Various Analytical Methods on Transmission Price Allocation in a Restructured Environment of Power Systems

M.Divya, V.Sumadeepthi

Department of EEE, Malla Reddy Engineering College (Autonomous), Hyderabad, India

Abstract—*In this competitive electricity markets the fixed costs of the transmission line should be allocated fairly because of reasonable pricing of the transmission line method could lead the existing transmission facilities and guiding future expansion and planning of the transmission line network. This paper presents various analytical methods on transmission price allocation. This paper is a literature review conducted from several papers including the different cost allocation methods evaluation of real and reactive power flows and characteristics of every method is analyzed.*

Keywords— cost allocation, pricing, electric market, planning.

I. INTRODUCTION

Transmission pricing and loss allocation are highly debated issues after the deregulation of power industry [1]. In the post deregulated, the transmission provision gets a good deal of importance. As per the planning policies developed in most of the countries, more emphasis was given on adding more generation to the system rather than improving and strengthening the transmission network [2]. But after reorganization of the power industry, after the issue of open access has compelled policy makers to re-think their approach towards transmission planning [2]. Open access demands sound transmission corridor availability for a transaction to become viable the transmission deregulation system is operated and owned by a separate company that is popularly known as *Transco*. For well-known reasons, the transmission activity remains a monopoly rather than being a competitive activity [2]. And since open access demands a not effecting in discrimination access to the transmission system by any qualified entity in the business, this monopoly entity has to be regulated by a higher governmental agency [2]. In many countries, the *Transco* are the dis-aggregated part of the then original vertically integrated utility that existed in the region, prior to deregulation [2].

However, success or failure of a market depends on market rules designing. Transmission pricing rules form one of the important parts of the market rules [1]. Successful competition at the generation level calls for a successful, fair and non-discriminatory open access for the transacting entities in the market. Evaluation of transmission services plays an important role to determine whether contribute transmission open access and allied services is economically favorable to both the wheeling usage and customers of transaction [1]. Few years back, electricity transmission pricing was more of an academic interest, rather than practical use [11]. This is because generation, transmission and distribution were vertically desegregated. The vertically integrated usages used to sell their power inside their region. Hence, the need for having a formal mechanism for pricing of transmission did not exist [11]. The costs incurred by the vertically integrated utilities were recovered by embedding them in the electricity price billed to the consumers. However, in recent times, as a primary step towards reforms, generation and transmission businesses have been separated from each other in many countries transmission costs are used to charge the transaction of power flow [11]. Engineering analysis determining the feasibility of supply and the cost of transmission services providing is only one of the many considerations in the overall process of pricing transmission services Apart from cost recovery, can the pricing provide any other information? Based on this, some principles of transmission pricing have been developed, which are discussed next [2].

II. PRINCIPLES OF TRANSMISSION PRICING

To control the power system network under the rules of transmission open access, a trade-off has to be solved: Economic marketing of energy has to be given importance while at the same time [4]. The transmission pricing scheme should do much more than that. In line with the above, following principles should be followed while designing the transmission pricing schemes:

1. The transmission prices should be devised so as to promote the efficiency gradually operates on bulk amount of power market [1].

2. The transmission prices should have advantages for generation and demand investments [1].
3. The transmission evaluation should recover the pricing of existing transmission assets [1].
4. The mechanism should be politically performable [1].

Out of these, the first three objectives are concerned with derivation of appropriate economic signals to either utility or the consumer [11]. Whether generator pays the wheeling charge or the consumer pays for it, or both pay a part of it in some proportion, etc. It is expected that while designing a transmission pricing mechanism, following cost components for providing transmission service should be taken into account:

1. Operating Cost: This includes the cost due to system voltage maintenance, rescheduling the generators, limits of line flow and support of reactive power [2].
2. Opportunity Cost: It is the transmission company cost (Transco) has to forgo due to operating constraints that are caused by the transmission transaction [2].
3. Reinforcement Cost: It is cost charged only on the firm transaction and capital cost of new facilities includes and required to meet transaction [2].
4. Existing System Cost: The investment pricing of occurring transmission facilities used by the transmission transaction [2].

III. CLASSIFICATION OF TRANSMISSION PRICING METHODS

1. Postage Stamp Method (transaction / non-transaction)
2. Contract Path Method (transaction based)
3. MW-Mile Method (transaction based)
4. MVA- Mile Method
5. Unused transmission capacity Method
6. Counter flow Method
7. Distribution factor Method
8. AC power flow Method
9. Tracing based power flow on proportionate sharing principle (non-transaction)

There are some methods that allocate costs to individual bilateral transactions. These methods are known as transaction based methods [1]. On the other hand the rest of the methods allocate the total costs to all the participants of the pool [1]. These methods are called as non-transaction based methods. All these methods will be explained one by one with an illustrative example in the following sub-sections [1].

1. Postage Stamp rate Method.

Postage stamp techniques are the simple and easy to implement technique of transmission price evaluation [1]. A postage stamp rate is a fixed charge method on where power transmitted in particular zone [2]. This method not depends on the transmission distance, length of the line, delivery points and sources. This method assign the charges based on the magnitude of the power transacted and average cost [1].

Advantages of Postage Stamp Rate Method are as follows:

- The method is easy to implement.
- Being very simple and straightforward, it is easy to get political backing for it to be implemented.

Disadvantage of the Postage Stamp Method can be quoted as follows:

- Pancaking: In case a transaction takes place such that the power is transmitted through multiple intermittent utilities or zones, pancaking of access charges takes place.

2. Contract Path Pricing Method.

This method is used for utilities of electric power to assign the charges on the transmission line [1]. In this method power flow calculations are not required. Transmission service can flow along the parallel paths, one is specified and another one is artificial throughout the transmission line [1]. After identifying the contract paths, then charges may assign using a postage stamp rate. The Recovery of costs could be limited to artificial contract paths. This method ignores the facility if power flow not along the identified path [1].

3. MW – Mile Pricing Method.

This method includes the charges of length, power flow in the line. And calculates the how much transacted power travelled in distance [1]. It's also determines the paths of the transmission line power transaction. This method the dc power flow studies are required to calculations [6].

MW – Mile method introduced the first method of pricing for fixed cost of transmission based on the utilization of the power flow in that transmission [4].

$$TC_t = TC \times \frac{\sum_{k\in K} C_k L_k MW_{t,k}}{\sum_{t\in T}\sum_{k\in K} C_k L_k MW_{t,k}} \qquad eq(1)$$

Where

TC_t = Cost assigned to transaction t
TC = Cost of total lines in $
L_k = line length in K miles
C_k = Price per MW per length of line in units k
$MW_{t,k}$ = flow on line k caused by transaction t
T = no. of transactions
K = no. of transmission lines

The magnitude of every line multiplies with the length of the line and price per MW per length in unit of network of the transmission line [1]. The main characteristic of MW-Mile methodology is that we need to find out usage of each transaction on every individual branch [1]. Based on this, there are various versions of MW-Mile approach.

4. Unused Transmission Capacity Pricing Method.

The dissimilar between the facility capacity of the line and actual power flow on that facility is called as the unused transmission line [1]. The transmission uses are has to pay the charges for both usage of actual capacity and capacity of unused transmission also [1].

$$TC_t = \sum_{k \in K} C_k \frac{|F_{t,k}|}{\sum_{t \in T} |F_{t,k}|} \qquad eq(2)$$

Where,

TC = Allocation of cost to transaction t

C_k = embedded facility cost k

$|F_{t,k}|$ = power flow facility k caused by transaction t

T = no. of transactions

K = no. of transmission facilities

This method is suggested that the uses of the transmission system will be charged depends on the usage of the percentage capacity of facility and not depends on the power flows [6].

5. MVA – Mile Pricing Method

This method is the expanded category of the MW-Mile pricing method. In Actual the assigning charge is depends on the utilization of the real power only [1]. But here proposed to include the real and reactive power flow in the method. In this line MVA loading is assigning of reactive power support from generators and facility of the transmission [4]. This method is used to proceed the measuring of the resources of the network of the transmission. Other methods also suggested decomposing the real and reactive power flow network by the every individual transaction [1].

6. Counter Flow pricing Method

In this method the transmission uses should be priced (or) credited depends on the Power flows of the line is in the clock wise flow or counter clock wise – flows with regards to the net power flow directions [1].

In this method proposes that if a specific transaction of power flows is in the opposite direction of the actual flow, then transaction will be credited [2]. Because of this happens then the transaction should pay the negative charge [1].

So this method proposed to those where usage of transmission with the direction of actual power flow will be charged on the proportion to their beneficial to the actual flow of power [6]. The difficulty of the method is hard to pay the service of transmission line to uses with counter – flows [4].

7. Distribution Factors pricing Method

These facilitated based on the linear load flows. This method is used to find out the signification and effect of the load and generation on the power flow transmission [1]. These factors are used to determine the usage and evaluation network of the transmission system. By using these factors, allocation of the charges on the transmission line usage related to net power injections [2].

a. Generation Shift Distribution Factors pricing (GSDF or A Factor)

These factors used to determine the line flow charges due to the charge in generation and also determine the maximum power flow by the generators and loads injections [1].

$$\Delta F_{l-k} = A_{l-k,i} \Delta G_i \qquad eq(3) \qquad \Delta G_r = -\Delta G_i \qquad eq(4)$$

Where

$\Delta F_{l\text{-}k}$ = change in active power flow and buses l and k

$A_{l\text{-}k,i}$= A factor (GSDF) of a line buses l and k corresponding to change in generator at bus i.

ΔG_i = change in generation source at bus i, with the reference bus excluded

ΔG_r = change in generation with reference bus (generator) r

b. Generalized Generation Distribution Factors pricing.

This method we can find out the effect of generation on active power flows. This method used for only active power flows [1].

$$F_{l-k} = \sum_{i=1}^{N} D_{l-k,i} G_i \qquad eq(5)$$

$$D_{l-k,j} = D_{l-k,r} + A_{l-k,j} \qquad eq(6)$$

$$D_{l-k,r} = \left[F^0_{l-k} - \left[\sum_{\substack{i=1 \\ i \neq r}}^{N} A_{l-k,i}\, G_i \right] \right] / \sum_{i=1}^{N} G_i \qquad eq(7)$$

And

$F_{l\text{-}k}$ = total amount of active power flow between buses l and k

$F^0_{l\text{-}k}$ = power flow of line between buses l and k from previous iteration

$D_{l\text{-}k,I}$= D factor of a line flow between buses l and k

$D_{l\text{-}k,r}$ = GGDF of a line flow between buses l and k because of the generation at reference bus r

G = overall generation at bus i

This method is used to measure the facilities of transmission network. And depends on the system conditions and line parameters [1].

c. Generalized Load Distribution Factors.

In this method we can determine the how much load on the system and how much line flows on that load facility. GLDF also allocate the cost of the transmission network by including the distribution company services [1].

$$F_{l-k} = \sum_{j=1}^{N} C_{l-k,j} L_j \qquad eq(8)$$

Where

$$C_{l-k,j} = C_{l-k,r} - A_{l-k,j}$$

$$C_{l-k,r} = \left\{F^0_{l-k} + \sum_{\substack{j=1\\ j\neq r}}^{N} A_{i-k,j} L_j\right\} / \sum_{j=1}^{N} L_j \quad eq(9)$$

And

F_{l-k} = total flow of active power between buses l and k

F^0_{l-k} = On a line poer flow between buses l and k from the previous iterations

$C_{l-k,j}$ = C factor (GLDF) of a line flow between buses l and k

$C_{l-k,r}$ = GLDF for a line flow between buses l and k causes to the load at reference bus r

L_i = overall demand at bus j

GLDF depends on the system conditions, line parameters and independent of the reference bus location [4].

8. AC Power Flow pricing Methods.

By utilizes if optimal power flow studies we can determine the full AC power flow solutions [1]. This method is depends on the power flow transaction of the network. For every individual transaction consider the real power and reactive power flow utilization of the transmission network [2]. By the net power flow imbalances are overcome by the adding the generators to the system [1].

9. Tracing pricing Methods.

In this methods determine the giving the offers to usage of transmission network to transmission users [1].

a. Bialek's Tracing Method.

In this we can determine the model inflows and out flows of the network. And to estimate the individual generator and load of the system [1]. This method used for both AC and DC. And used to determine the contribution of Real power and Reactive power flows [4].

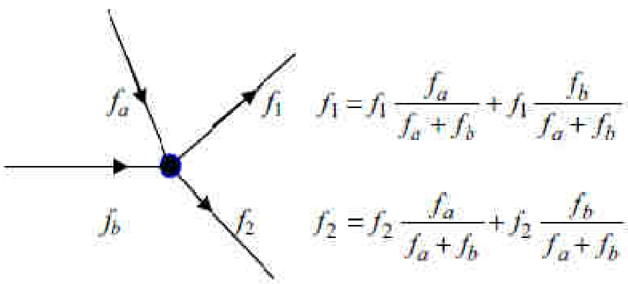

Fig.1: Power tracing in a network

f_a, f_b are inflows and f_1, f_2 are outflows.

The figure shows few lives connected to the node. In this we can determine the f1 and f2.Determine the how much amount of the power f1 comes from fa and fb. By looking algorithm [2].

$$P^g_{ij} = \frac{P^g_{ij}}{P^g_i} \sum_{k=1}^{n} [A_u^{-1}{}_{ik}]\, P_{Gk} = \sum_{k=1}^{n} D^g_{ij,k} P_{Gk};\, j = \alpha^d_i \quad eq(10)$$

Where

$$P^g_{ij} = \sum_{j\in\alpha^u_i} \left|P^g_{ij}\right| + P_{Gi}\,; \qquad i = 1,2, \dots, n$$

$$[A_u]_{ij} = \begin{Bmatrix} 1 & i = j \\ \frac{|P_{ij}|}{P_j} & j = \alpha^u_i \\ 0 & \text{othewise} \end{Bmatrix}$$

And

P_{gij} = unknown gross line power flow in i-j

P_{gi} = unknown gross nodal power flow through node i

A_u = distribution matrix of upstream

P_{Gk} = generation at node of k

$\propto_{di}$ = no. of nodes supplied from node i by directly

$\propto_{ui}$ = no. of buses supplying bus i directly

$D_{gij,k}$ = distribution factors of topological

Individual benefactions (multiplied by line weights) of that gsenerator to power flows line. Is given by:

$$U_{Gk} = \sum_{i=1}^{n} \sum_{j\in\alpha^d_i} W^g_{ij} D^g_{ij,k} P_{Gk} = P_{Gk} \sum_{i=1}^{n} \left\{ \frac{[A_u^{-1}]_{ik}}{P^g_i} \sum_{j\in\alpha^d_i} C_{ij} \right\} \quad eq(11)$$

C_{ij}= supplement charge for total use of line i–j

w_{ijg}= pricing per MW of every line i–j

The method can be summarized as follows:

1. Solve power flow calculation either ac or dc and define line power flows (inflows and outflows) [1].
2. If losses occur, assign each line loss as additional loads to ends of the line [1].
3. Find out the matrix Au .
4. Determine vector of generation PGss
5. Find the Invert matrix Au (i.e., Au-1)
6. Find out the gross power ***Pg*** using $P_g = A_U^{-1} P_G$ The gross power at node i is given as

$$P^g_i = \sum_{k=1}^{n} [A_u^{-1}]_{ik} P_{Gk} \qquad eq(12)$$

7. The gross discharge of line *i–j*, using of the corresponding sharing principle, is given as

$$P^g_{ij} = \frac{P^g_{ij}}{P^g_i} P^g_i = \frac{P^g_{ij}}{P^g_i} \sum_{k=1}^{n} [A_u^{-1}]_{ik} P_{Gk} = \sum_{k=1}^{n} D^g_{ij,k} P_{Gk} \quad eq(13)$$

$$D^g_{ij,k} = \frac{P^g_{ij}[A_u^{-1}]_{ik}}{P^g_i} \cong \frac{P_{ij}[A_u^{-1}]_{ik}}{P_i}$$

And *j* is the no. of supplied nodes directly from node *i*.

b. Kirchen's Tracing Pricing Method

In this method determines the contribution of individual loads to power flow lines and individual generators to power flow lines [1]. By using domains, commons and lines we can determine the cost allocation. Domain means no. of the buses from the specific individual generator [2]. Links are branches that are inter connect each other called commons. To calculate the inflow to each commons by using the each generation [1].

To calculate the benefaction of each generation to commons and power line flows, the method used to evaluate the inflow to individual common [1]. Mathematically,

$$I_k = g_k + \sum_j F_{jk} \qquad \text{eq(14)}$$

Where

Ik = inflow of common

Gk = net generation in common k

Fjk = flow(from j to k) in a link connecting commons j ana k

The next step is to recursively evaluate relative benefits by individual generator to the load and discharge of each individual common, Let

Rij= relative beneficial of common i to the load and the discharge of common j

Aij= complete inflow beneficial of common j to common i, N = set of commons ,

F_{ki}= flow between commons k and i

The elements of complete beneficial matrix (A) and relative beneficial matrix (R) are evaluated by usage of the following algorithm

do j = 1,Nc

$A_{jj} = g_j$

$R_{jj} = A_{jj} / I_j$

end do

do i = 1, NC

do j = i+1, Nc

$A_{ij} = 0$

do k = 1,j

$A_{ij} = 0$

$R_{ji} = 0$

$A_{ij} = A_{ij} + R_{ik} F_{kj}$

$R_{ij} = A_{ij} / I_j$

end do

end do

end do

IV. CONCLUSION

The Transmission price allocation is an important feature in an electric market planning and design. To increase the Revenue of the transmission system depends on fixed cost allocation of the transmission line these methods are used. By using reasonable method for the cost allocation on transmission line could lead to systematic utilization of the existing facilities of transmission and provide future generation planning of the transmission line cost. Cost allocation easy to implement for users of transmission network. It's necessary to develop the evaluation methods on transmission services.

In this paper overall analysis of methods transmission cost evaluation are presented. Due to this different view angles of methods and understanding the function of transmission network can be done.

REFERENCES

[1] Shahidehpour,Ph.D Hatimyamin,Ph.D and Zuyi li, Ph.D "Market operations in electric power systems" IEEE in 2002 publication by john willey & sons.

[2] "Making competition work in electricity" published by sally hunt in 2002.

[3] B. F. Hobbs, J. C. Honious and J. Bluestein, "Estimating the Flexibility of Utility Resource Plans: An Application to Natural Gas Cofiring forSO2 Control." IEEE Transactions on Power Systems, vol. 9, No. 1, pp. 167 – 173, February1994.

[4] A new strategy for transmission expansion in competitive electricity markets by Risheng fang and david J.Hill, fellow,IEEE in February 2003

[5] D. M. Upton, "The Management of Manufacturing Flexibility." California Management Review, vol.36, No. 2, pp.72 -89, 1994.

[6] D. T. Gardner, "Flexibility in Electric Power Planning: Coping With Demand Uncertainty." Energy - The International Journal, vol. 21, No. 12, pp. 1207 – 1218, 1996.

[7] F. P. Sener, "System Planning Using Existing Flexibility" IEEETransactions on Power Systems, vol. 11, No. 4, pp. 1874 – 1878, 1996.

[8] Powerlink Queensland, "Annual Planning Report 2004", [Online].Available: http://www.powerlink.com.au/

[9] IEEE Committee Report , "The IEEE Reliability Test System - 1996", IEEE Transactions On Power Systems, vol. 14, No. 3, pp. 1010 – 1020, 1999.

[10] D. Kirschen and G. Strbac, "Fundamentals of Power System Economics", Wiley, 2004, pp. 229

[11] C. A. C. Coello, "An Updated Survey of GA-Based MultiobjectiveOptimization Techniques", ACM Computing Surveys, Vol. 32, No. 2, June 2000, pp. 109 – 143.

[12] J. E. Dagle , " Data Management Issues Associated With The August 14, 2003 blackout investigation", Power Engineering Society General Meeting,IEEE.2004, pp.1680 -1684

[13] M. O. Buygi, G. Balzer, H. M. Shanechi," Market-based transmissionexpansion planning," IEEE Transactions on Power Systems, vol.19, no.4, pp. 2060-2067, 2004.

[14] M. O. Buygi, M. Shahidehpour, H. M. Shanechi," Market based transmission planning under

uncertainties," presented at the ProbabilisticMethods Applied to Power Systems 2004 International Conference. Iowa 2004, pp.563-568.

[15] I. De J. Silva，M. J. Rider，R. Romero，C. A. F. Murari," Transmission network expansion planning considering uncertainty in demand," IEEETransactions on Power Systems, vol. 21, no.4, pp. 1565-1573, 2006

[16] A. M. Leite da Silva, S. M. P. Ribeiro, V. L. Arienti, et al," Probabilisticload flow techniques applied to power system expansion planning," IEEE Transactions on Power Systems, vol.5, no.4, pp.1047-1053, 1990.

[17] Jaeseok Choi, A. A. El-Keib, T. Tran," A fuzzy branch and bound-based transmission system expansion planning for the highest satisfaction level of the decision maker," IEEE Transactions on Power Systems, vol. 20, no.1, pp.476-484, 2005.

[18] H. M. Zhang, P. H. Liao," Application of grey system principles to transmission network planning," Proceedings of the International PowerEngineering Conference, Singapore ,1995, pp.1-6.

[19] C. W. Gao, H. Z. Cheng, X. Wang,"Application of fuzzy evaluation of blind information in electric network planning, "Proceedings of theChinese Society of Electrical Engineering, vol.24, no.9, pp.24-29, 2004.

[20] H. Z. Jin, H. Z. Cheng, X. M. Yang, et al, "Transmission network flexible planning based on conncection number model, "Proceedings of theChinese Society of Electrical Engineering, vol. 26, no.12, pp.16-20, 2006.

[21] N. Yang, F. S. Wen," A chance constrained programming approach to transmission system expansion planning," Electric Power SystemsResearch,vol.75, no.2-3, pp.171-177, 2005.

[22] B. Sareni and L. Krahenbuhl," Fitness sharing and niching method revisited," IEEE Transaction on Evolution Computation ,vol. 2, no.3, pp. 97–106,1998.