and each load to the line flows under all methods. It illustrate the different results and characteristics between the pricing schemes for each pricing method. The obtained results are shown in Figure 4

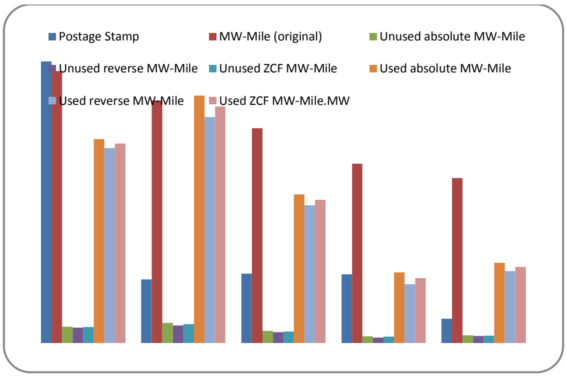

Figure 4. Transmission Pricing based on different pricing methods at Generator Buses when load demand is actual

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Table 3. Tabulated Transmission Pricing based on different methods when load demand is actual

Methodology	G1	G2	G3	G4	G5
Postage Stamp	40970	9279	10118	10000	3559
MW-Mile (original)	39595	35331	31248	26098	24000
Unused absolute MW-Mile	2383	2918.7	1761.3	999.2	1116.8
Unused reverse MW-Mile	2252.7	2546.8	1574.7	813.8	1011.8
Unused ZCF MW-Mile	2325.7	2754.1	1678.8	917.5	1071
Used absolute MW-Mile	29682	35987	21614	10307	11661
Used reverse MW-Mile	28380	32898	20065	8582	10477
Used ZCF MW-Mile.MW	29031	34443	20840	9444	11069

This figure gives the solution for the minimum power transaction problems. Unused reverse Mw-mile method gives the minimum price. Figure 11, Figure 12 and Figure 13givesTransmission Pricing based on different pricing methods at Generator Buses tested under three conditions like on actual load, 5% increase in load and 10 % increase in load.

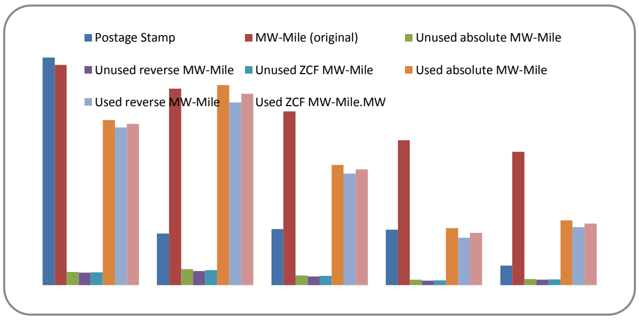

Figure 5. Transmission Pricing based on different pricing methods at Generator Buses when load demand is actual

Table 4. Tabulated Transmission Pricing based on different methods when load demand increased by 5%

Methodology	G1	G2	G3	G4	G5
Postage Stamp	35031	9774	13524	38	5150
MW-Mile (original)	24617	27234	26431	24104	24000
Unused absolute MW-Mile	2159.8	2992.7	2178.6	1226	1156.2
Unused reverse MW-Mile	2018	2778.9	1891.6	1161.2	1165.8
Unused ZCF MW-Mile	2095.4	2895.2	2047.7	1196.8	1161.1
Used absolute MW-Mile	27494	40258	26630	14402	13246
Used reverse MW-Mile	25824	38209	23793	13404	12922
Used ZCF MW-Mile.MW	26659	39233	25212	13903	13084

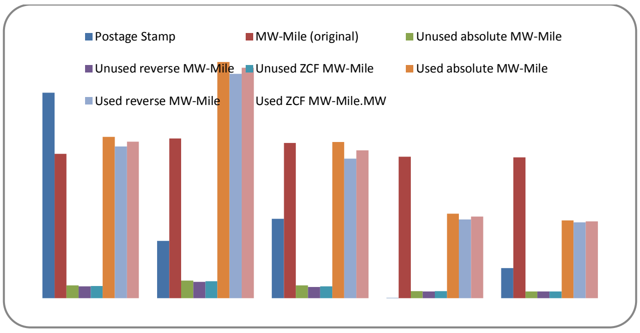

Figure 6 . Transmission Pricing based on different pricing methods at Generator Buses when load demand is increased by 5%

Tabular representation is given in table 3,table 4 and table 5 Analysis is that Unused reverse Mw-mile method gives the minimum price under three different load conditions. The results indicate that the unused MW-mile method will be the preferred for calculating the transmission pricing. Numerical examples are provided to compare the results using different pricing methodology. At the End of the paper, a case study is carried out to access the effectiveness of the methodology developed.

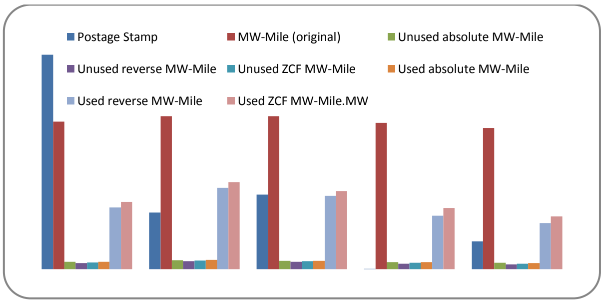

Figure 7. Transmission Pricing based on different pricing methods at Generator Buses when load demand increased by 10 percent

Table 5. Tabulated Transmission Pricing based on different methods when load demand is increased by 10 %

Methodology	G1	G2	G3	G4	G5
Postage Stamp	36521	9650	12676	8	4758
MW-Mile (original)	25130	26014	26047	24904	24000
Unused absolute MW-Mile	1221.7	1528.8	1405	1214.9	1060.3
Unused reverse MW-Mile	1025.3	1363.3	1259.5	914.1	785
Unused ZCF MW-Mile	1137.3	1458.6	1343	1085	941.4
Used absolute MW-Mile	1233.8	1576.9	1407.2	1165.4	1008
Used reverse MW-Mile	10489	13857	12449	9088	7830
Used ZCF MW-Mile.MW	11414	14813	13260	10371	8955

IV. CONCLUSION

This paper presents computation of different transmission pricing for a case study of standard IEEE 14 bus system as an integral part of simulator built for deregulated power trading. Features of simulator include in depth analysis of various pricing schemes, management scheme and effect of Re-dispatch with optimal power flow constraint to relieve congestion. The programmed simulator offers a set of methods to calculate the allocation of these costs by the loads and generators and re-dispatch criteria. The trading philosophy with contracts based on different pricing can be negotiated in techno-economical way. In this paper we presented a case study based on the IEEE bus network. Several congestion situations and transactions along with pricing both in the pool and bilateral contracts were analyzed and pricing based re-dispatch congestion management were implemented in MATLAB, while optimal power flow was also used for the purpose of the method's evaluation. In this paper eight transmission pricing methodologies have been evaluated. Moreover, it is clear that Unused reverse MW-Mile method gives minimum pricing method even when the load changes. However, this pricing method is able to fulfill transmission pricing objectives: economic efficiency non-discrimination, transparency and cost coverage and can be also applied to large power system with economics as integral part proved to be effective as a temporary solution. MATPOWER calculation gets economical boost with such strategy. All the methods have been tested for all the pricing methods on IEEE 14 bus system. The methods were implemented in MATLAB, while optimal power flow was also used for the purpose of the method's evaluation. In this paper eight transmission pricing methodologies have been evaluated. Moreover, it is clear that Unused reverse MW-Mile method gives minimum pricing method even when the load changes. However, this pricing method is able to fulfill transmission pricing objectives: economic efficiency non-discrimination, transparency and cost coverage and can be also applied to large power system

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