A Modified Postage-stamp Coverage Method for Local Load Case of Transmission Service Charges

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Abstract - **The conventional postage-stamp coverage method assumes that the entire transmission system is used in wheeling, irrespective of the actual transmission facilities that carry the transaction. In order to achieve a fair transmission service charge methodology, modification need to be implemented on the conventional postage-stamp coverage method for a system that consists of local load case. The purpose of this modification is to trace the actual usage of an individual generator injecting power to the transmission line and charge the generator based on the actual amount of power usage in the transmission network. Two case studies based on an idealized 3-bus system and 10-machine IEEE 39-bus (New England) system are used to illustrate the proposed approach. The results show that with the proposed pricing approaches reflect a fair and equitable transmission pricing method as the generators are charged based on the actual usage in the transmission lines.**

Index Terms – Local load case, Postage-stamp coverage method and transmission pricing method.

I. INTRODUCTION

The electricity industry has been undergoing a major transition over the past two decades. Utility power generation, transmission, and distribution used to be considered a natural monopoly. As a state-regulated monopoly, each local utility company was vertically integrated, meaning that it was responsible for providing its customers with the full range of electric services including all aspects of generating, delivering, and metering electricity.

In a restructured environment, the transmission network is where generators compete to supply large users and distribution companies. Thus, transmission pricing should be a reasonable economic indicator used by the market to make decisions on resource allocation, system expansion, and reinforcement [1]. The competitive environment of electricity markets necessitates wide access to transmission and distribution networks that connect dispersed customers and suppliers. Moreover, as power flows influence transmission charges, transmission pricing may not only determine the right entry but also encourage efficiencies in power market [1]. A proper transmission pricing could meet revenue expectations, promote an efficient operation of electricity markets, encourage investment in optimal locations of generation and transmission lines, and adequately reimburse owners of transmission assets [1]. Most important, the pricing strategies should implement fairness and be practical.

Based on [2], the transmission pricing philosophies prevailing all over the world can be classified into three paradigms: embedded cost, incremental cost, and composite. Generally, the degree of liberalization in the power sector of that country will influence the choice of adopting particular types of pricing. However, the embedded cost methods are commonly used throughout the utility industry to allocate the cost of transmission services [1]. These methods have suggested to allocate such pricing since the application of marginal cost in pricing the transmission services has shown not effective mainly due to revenue reconciliation problems. In these methods, transmission system is assumed to be one integrated facility and all costs to meet transmission system revenue requirements are distributed across all customers. There are four different embedded costs of wheeling methods could be used namely, postage stamp method, contract path method, distance based MW-mile method and power flow based MW-mile method [3]. In order to achieve a fair transmission pricing strategies, a new method combining the principles of MW-mile and Postage-stamp coverage methods is introduced.

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II. TRANSMISSION PRICING METHOD

The transmission pricing methods can be distinguished into two parts [4]: (1) Locational charges: these charges differentiate the transmission use of system charges (TUoS) tariff according to the customers' location within the grid; and (2) Non-locational charges: these chargers (also referred to as postage stamp methods) uniformly charge all transmission customers, irrespective of their location within the grid, according to a measure of their usage of the transmission network; this is usually their system-peak-coincident demand (kW) or annual energy demand (kWh).

A. *MW-mile method*

The most common method for locational charges that have been implemented by the utilities is the MW-mile method. This method is first transmission pricing strategy proposed for the recovery of fixed transmission costs based on the actual use of transmission network [5]. The method calculates charges associated with each wheeling transaction based on the transmission capacity use as a function of the magnitude of transacted power, the path followed by transacted power, and the distance traveled by transacted power [6]. Equation (1) shows the cost allocation principle of the method.

$$R(u) = \sum_{all\ k} C_k \frac{f_k(u)}{\overline{f_k}} \tag{1}$$

where	$R(u)$	is the allocated cost to customer u,
	C_k	cost of circuit k
	$f_k(u)$	k-circuit flow caused by customer u
	$\overline{f_k}$	k-circuit capacity

Total cost = $\sum_{all\ k} C_k$

The MW-mile method is also used in identifying transmission paths for a power transaction. As such, this method requires active power flow calculations. The MW-mile method is the first transmission pricing strategy proposed for the recovery of fixed transmission costs based on the actual use of transmission network [6]. The method reasonably reflects the actual usage of transmission systems.

In MW-mile method, there are three different approaches on how the cost of each circuit is allocated to various users of the network that are [7]:

i) Absolute MW-Mile Method

Calculation is based on the magnitude of the MW-miles of network used and the directions of the power flow imposed on the circuit by user are ignored. Power flow imposed on the circuit i by the user k, f_k, and is treated based on the following condition:

$f_k(u) = |f_k(u)|$ for direct and reverse power flows (2)

ii) Reverse MW-Mile Method

The reverse MW-mile approach takes into account of the power flows that are in reverse direction and the charge for each line is based on the net flows. The reason is that the reverse power flows reduce the burden on the line. Power flow imposed on the circuit i by the user k, f_k, is treated based on the following condition:

$f_k(u)$ = +ve for direct power flows and –ve for reverse power flows (3)

iii) Dominant MW-Mile Method

The dominant MW-mile method can be considered as a hybrid of the absolute and reverse approaches. In this approach, network users are only charged on the basis of direct power flow imposed on each line. Reverse power flows are not counted so users responsible for the reverse power flows do not receive a credit like reverse MW-mile approach and do not pay any charge like the absolute MW-mile approach. In this method, power flow imposed on the circuit i by the user k, f_k, is treated based on the following condition,

$f_k(u) = |f_k(u)|$ for direct power flows, or (4)
0 for reverse power flows

However, the existing MW-mile methods have limitations which prevent the wider application of this technique in electricity market practices. The issue in this method concerns with the counterflow users. This issue is still being debated on what basis the credit or reward should be given to the transmission user who reduces the total net flow of the transmission system. However, many transmission utilities felt uncomfortable with the idea of providing a service and in addition paying the users for using it. The reason is clear because by giving the credit to the transmission users for their contribution in counter flow could cause difficulties to the transmission utilities to recover the revenue requirement. Hence, the MW-mile method (negative-flow sharing) was introduced in [3].

iv) MW-mile method (negative flow-sharing approach)

In [3], counterflow or negative flow is the flow component of a particular transaction that goes in the opposite direction of the net flow. In the original MW-mile formulation as well as some usage-based allocation pricing rules, the impact of each transaction on the flows is measured by the magnitude so that all transmission users irrespective of the flow directions are required to pay for the use of paths providing the service. However, in view of the contributions of counterflows in relieving the congested transmission lines, the proposals of giving a negative charge or credit to the users producing counterflows may not be easily accepted by the transmission service providers. In the proposed approach, the transmission owner and the users will share the benefits of the counterflow using the profit-sharing approach. The concept and formulation of the proposed approach in detail is explained in [3]. In this method, the negative value of $f_k(u)$ is shared between the transmission owner and users using profit sharing factor, r. This factor is determined according to the willingness of the transmission owner to share profit with the transmission users [6].

$$f_k(u) = +f_k(u) + \frac{1}{r}\,|-f_k(u)| \tag{5}$$

v) Monetary Flow Method

This method is an extension of the MW-mile method where it has some similar formulas and procedures as the MW-mile method. This method introduces a uniform measurement for transmission service usages by active and reactive powers [8]. These power flows are converted into monetary flows by using nodal prices. Because monetary flows are related to the nodal prices, the impacts of generators and loads on operation constraints and the interactive impacts between active and reactive powers can be considered [8].

However, in this paper only the active power is considered as it is more simple and easy to measure, fast and commonly used throughout the transmission utilities for determine the transmission service charges.

B. Postage-Stamp approach

For the non-locational charges, the Postage-stamp method has been used to cover the total transmission revenue. This method is traditionally used by electric utilities to allocate the fixed transmission cost among the users of firm transmission service. This method is an embedded cost method, which also known as the rolled-in embedded method. Postage-stamp method is based on the assumption that the entire transmission system is used, regardless of the actual facilities that carry the transmission service. The method allocates charges to a transmission user based on an average embedded cost and the magnitude of the user's transacted power [1]. The wheeling charge for this scheme can be written mathematically as

$$R_t = TC \times \frac{P_t}{P_{peak}} \tag{6}$$

Where R_t is wheeling charge for transaction t, TC the total transmission cost, P_t the power of transaction, P_{peak} the system peak load.

The postage stamp method is considered to send incorrect and unfair economic signals since it ignores the state of the actual system operation. The method is very simple as no distinction is made between transactions with regard to the power flow path, supply or delivery points, or the time when the transaction takes place [6].

i) Postage-Stamp coverage method

The postage-stamp coverage (or average) method is the methodology used to cover the total transmission system cost by sharing among the generators the costs associated with the unused capacity. The mathematical equation for the postage-stamp coverage method are:

for generator:

$$PS = \frac{\sum_{k=1}^{nlin} c_k - \sum_{i=1}^{n} R_i}{\sum_{i=1}^{n} P_{Gi}} \tag{7}$$

where C_k is the cost of circuit k, R_i the locational charges i, P_{Gi} the power served by generator i.

locational tariff for G_i

$$\pi_{Gi} = \frac{R_i}{P_{Gi}} \tag{8}$$

for load:

$$PS = \frac{\sum_{k=1}^{nlin} c_k - \sum_{i=1}^{n} R_i}{\sum_{i=1}^{n} P_{Li}} \tag{9}$$

where C_k is the cost of circuit k, R_i the locational charges i, P_{Li} the power served by load i.

locational tariff for L_i

$$\pi_{Li} = \frac{R_i}{P_{Li}} \tag{10}$$

III. TRACING-BASED POSTAGE-STAMP METHOD

The previously stated methods in Section II have been used by the power industry; they considered the real network conditions using power flow analysis, forecasted loads and the generation configuration. However, there is still room for improvement in order to achieve fairness and practicability such as the Postage-stamp coverage method. In this method, local load case is not considered. With the existence of local load at buses, the power served by generator or load to the transmission line system was reduced as some of the power will flow directly to the local load. Therefore, in this paper, the local load case is considered by modified the Postage-stamp coverage method and introduced the tracing-based Postage-stamp method.

The main purpose of this modification is to achieve the fair and equitable transmission pricing strategies where only the actual usage of an individual generator injected into the transmission line will be charged. This method can be implemented to both network systems either with or without local load case in order to determine a fair and equitable transmission charges for market users.

For generator, we determine the power injected from G_i to the transmission line which are connected directly to the bus i where the G_i is located. Power from generator at bus i, G_i, injected to transmission line system:

$$P_{GiT} = P_{ix} + P_{iy} + \ldots + P_{in} \tag{11}$$

where P_{ix}, P_{iy} and P_{in} is the power flow in the transmission line which connected directly with the bus i where generator, G_i is located.

$$\text{Remaining of } G_i\ (RG_i) = P_{Gi} - P_{GiT} \tag{12}$$

$$G_i \text{ contribute to } L_i = RG_i \tag{13}$$

where P_{Gi} is the power generation and L_i the load at bus i. Hence, the actual usage of G_i in the transmission line system is P_{GiT}.

For load, the steps are similar with the generator in order to trace the power usage in transmission line system. L_i used the transmission line system:

$$P_{LiT} = P_{ix} + P_{iy} + \ldots + P_{in} \tag{14}$$

where P_{ix}, P_{iy} and P_{in} is the power flow in the transmission line which connected directly with the bus i where load, L_i is located.

$$\text{Remaining of } L_i\ (RL_i) = P_{Li} - P_{LiT} \tag{15}$$

$$L_i \text{ received power from } G_i = RL_i \tag{16}$$

Therefore, the actual usage of L_i in the transmission line system is P_{LiT}.

The development of new technique for transmission pricing method is to charge the market participants based on the actual usage in the transmission line system. The actual power usage in the line system from (11) and (16) will be used in postage-stamp coverage method to achieve a fair and equitable transmission service charge methodology.

Tracing-based postage-stamp method (for generator):

$$PS = \frac{\sum_{k=1}^{nlin} c_k - \sum_{i=1}^{n} R_i}{\sum_{i=1}^{n} P_{GiT}} \tag{17}$$

modified locational tariff for G_i

$$\pi_{Gi} = \frac{R_i}{P_{GiT}} \tag{18}$$

Tracing-based postage-stamp method (for load):

$$PS = \frac{\sum_{k=1}^{nlin} c_k - \sum_{i=1}^{n} R_i}{\sum_{i=1}^{n} P_{LiT}} \tag{19}$$

modified locational tariff for L_i:

$$\pi_{Li} = \frac{R_i}{P_{LiT}} \tag{20}$$

Through equations (11) – (20) the modification made on the conventional Postage-stamp coverage method where the local load case is considered. The new method which called the tracing-based Postage-stamp method was introduced in order to achieve fair and equitable transmission pricing strategies where considering the actual usage of individual users to the transmission line systems. In addition, it also covers the total transmission system cost by sharing among the users the costs associated with the unused capacity.

IV. CASE STUDIES

The modification approach has been tested on 3-bus system and 10-machine IEEE 39-bus (New England) system by using Matlab simulation programs. These case studies are based on DC power flow and losses are neglected. The wheeling transaction is assumed to involve only real power and the contributions of reactive power flows are also neglected. For simplicity, the percentages of charging between the users are divided equally which is 50% to the loads and 50% to the generators. In practice, the cost would be shared between the generator and the consumer in certain ratio, which would be determined by the regulatory authority [2].

A. *Case 1: 3-bus system*

A simple 3-bus system illustrated in Fig. 1 is used to provide an understanding on the basic concept of proposed approach. The value of the impedances at line 1-2 is 0.02 p.u. and 0.01 p.u. for line 1-3 and 2-3. The total transmission revenue is $2,203,902.

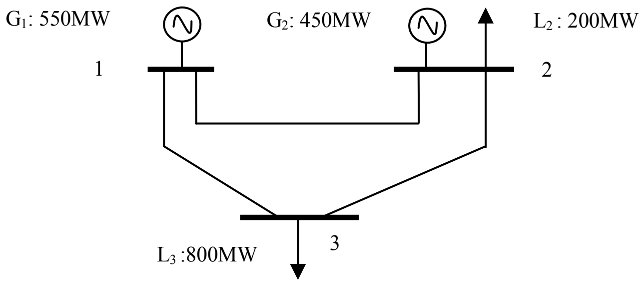

Figure 1. An idealized lossless 3-bus system

Table I-IV illustrate the data obtained from a 3-bus system that are used in calculating the transmission service charge for the individual users. Each generating plant allocates its share with the Generalized Generation Distribution Factors *(GGDFs)* method while each customer's share is determined with the Generalized Load Distribution Factors *(GLDFs)* method [9].

TABLE I. DATA OF GENERATOR 1 FOR 3-BUS SYSTEM

Line	Cost, k$	Capacity, MW	Total Power Flow, MW	Generator 1
1-2	560.155	800	75	165
1-3	754.385	800	475	385
2-3	889.362	800	325	55

TABLE II. DATA OF GENERATOR 2 FOR 3-BUS SYSTEM

Line	Cost, k$	Capacity, MW	Total Power Flow, MW	Generator 2
1-2	560.155	800	75	-90
1-3	754.385	800	475	90
2-3	889.362	800	325	270

TABLE III. DATA OF LOAD 2 FOR 3-BUS SYSTEM

Line	Cost, k$	Capacity, MW	Total Power Flow, MW	Load 2
1-2	560.155	800	75	55
1-3	754.385	800	475	55
2-3	889.362	800	325	-55

TABLE IV. DATA OF LOAD 3 FOR 3-BUS SYSTEM

Line	Cost, k$	Capacity, MW	Total Power Flow, MW	Load 3
1-2	560.155	800	75	20
1-3	754.385	800	475	420
2-3	889.362	800	325	380

As can be seen in Fig. 1, there is a local load at bus 2. Therefore, an analysis should be done by using the equation from (11) to (16) in order to trace the actual usage of generator G_2 and load L_2 in the transmission lines system.

Analysis for local load case at bus 2:

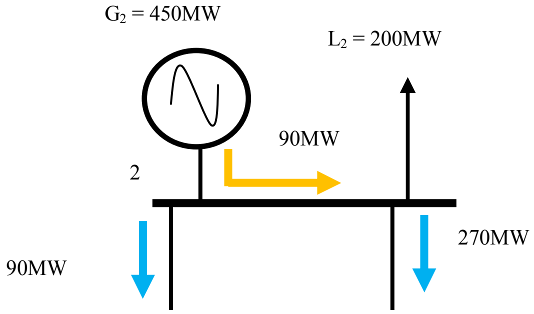

Figure 2. Local load case at bus 2: Analysis for G_2

Generator at bus 2, G_2

G_2 injected power to transmission line system, P_{G2T}:
$P_{G2T} = P_{21} + P_{23} = 90 + 270 = 360MW$

$RG_2 = P_{G2} - P_{G2T} = 450 - 360 = 90MW$

$G_2 contribution\ to\ L_2 = 90MW$

As can be seen, instead of 450MW, G_2 only uses 360MW in the transmission line system.

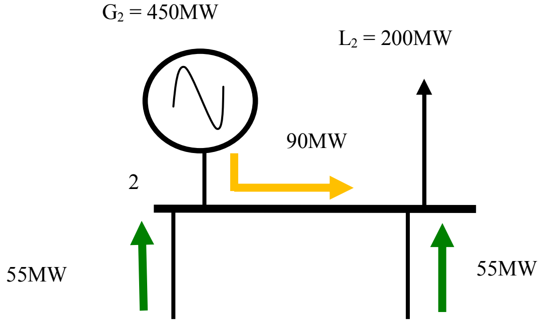

Figure 3. Local load case at bus 2: Analysis for L_2

<u>Load at bus 2, L_2</u>

L_2 used the transmission line system, P_{L2T}:

$$P_{L2T} = P_{12} + P_{32} = 55 + 55 = 110MW$$

$$RG_2 = P_{G2} - P_{G2T} = 450 - 360 = 90MW$$

$$L_2 \; receives \; power \; from \; G_2 = 90MW$$

Similar to generator case, instead of using 200MW, L_2 actually uses 110MW in the transmission network system.

According to the proposed approach, the negative flow MW-mile impacts of each line should be shared between the transmission owner, generators and loads. Therefore, the profit sharing factor, r will be 3. The effectiveness of this proposed method by applying the tracing-based Postage-stamp method can be seen by comparing it with the existing method (before modification on local load case) which illustrated in Table V and VI.

TABLE V. TRANSMISSION CHARGES FOR MARKET USERS BY USING THE EXISTING METHOD

User	Generation/Load (MW)	MW-mile (negative-flow sharing) + Postage-stamp coverage method ($)
G_1	550	638,487.23
G_2	450	474,174.50
L_2	200	190,080.35
L_3	800	901,159.92

TABLE VI. TRANSMISSION CHARGES FOR MARKET USERS BY USING THE PROPOSED METHOD

User	Power usage in the network (MW)	MW-mile (negative-flow sharing) + Tracing-based Postage-stamp method ($)
G_1	550	674,161.23
G_2	**360**	438,500.50
L_2	**110**	138,190.90
L_3	800	953,049.37

As shown in Fig. 4, the transmission charge for G2 and L2 are decreased about 8.14% and 37.5%, respectively. In contrast, for G1 and L3, the transmission charges increased because they fully utilized the lines. In conclusion, by using the proposed method, it reflects a fair and equitable charging method as the charge is based on the actual usage in the transmission lines system.

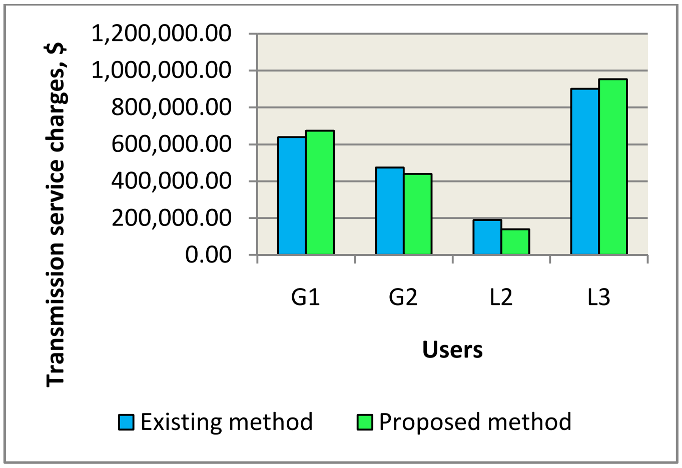

Figure 4. Transmission service charges based on existing and proposed methods

B. *Case II: 10-machine IEEE 39-bus (New-England) system system*

Fig. 5 shows the IEEE 39-bus (New England) system with local load at bus 31 and 39. The transmission revenue is $ 12,224,200.00.

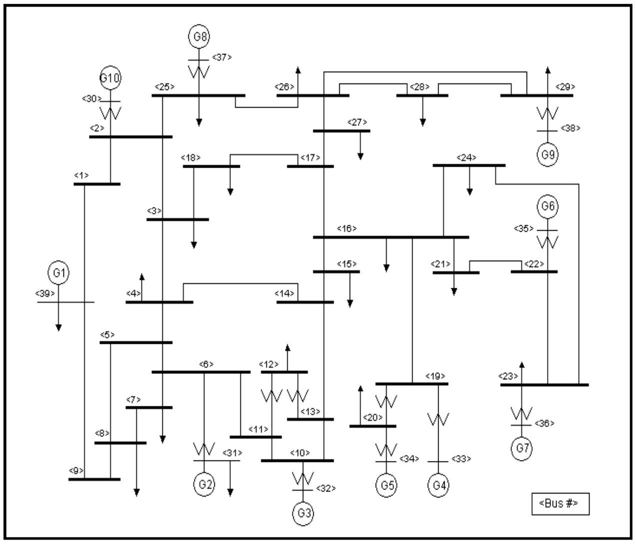

Figure 5. 10 machine IEEE 39-bus (New England) System

TABLE VII. GENERATORS USAGE OF TRANSMISSION LINES SYSTEM

Users	Generation (MW)	Actual Power Usage (MW)	Remaining of G_i (MW)
G30	250	250	0
G31	**1000**	**919.62**	**80.38**
G32	650	650	0
G33	632	632	0
G34	508	508	0
G35	650	650	0
G36	560	560	0
G37	540	540	0
G38	830	830	0
G39	**1000**	**833.23**	**166.77**

TABLE VIII. LOADS USAGE OF TRANSMISSION LINES SYSTEM

Users	Load (MW)	Actual Power Usage (MW)	Remaining of L_i (MW)
L3	322	322	0
L4	500	500	0
L7	233.8	233.8	0
L8	522	522	0
L12	7.5	7.5	0
L15	320	320	0
L16	329	329	0
L18	158	158	0
L20	628	628	0
L21	274	274	0
L23	247.5	247.5	0
L24	308.6	308.6	0
L25	224	224	0
L26	139	139	0
L27	281	281	0
L28	206	206	0
L29	283.5	283.5	0
L31	**532.1**	**451.72**	**80.38**
L39	**1104**	**937.23**	**166.77**

Tables VII and VIII show the generation / load and the actual power usage of each generator and load to the line flow. It can be seen that generators G30, G32, G33, G34, G35, G36, G37, and G38 have fully utilized the transmission lines to deliver their available power to the load. The same case happens to load L3, L4, L7, L8, L12, L15, L16, L18, L20, L21, L23, L24, L25, L26, L27, L28, and L29. On the other hand, G31, G39, L31 and L39 have slightly difference from the generation and load due to the local load case at bus 31 and 39.

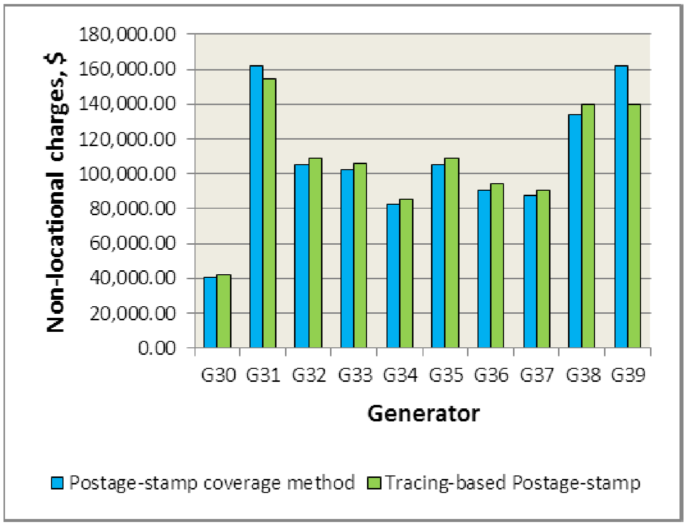

Figure 6. Non-locational transmission service charges based on existing and proposed Postage-stamp method for generator

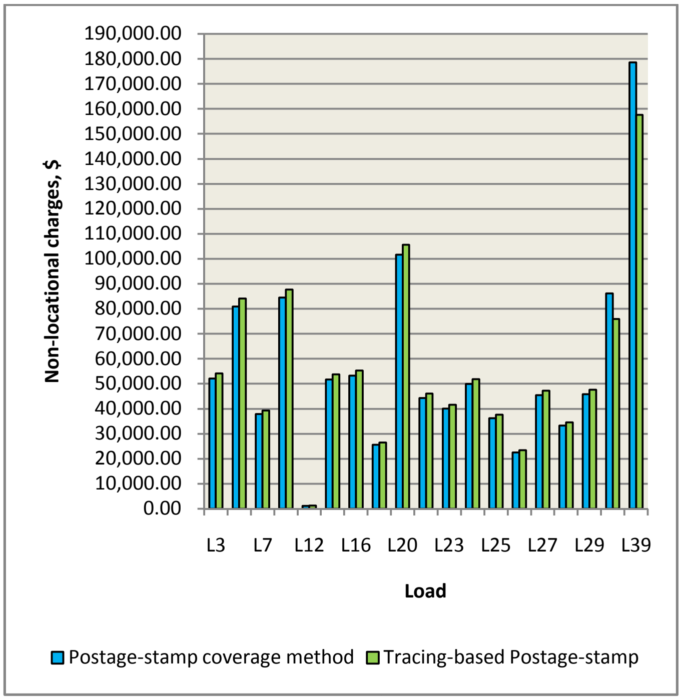

Figure 7. Non-locational transmission service charges based on existing and proposed Postage-stamp method for load

Figures 6 and 7 show the non-locational transmission charges for the transmission users calculated based on traditional and proposed postage stamp methods. It can be clearly seen that the generators and loads with the existence of local load pay less charges compared to those market user without local load. With the proposed method, the charges for G31, G39, L31 and L39 are reduced by 0.91%, 3.57%, 1.94% and 1.87% and on the other hand it increases the charges for other users by 0.56% to 0.86%.

TABLE IX. TRANSMISSION SERVICE CHARGES USING COMBINED MW-MILE (NEGATIVE FLOW-SHARING) WITH EXISTING AND PROPOSED POSTAGE-STAMP METHOD

Users	Transmission service charges ($)	
	Existing method	Proposed method
G30	186,957.73	188,526.75
G31	**792,035.82**	**784,799.16**
G32	638,613.74	642,693.20
G33	620,828.04	624,794.53
G34	516,447.04	519,635.30
G35	774,756.76	778,836.22
G36	648,951.76	652,466.38
G37	462,322.91	465,712.00
G38	880,008.92	885,218.08
G39	**609,601.36**	**587,841.59**
L3	278,651.31	280,672.21
L4	474,269.25	477,407.30
L7	254,577.54	256,044.89
L8	588,211.46	591,487.58
L12	7,199.91	7,246.98
L15	263,926.99	265,935.34
L16	239,584.47	241,649.31
L18	134,150.63	135,142.26
L20	561,747.60	565,688.99
L21	212,180.20	213,899.85
L23	208,602.04	210,155.37
L24	234,726.13	236,662.93
L25	178,492.61	179,898.45
L26	116,156.69	117,029.07
L27	247,059.49	248,823.07
L28	190,795.23	192,088.11
L29	248,624.96	250,404.24
L31	**523,902.07**	**513,728.82**
L39	**1,130,817.36**	**1,109,712.01**
Total	12,224,200	12,224,200

Table IX shows the transmission service payment for generators and loads based on postage-stamp method incorporated with the MW-mile method. Again, it can be observed that the proposed method provides opportunity to G31, G39, L31 and L39 to pay less charge due to the existence of the local load.

V. CONCLUSION

In conclusion, it is very important to design and develop an appropriate methodology that could allocate the transmission services based on the actual usage. The main goal of this paper is to develop a fair and equitable transmission pricing methodology for restructured market. The *GGDFs* and *GLDFs* are used to identify the net power flow and trace the contribution of each market user to the transmission lines system. The proposed pricing method, which includes the MW-mile (negative-flow sharing) and tracing-based Postage-stamp can be implemented in any situation of network system either with or without local load case. This method successfully provides a fair and equitable transmission service charges as the market participants are charged based on their actual usage of the transmission lines system.

ACKNOWLEDGEMENT

Mrs. N. H. M. Radzi wishes to acknowledge the University Tun Hussein Onn Malaysia for their financial support. This work is supported in part by a Hong Kong Polytechnic University grant (G-U791) - Electricity Market Risk Management and Planning.

REFERENCES

[1] M. Shahidehpour, H. Yamin, and Z. Li, *Market Operations in Electric Power Systems*. New York: United States of America: The Institute of Electrical and Electronics Engineers, Inc., 2002.

[2] A. R. Abhyankar, S. A. Soman, and S. A. Khaparde, "Optimization approach to real power tracing: an application to transmission fixed cost allocation," *IEEE Transactions on Power Systems,* vol. 21, no. 3, pp. 1350-1361, 2006.

[3] K. L. Lo, M. Y. Hassan, and S. abd Jovanovic, "Assessment of MW-mile method for pricing transmission services: a negative flow-sharing approach," *IET Proceedings -Generation, Transmission & Distribution,* vol. 1, no. 6, pp. 904-911, 2007.

[4] A. Bakirtzis, P. Biskas, A. Maissis, A. Coronides, J. Kabouris, and M. Efstathiou, "Comparison of two methods for long-run marginal cost-based transmission use-of-system pricing," *IEE Proceedings-Generation, Transmission and Distribution,* vol. 148, no. 5, pp. 477-481, 2001.

[5] M.Z. Meah, A. Mohamed, and S. Serwan, "Comparative analysis of using MW-Mile methods in transmission cost allocation for the Malaysia power system," in *Power Engineering Conference,* Bangi, Malaysia, 2003, pp. 379-382.

[6] M. Y. Hassan, M. S. Majid, F. Hussin, H. A. Rahman, and K. L. Lo, "Certain Considerations In Pricing Unbundled Transmission Services," in *IEEE International Power and Energy Conference, 2006*, pp. 272-275.

[7] J. Bialek, "Topological generation and load distribution factors for supplement charge allocation in transmission open access," *IEEE Transactions on Power Systems,* vol. 12, no. 3, pp. 1185-1193, 1997.

[8] G. Duan, Z. Y. Dong, W. Bai, and X. F. Wang, "Power flow based monetary flow method for electricity transmission and wheeling price," *Electric Power Systems Research,* vol. 74, no. 2, pp. 293-305, 2005.

[9] A. Galetovic and C. M. Montecinos, "The new Chilean transmission charge scheme as compared with current allocation methods," *IEEE Transactions on Power Systems,* vol. 21, no. 1, pp. 99-107, 2006.