

Evaluation of Transmission Pricing Methodologies for Pool Based Electricity Markets

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Abstract—This paper presents and analyses several approaches for transmission cost allocation in a centralized pool based electricity market environment that includes composite embedded/marginal transmission pricing mechanisms. The revenue from marginal cost based remuneration (MBR) necessitates supplementary charges; thus it is required to identify the contribution of individual generators and loads to the line flows using tracing methods and implement usage-based transmission pricing methods for allocating the remaining fixed cost. Eight transmission pricing schemes and three tracing methods are being evaluated and applied on Garver's 6-bus system and on IEEE 24-bus reliability test system to illustrate the different results derived among the pricing schemes for each tracing method or among tracing methods for each pricing scheme.

Index Terms—Transmission pricing, electricity tracing, embedded costs, MW-Mile, counter-flow.

I. INTRODUCTION

IN the deregulated electricity markets, cost allocation of transmission services is a major issue for transmission open access. The cost of the basic transmission services corresponds primarily to the fixed transmission cost that is also referred to as the embedded transmission facility cost. The cost of the transmission network can be interpreted as the cost of operation, maintenance and planning of the transmission system. All the users of the transmission facilities (generators and loads) should pay for the network usage of the system following an efficient transmission pricing mechanism that is able to recover transmission costs and allocate them to transmission network users in a proper way.

Several methodologies have been proposed for the allocation of all or part of the existing network cost to the users of the transmission system [1]. Some of them (e.g. postage stamp, contract path, MW-Mile) are based on the actual network usage of a transaction and can be also addressed as embedded methods, while others (marginal/incremental) on the additional transmission cost that a specific electricity transaction causes [2]. However, in a centralized/pool-based market (or a coexisting bilateral and

pool market), there are no (or some) direct transactions between producers and consumers. The usage-based allocation of the fixed transmission costs should be made through power tracing methods in order to trace the actual contribution of each user (generator or load) to each line flow. Then, the transmission cost can be calculated and allocated based on these contributions following one of the embedded pricing methods mentioned above.

Due to the nonlinear nature of power flow equations, it is very difficult to decompose the network flows into components associated with individual customers. However, it is possible and acceptable to apply approximate models or sensitivity indices to estimate user's contributions to the network flows. Distribution factors are defined through a sensitivity analysis and indicate the relation between a change in power injection in a certain bus and a change in the power flow in a particular line [3]. In Bialek's tracing method it is assumed that nodal inflows are shared proportionally among nodal outflows [4] while Kirschen's tracing method is based on a set of definitions for domains, commons and links [5]. It is also possible to calculate equivalent transactions by minimizing the total MW-km covered in the entire system [6].

After defining each user's contribution to the network flows, total costs are allocated through an embedded method. Postage-stamp rates are based on average system costs and often include separate charges for peak and off-peak periods, which are functions of season, day or holidays. MW-Mile is a flow-based pricing scheme where power flow and the distance between points of injection and withdrawal reflect transmission charges [7]. However, both pricing approaches do not consider transmission congestion and the corresponding change in the generation mix. A proper pricing scheme should reward participants whose schedules tend to relieve congestion in the network.

Marginal pricing of electricity has been employed or proposed in many electricity markets. The marginal network revenue for a transmission entity results from the spatial discrimination of spot prices (LMPs) due to losses and transmission constraints. This revenue can be also used for financing future transmission investments. However, typical marginal revenues account for a small percentage of the total fixed cost, which leads to additional charges, called the "complementary charges", which are calculated using an embedded pricing method [8].

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The problem of transmission cost allocation to network users is divided into several sub-problems. A load flow solution that may be representative of a certain load and generation pattern or an outcome of an optimal power flow is initially needed; then the marginal based remuneration if congestions occur in the network is calculated. The complementary cost is divided between generators and loads by setting a regulated percentage share. The allocation of transmission line power flows to each network user is performed by using a tracing method, and finally the remaining fixed transmission cost is allocated to the already allocated flows using an embedded method. Instead of calculating users' contribution to the power flows for only one system configuration (e.g. peak load conditions), it is possible to examine the statistical analysis of the power flow tracing results and the network's users average participation in the network loading for a certain period of time and for several operation states of the power system [9].

This paper evaluates and compares different pricing schemes and different tracing algorithms in order to directly compare and find each alternative's advantages and drawbacks. A detailed analysis like this can reveal which pricing and tracing method suits better a certain transmission network's special characteristics. In this paper, eight transmission pricing methodologies via three tracing methods are evaluated and tested on Garver's 6-bus and on IEEE 24-bus reliability test systems. The charges obtained from the different tracing methods and the different pricing schemes are compared for the same pricing method and the same tracing method, respectively. If congestions occur in the system, the corresponding marginal remuneration (MBR) is subtracted from total embedded cost and if the sum of total charges cannot satisfy this transmission fixed revenue, supplementary charges are being calculated.

II. TRANSMISSION PRICING METHODS

One of the most challenging issues in the restructured market environment is the "fair" allocation of the transmission costs to the transmission network users. The corresponding tariffs should not only reflect the actual usage of the network but should also give incentives for the right placement of new generation facilities. The tariffs can be calculated ex-ante, taking into consideration load forecast, generation availabilities and possible line outages, and evaluated ex-post when all the necessary data are available. Nevertheless, this fixed transmission cost could be allocated to both producers and consumers in a way that matches each transmission system's special characteristics to its targets (e.g. promotion of installation of new power plants).

A. Tracing Methods

This paper evaluates the following three tracing algorithms:

1. Distribution factors or Rudnick method;
2. Bialek method;
3. Minimum "power distance" method.

Distributions factors (Rudnick method), based on DC power flows, can be used as an efficient tool for evaluating

transmission capacity use under various open access structures. These distribution factors, i.e., Generation Shift Distribution Factors (GSDFs) and Generalized Generation/Load Distribution Factors (GGDFs/GLDFs) have been used extensively in the domain of power system security analysis to approximate the relationships between transmission line flows and the generation/load values [3]. GSDFs are dependent on the selection of the reference bus and independent of operational conditions of the system, though GGDFs/GLDFs depend on line parameters, system conditions and not on the reference bus location. In order to reduce the computational time in generating a new set of distribution factors when transmission users request the use of a different reference node to accommodate their transaction, the Justified Distribution Factors (JDFs) can be used instead of GSDFs [10]. JDFs are independent of the reference bus and produce the same GGDFs and GLDFs as GSDFs do.

In *Bialek tracing algorithm*, the topological approach is used and the topological distribution factors are calculated in order to determine the contribution of individual generators or loads to every line flow [4]. It uses either the upstream-looking algorithm or the downstream-looking algorithm whether the transmission usage or complementary charges are allocated to generators or loads, respectively.

In the *minimum power distance method*, it is assumed that electricity flows through paths that minimize the total MW-km covered in the power system. Based on the linearity of the DC model of the network, a linear minimization problem provides an allocation of generation to loads (minimum power distance transactions) that allows decomposing every real flow of the network in "partial flows" according to each pair of generation and load [6].

B. Transmission Pricing Methodologies

This paper evaluates the following eight transmission pricing algorithms:

- 1) Postage Stamp;
- 2) MW-Mile (original);
- 3) Unused absolute MW-Mile;
- 4) Unused reverse MW-Mile;
- 5) Unused zero counter-flow MW-Mile;
- 6) Used absolute MW-Mile;
- 7) Used reverse MW-Mile and
- 8) Used zero counter-flow MW-Mile.

Postage Stamp is the most common but unsophisticated method used by electric utilities, where an entity pays a rate equal to a fixed charge per unit of energy transmitted. This rate does not reflect the actual use of the system and is calculated taking into account the magnitude of the user's transacted power in a certain snapshot of the system [7]. If only the peak conditions are taken into consideration, the postage stamp method allocates the total transmission cost to network users (generators and loads) as follows:

$$TC_t = TC \cdot \frac{P_t}{P_{peak}} \quad (1)$$

where TC_t is the cost allocated to network user t , TC is the

total transmission cost, P_t is the power (production or consumption) of user t at the time of system peak, and P_{peak} is the system peak load.

MW-Mile (MWM) allocates fixed costs to users based on the “extend of use” of each network facility. The method ensures the full recovery of fixed transmission costs and reflects, to some extent, the actual usage of transmission systems:

$$TC_t = TC \cdot \frac{\sum_{k \in K} c_k \cdot L_k \cdot MW_{t,k}}{\sum_{t \in T} \sum_{k \in K} c_k \cdot L_k \cdot MW_{t,k}} \quad (2)$$

where c_k is the cost per MW per unit length of line k , L_k is the length of line k , $MW_{t,k}$ is the power flow in line k due to user t , T is the set of users, and K is the set of transmission lines.

In the MW-Mile method, there are three different approaches in relation with how users that cause *counter-flows* in the network are charged. In addition, total charges for the network facilities can be based either on the unused (total) transmission capacity or on the used capacity of the facilities. When based on the *unused transmission capacity*, full recovery of the embedded transmission cost is guaranteed, while for the *used transmission capacity* methods supplementary charges usually occur that can be calculated through other embedded methods (e.g. postage stamp, MWM). However, in the unused capacity methods users are forced to pay for a part of the transmission capacity that they are not actually using, since power flows are always smaller than the actual transmission capacity of the facilities.

In the unused or used *absolute MW-Mile*, charges are being calculated based on the magnitude of the MW-Miles of network used from each user, ignoring the direction of the power flow on the circuit:

$$TC_{t,unused} = \sum_{k \in K} C_k \cdot \frac{|F_{t,k}|}{\sum_{t \in T} |F_{t,k}|} \quad (3)$$

$$TC_{t,used} = \sum_{k \in K} C_k \cdot \frac{|F_{t,k}|}{F_{k,max}} \quad (4)$$

where C_k is the cost of line k , $F_{t,k}$ is the power flow on line k caused by user t and $F_{k,max}$ is the capacity of line k .

The *reverse MW-Mile* approach takes into account power flows that are in the opposite direction and charges for each line are based on the net flows:

$$TC_{t,unused} = \sum_{k \in K} C_k \cdot \frac{F_{t,k}}{\sum_{t \in T} F_{t,k}} \quad (5)$$

$$TC_{t,used} = \sum_{k \in K} C_k \cdot \frac{F_{t,k}}{F_{k,max}} \quad (6)$$

In the *zero counter-flow method (zcf)*, reverse power flows are not counted so users responsible for the counter-flows do not pay any charge (as happens in the absolute MW-Mile approach) and do not receive any credit like (as happens in reverse MW-Mile method):

$$TC_{t,unused} = \sum_{k \in K} C_k \cdot \frac{F_{t,k}}{\sum_{t \in T} F_{t,k}}, \quad \forall F_{t,k} > 0 \quad (7)$$

$$TC_{t,used} = \sum_{k \in K} C_k \cdot \frac{F_{t,k}}{F_{k,max}}, \quad \forall F_{t,k} > 0 \quad (8)$$

III. RESULTS AND DISCUSSION

All the tracing methods have been tested for all the pricing methods mentioned above on Garver’s 6-bus test system and on the IEEE 24-bus reliability test system. For all the cases it was assumed a 30%-70% allocation of the total fixed transmission cost between producers and consumers. The methods were implemented in MATLAB, while a Graphical User Interface was also created for the purpose of the methods’ evaluation. If after implementing a used transmission capacity pricing scheme, under-recovery of the fixed transmission cost exists, supplementary charges are calculated through postage stamp method. If there is an over-recovery, an adjustment is made to the users’ transmission fixed charges.

For the Garver’s test system, results are based on the transmission expansion planning without generation resizing provided in [11] where the marginal network remuneration is zero. The total embedded transmission cost that has to be recovered per year equals 400k€. Tables 1 and 2 provide the contribution of each generator and each load to the line flows under all three tracing methods while Table 4 gives the solution for the minimum power distance transactions problem. The seven transactions resulting from the minimum power distance problem provide the flows that minimize the total MW-km covered in the power system. Figures 1 to 3 and Table 3 illustrate the different results and characteristics between the pricing schemes for each tracing method. In the used capacity methods, supplementary charges that have been calculated via postage stamp method are added to the initial charges obtained from each counter-flow pricing scheme.

The marginal network revenue has been calculated for the IEEE 24-bus reliability test system based on the yearly load curve and on the generation and transmission data provided in [12] and [13], by computing the congestion revenue (MBR) for each time period and multiplying it with the corresponding load duration. The obtained results are shown in Table 5, where although MBR for the peak load conditions account only for the 1,65% of total fixed cost, the annual MBR equals 50,62% of the total embedded transmission cost. The fixed transmission cost for the existing network is 139,105k€ per year while the fixed charges have been calculated only for the peak loading condition although all demand levels could be easily used instead. Figures 4 to 9 summarize the outcomes of all the methodologies for the IEEE 24-bus reliability test system.

TABLE 1
GENERATOR'S CONTRIBUTION TO LINE FLOWS USING GGDF'S, BIALEK'S UPSTREAM AND MINIMUM POWER DISTANCE
TRANSACTIONS METHODS ON GARVER'S 6-BUS TEST SYSTEM

LINES		LINE FLOW (MW)	GGDF			BIALEK			MINIMUM TRANSACTIONS		
FROM	TO		G1 (MW)	G3 (MW)	G6 (MW)	G1 (MW)	G3 (MW)	G6 (MW)	G1 (MW)	G3 (MW)	G6 (MW)
1	2	-51,25	13,76	3,07	-68,08	0	0	-51,25	0	-10,69	-40,56
1	4	-31,75	9,44	8,37	-49,56	0	0	-31,75	0	-5,75	-26
1	5	53	21,54	-28,81	60,27	19,93	0	33,07	0	16,44	36,56
2	3	62	-3,12	-75,40	140,52	0	0	62	0	-16,45	78,45
2	4	3,63	0,39	9,49	-6,25	0	0	3,63	0	2,07	1,56
3	5	187	-5,75	80,91	111,84	0	135,92	51,08	0	108,55	78,45
2	6	-188,12	-0,70	-16,87	-170,55	0	0	-188,12	0	-3,68	-184,44
4	6	-356,88	0,70	16,87	-374,45	0	0	-356,88	0	3,68	-360,56

TABLE 2
LOAD'S CONTRIBUTION TO LINE FLOWS USING GLDF'S, BIALEK'S DOWNSTREAM AND MINIMUM POWER DISTANCE
TRANSACTIONS METHODS ON GARVER'S 6-BUS TEST SYSTEM

LINES		LINE FLOW (MW)	GLDF					BIALEK					MINIMUM TRANSACTIONS				
FROM	TO		L1 (MW)	L2 (MW)	L3 (MW)	L4 (MW)	L5 (MW)	L1 (MW)	L2 (MW)	L3 (MW)	L4 (MW)	L5 (MW)	L1 (MW)	L2 (MW)	L3 (MW)	L4 (MW)	L5 (MW)
1	2	-51,25	-27,42	20,42	-3,44	0,37	-41,18	-30,83	0	0	0	-20,42	-12,01	6,62	0	-8,82	-37,04
1	4	-31,75	-18,45	-0,12	-3,70	23,76	-33,24	-19,10	0	0	0	-12,65	-8,39	-11,92	0	15,90	-27,34
1	5	53	-28,88	-4,51	9,77	-13,59	90,21	0	0	0	53	-9,60	5,30	0	-7,07	64,37	
2	3	62	11,51	-47,60	21,54	-21,13	97,68	0	0	10,92	0	51,08	9,60	-5,30	0	7,07	50,63
2	4	3,63	-0,25	-20,61	-2,11	35,28	-8,68	0,36	0	0	3,03	0,24	-0,58	-24,51	0	32,68	-3,96
3	5	187	28,88	4,51	-9,77	13,59	149,79	0	0	0	187	9,60	-5,30	0	7,07	175,63	
2	6	-188,12	-18,69	-20,73	-5,81	-100,96	-41,93	-18,74	0	0	-156,97	-12,41	-8,97	-36,43	0	-111,43	-31,29
4	6	-356,88	-38,68	-151,37	-22,87	-13,78	-130,18	-31,19	-240	-10,92	-3,03	-71,74	-21,03	-203,57	0	-48,57	-83,71

TABLE 3
PRODUCERS AND CONSUMERS CHARGES FOR THE GARVER'S TEST CASE

TRACING METHOD	USER	TRANSMISSION PRICING METHOD										POSTAGE STAMP
		MWM	UNUSED ABSOLUTE	UNUSED ZCF	UNUSED REVERSE	USED ABSOLUTE		USED ZCF		USED REVERSE		
						FINAL	INITIAL	FINAL	INITIAL	FINAL	INITIAL	
GGDF	G1 (€/MW)	58,73	129,80	42,45	-110,24	127,03	115,43	59,56	28,04	-7,90	-59,35	157,89
	G3 (€/MW)	84,12	129,77	110,16	124,02	117,87	106,28	77,05	45,53	36,23	-15,22	
	G6 (€/MW)	189,33	168,99	182,94	192,75	172,84	161,24	191,39	159,87	209,94	158,49	
	TOTAL (€)	120000	120000	120000	120000	120000	111185	120000	96042	120000	80899	
GLDF	L1 (€/MW)	432,40	486,17	540,35	625,64	492,00	489,65	499,45	438,25	506,90	386,85	368,42
	L2 (€/MW)	323,09	247,86	170,81	-58,74	234,10	231,75	214,69	153,49	195,28	75,23	
	L3 (€/MW)	396,32	358,26	362,35	79,04	384,18	381,83	394,05	332,86	403,93	283,88	
	L4 (€/MW)	256,70	361,66	348,24	1624,91	335,58	333,23	285,43	224,23	235,27	115,22	
	L5 (€/MW)	462,25	455,93	523,19	449,12	480,82	478,47	529,53	468,34	578,25	458,20	
TOTAL (€)	280000	280000	280000	280000	280000	278217	280000	233490	280000	188764	280000	
BIALEK UPSTREAM	G1 (€/MW)	14,07	45,11	45,11	45,11	75,36	23,91	75,36	23,91	75,36	23,91	157,89
	G3 (€/MW)	58,16	52,86	52,86	52,86	100,88	49,43	100,88	49,43	100,88	49,43	
	G6 (€/MW)	201,29	200,04	200,04	200,04	182,73	131,28	182,73	131,28	182,73	131,28	
	TOTAL (€)	120000	120000	120000	120000	120000	80899	120000	80899	120000	80899	
BIALEK DOWNSTREAM	L1 (€/MW)	373,73	705,23	705,23	705,23	485,58	365,54	485,58	365,54	485,58	365,54	368,42
	L2 (€/MW)	494,17	235,37	235,37	235,37	330,05	210,00	330,05	210,00	330,05	210,00	
	L3 (€/MW)	157,47	125,96	125,96	125,96	215,64	95,60	215,64	95,60	215,64	95,60	
	L4 (€/MW)	254,88	369,52	369,52	369,52	335,35	215,30	335,35	215,30	335,35	215,30	
	L5 (€/MW)	351,76	428,88	428,88	428,88	415,25	295,21	415,25	295,21	415,25	295,21	
TOTAL (€)	280000	280000	280000	280000	280000	188764	280000	188764	280000	188764	280000	
MINIMUM TRANSACTIONS	G1 (€/MW)	0	0	0	0	22,34	0	36,90	0	51,45	0	157,89
	G3 (€/MW)	62,57	81,10	82,71	120,15	94,92	72,57	101,48	64,59	108,05	56,60	
	G6 (€/MW)	201,24	195,63	195,14	183,81	189,40	167,05	186,07	149,18	182,75	131,30	
	TOTAL (€)	120000	120000	120000	120000	120000	103018	120000	91959	120000	80899	
	L1 (€/MW)	223,45	275,62	288,88	265,11	280,42	228,28	295,54	209,44	310,66	190,61	368,42
	L2 (€/MW)	446,54	327,37	279,73	-506,12	333,81	281,67	325,26	239,17	316,72	196,67	
	L3 (€/MW)	0	0	0	0	52,14	0	86,09	0	120,05	0	
	L4 (€/MW)	362,50	421,23	431,30	1706,24	405,49	353,35	381,10	295,00	356,71	236,66	
	L5 (€/MW)	403,97	466,61	503,11	446,92	460,37	408,23	474,48	388,39	488,59	368,54	
TOTAL (€)	280000	280000	280000	280000	280000	240376	280000	214570	280000	188764	280000	

It is obvious that each pricing scheme has its advantages and disadvantages. Therefore a sensitivity analysis that takes into account each network's special characteristics should be performed before deciding which scheme(s) suits better each case. The main conclusions deriving from the results are the following:

1. In the original MW-Mile, the transmission cost is fully recovered; however, the method can be unfair for the users that cause counter-flows, since these users are charged independently of the direction of the flows they cause.
2. The fairest methods are the zero counter flow methods since they provide a satisfactory income to the transmission owner, while giving incentive to the users that cause counter-flows.
3. Bialek's tracing method creates only positive contributions to the line flows, thus the same charges occur under all three MW-Mile approaches for counter-flows.
4. Both Bialek's and minimum power distance methods can produce zero charges for some users.
5. The Distribution Factors tracing method charges all users of the system, since all users utilize all transmission lines no matter how far they are located. However, it is very sensitive to system operating conditions and can produce relative different results for different operating points.
6. The reverse MW-Mile method can produce relatively large price spikes to the users (charges or credits), which cannot always be accepted by all the users.
7. When the used transmission capacity methods are used, a supplementary charge usually occurs; for Garver's test case this charge reaches 32.5% of the fixed transmission cost. An embedded method, such as postage stamp, can be used for the allocation of the aforementioned cost. This combination reduces the relative large differences between charges for users located in different areas of the network.
8. The unused methods produce charges that reflect lines' usage for the examined system operation point. Used methods show which users stretch the network to its limits the most. Those charges could also involve the reliability margin of the transmission lines' capacity.
9. A yearly simulation of the power system is needed in order to capture all possible effects users cause in the network.

TABLE 4
MINIMUM POWER DISTANCE TRANSACTIONS FOR THE
GARVER'S 6-BUS TEST SYSTEM

NO	TRANSACTIONS		PTRANS, (MW)
	FROM GEN	TO LOAD	
1	1	1	50
2	3	3	40
3	3	5	125
4	6	1	30
5	6	2	240
6	6	4	160
7	6	5	115

TABLE 5
MARGINAL REMUNERATION FOR EACH LOAD LEVEL FOR THE
IEEE 24-BUS RELIABILITY TEST SYSTEM

% PEAK LOAD (91-100)	DURATION (H)	MBR (€/H)	MBR (€)	MBR (%TC)
(81-90)	88	26155,95	2301,72	1,65
(71-80)	901	8113,61	7310,37	5,26
(61-70)	1463	8113,61	11870,22	8,53
(51-60)	2009	8629,99	17337,65	12,46
(41-50)	1864	6873,04	12811,35	9,21
(31-40)	2025	8447,52	17106,23	12,30
	386	4342,48	1676,20	1,20
SUM			70413,73	50,62

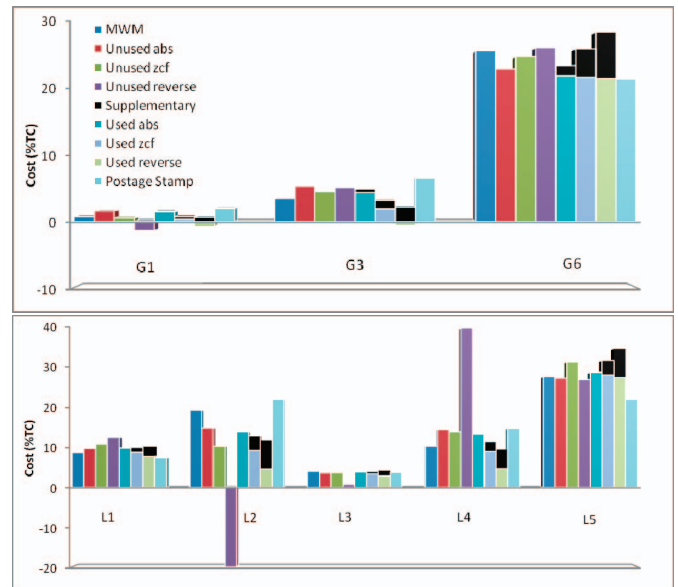


Fig. 1. Producers and consumers total charges using GGDFs and GLDFs on Garver's 6-bus test system. The charge per user is expressed as a percent of the total transmission cost (TC).

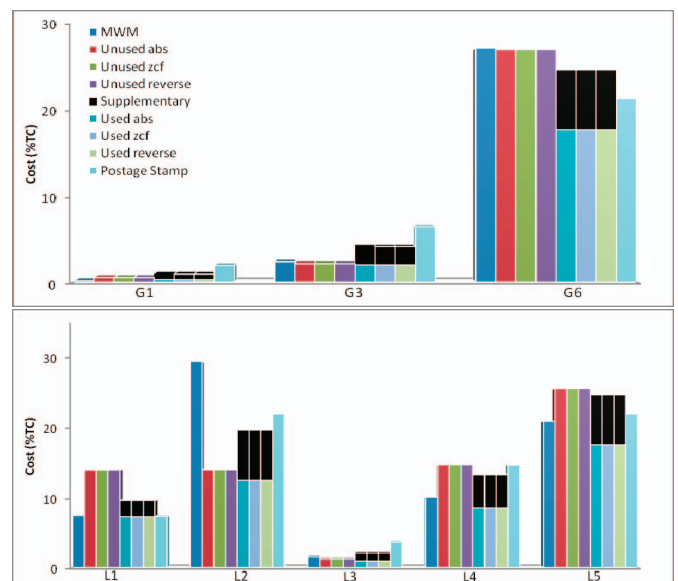


Fig. 2. Producers and consumers total charges using Bialek's upstream and downstream methods on Garver's 6-bus test system.

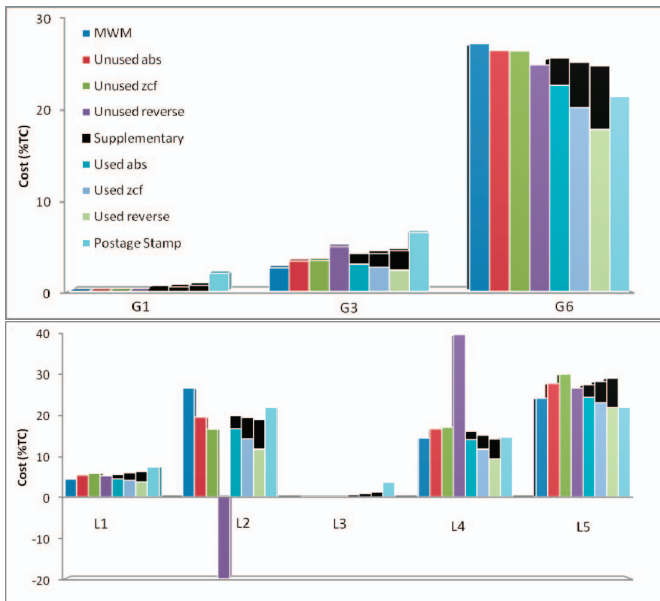


Fig. 3. Producers and consumers total charges using *minimum power distance transactions* on Garver's 6-bus test system.

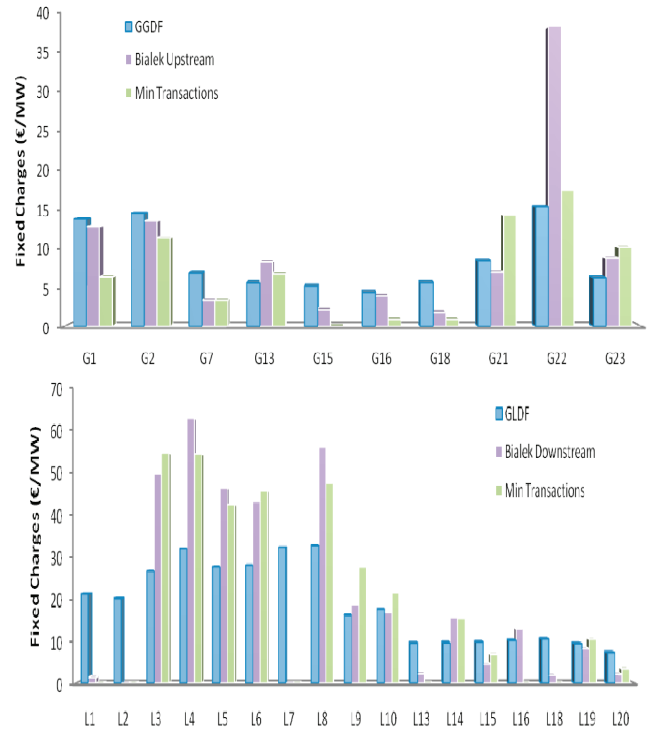


Fig. 5. Producers and consumers charges based on the *unused zero counter-flow MW-Mile method* on IEEE 24-bus reliability test system.

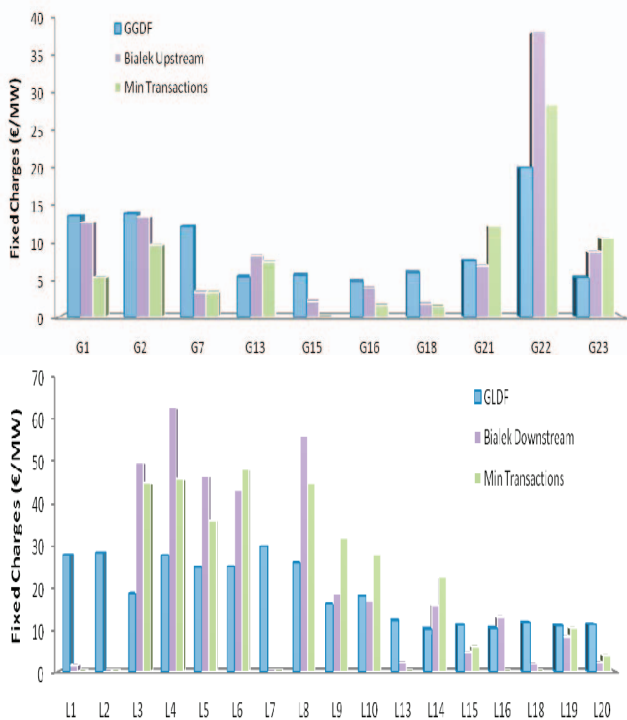


Fig. 4. Producers and consumers charges based on the *unused absolute MW-Mile method* on IEEE 24-bus reliability test system.

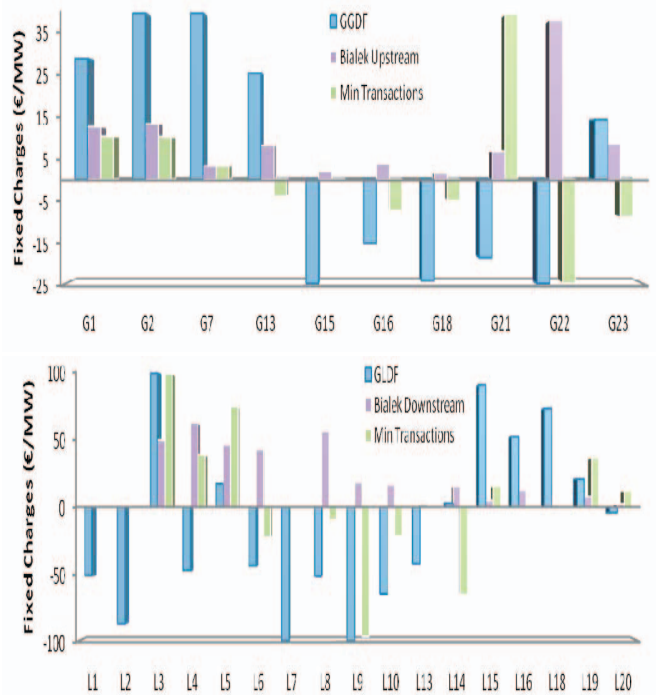


Fig. 6. Producers and consumers charges based on the *unused reverse MW-Mile method* on IEEE 24-bus reliability test system.

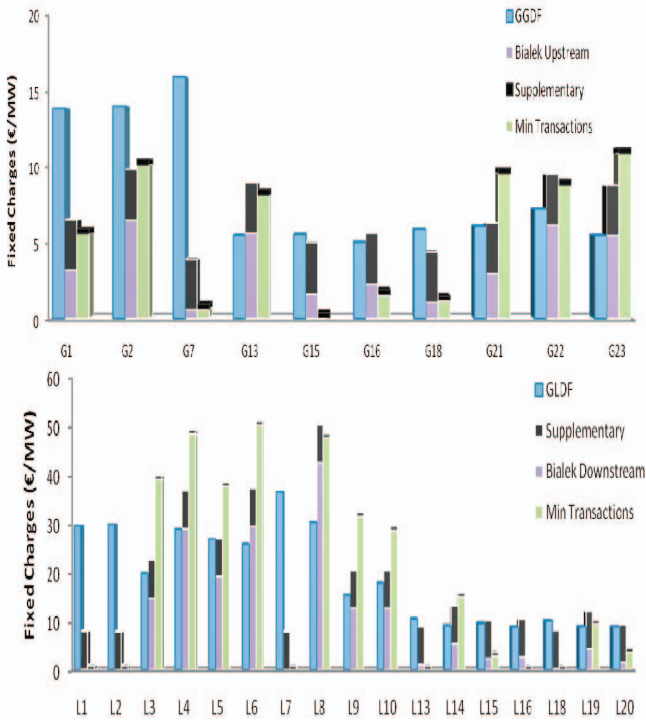


Fig. 7. Producers and consumers charges based on the *used absolute MW-Mile* method on IEEE 24-bus reliability test system.

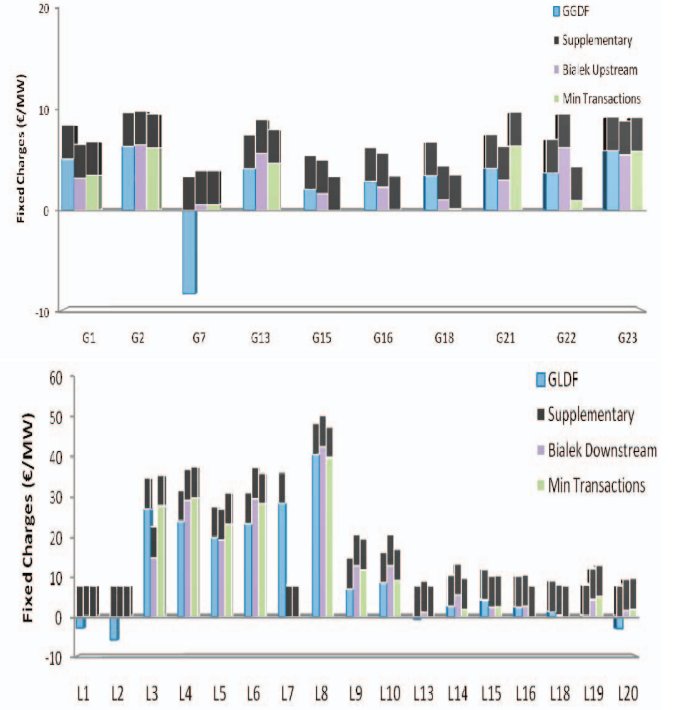


Fig. 9. Producers and consumers charges based on the *used reverse MW-Mile* method on IEEE 24-bus reliability test system.

IV. CONCLUSION

In this paper, eight transmission-pricing methodologies via three tracing methods have been evaluated. They are theoretically discussed and applied on Garver's 6-bus system and on IEEE 24-bus reliability test system in order to identify the advantages and drawbacks of each method. In case of Garver's 6-bus test system, a comparison between used and unused MW-mile methods is made for each tracing method where under used methods a supplementary charge was calculated in order to cover the transmission network owner's revenue. In case of the IEEE 24-bus reliability test system, the annual marginal network revenue was first calculated based on the annual load curve and the remaining network costs not covered were allocated between network users using embedded methods. A comparison between tracing methods for each pricing scheme is made. Different results were derived because each tracing method is based on different principle. Moreover, it is not always clear which pricing method suits better a transmission network; it depends mostly on the generation and load location as well as the network topology itself. However, these pricing methods are able to fulfill transmission pricing objectives: economic efficiency, non-discrimination, transparency and cost coverage and can be also applied to large power systems.

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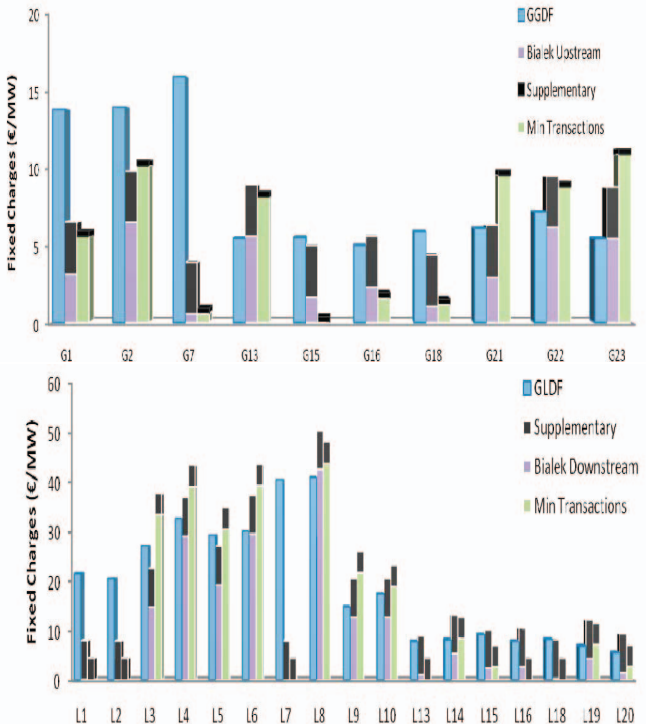


Fig. 8. Producers and consumers charges based on the *used zero counter-flow MW-Mile* method on IEEE 24-bus reliability test system.

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