International Journal of Applied Engineering Research ISSN 0973-4562 Volume 12, Number 20 (2017) pp. 9674-9678
© Research India Publications. http://www.ripublication.com

A Novel Method for Allocation of Transmission Cost in a Multiple Transaction Framework

M.S.G.Smitha
Research Scholar, JNTUA
Associate professor, Electrical and Electronics Engineering,
Anantha Lakshmi Institute of Technology and Sciences,
Anantapur, Andhra Pradesh, India.
Orcid Id:000-0002-7947-3913.

P.V.Satyaramesh
Divisional Engineer, Vidyuth Souda, Gunadala,
Vijayawada, Andhra Pradesh, India.

P.Sujatha
Professor, Electrical and Electronics Engineering,
JNTU, Anantapur, Andhra Pradesh, India.

P.Bharat Kumar
Lecturer, Electrical and Electronics Engineering,
JNTU, Anantapur, Andhra Pradesh, India.

Abstract

In view of Multiple Transaction framework, transmission cost allocation among market participants in restructuring of power industry has becoming an important task. This paper presents usage based methodology for transmission cost allocation in deregulated power system. Accordingly, this new approach calculates the utilization of each line by the generators and loads considering their contract obligations in the open access environment. With this methodology, the transmission costs are allocated among the transactions by using the converged load flow solution. Zero Counter flow method is implemented for counter flows. The proposed methodology has been applied on a simple 6-bus system, and the results have proven that the allocation scheme produces appropriate cost allocations.

Keywords: Multiple Transaction Framework, counters flows.

INTRODUCTION

The competitive market for electricity has been developed at two ends, i.e. generation end and retail supply end, while the transmission sector remains a monopoly and therefore regulated. The Transmission Company facilitates trading between parties and therefore plays a vital role in the restructuring of power industry in all countries. Open access transmission regime is leading the rapid disintegration of the vertically integrated structure of electric power industry. Unbundling of electricity services and entry of large number of new pleases have forced the industry towards widespread use of transactions to meet customer demands. These changes result in the establishment of independent transmission system operator whose function is to provide necessary ancillary services and their allocations among the transaction in the system. A quadratic Taylor expansion of losses in terms of transaction at a given operating point is discussed in [1]. Each transaction at a multilateral framework can choose either injection or withdrawal bus. Till now, several allocations schemes have been proposed based on various assumptions and approximations. To determine the proportion of active power flow in a transmission line contributed by each generator an assumption of proportionality is introduced in [2]. This method determines the share rather than impact of a particular generator on each line flow. Under vertically integrated structure, the transmission cost allocation was not an issue due to limited number of third party users. The issue of allocating the transmission cost needs to be addressed as the industry is moving towards transaction-based paradigm [3]. A generalized linear programming model is proposed to solve various system operation and planning problems under deregulated environment subjected to the steady state security constraints in [4]. A framework for explicit consideration of the transactions in the system is developed in [5] which is a simpler construct to formulate the power flows in terms of amounts of transactions in the system explicitly. This concept is used in this paper. An effective procedure for compensating losses in a multi-transaction framework is developed in [6]. A review of transmission fixed cost allocation methods is presented in [7]. The transmission cost allocation based on Z-bus matrix [8] is presented which apportion the cost of transmission network to generators and demands that use it. A min-max fair allocation criteria is explained in [9] for usage of transmission system. In [10], a set of coefficients that measure the participation of each generator with respect to contracted demands and vice-versa are calculated. These coefficients are called usage coefficients. There are no additional approximations assumed resulting in avoidance of inaccuracies induced during formulation stages. Another method for transmission cost allocation based on use of system and considering the congestion cost is presented in [11]. To deal with the cost allocation problem, a number of allocation schemes have been proposed in the literature. These schemes fall into the following categories: Prorata, proportional sharing, incremental transmission loss, loss formula, and circuit theory. Some approaches are based on DC power flow, while some methods use AC load flow for matching the calculation results and actual power flows. Some schemes are branch-power-flow based, while some others focus on the branch-current based allocation techniques.

In this paper, the expression for each transaction is presented which allocates the transmission cost in an appropriate way. The organization of the paper is as follows. Section II presents the formulation of a transaction based framework. An expression for transmission cost allocated to particular transaction is developed. Section III presents an example for implementation of the proposed method. Section IV deal with the results and conclusion.

MULTIPLE TRANSACTION FRAMEWORK

Problem Formulation

The methodology presented in this paper allocates the cost pertaining to the transmission lines of network to all the transactions using their contract obligations in the open access markets.

Background

Consider the Π equivalent of a line shown in fig.1 having primitive line admittance y_{jk} and then half-line charging susceptance connected between buses j and k.

As per the load flow solution, the complex power flow S_{jk} can be expressed as

$$S_{jk} = V_j I_{jk}^* \tag{1}$$

Using the Zbus based system equations the voltage at the node j is given by,

$$V_j = \sum_{i=1}^{n} Z_{ij} I_i \tag{2}$$

The current through the line j-k i.e., I_{jk} is obtained by the expression,

$$I_{jk} = (V_j - V_k) y_{jk} + V_j y_{jk}^{sh} \tag{3}$$

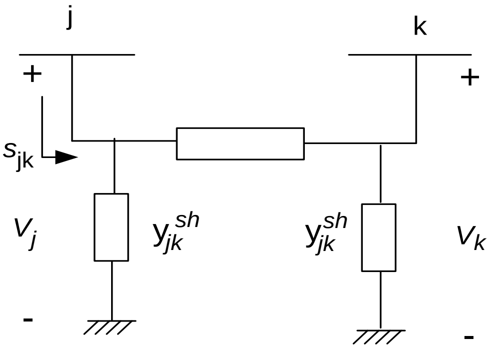

Figure 1: Π equivalent circuit of the line j-k

Substituting equation (2) in the equation (3), and rearranging we get,

$$I_{jk} = \sum_{i=1}^{n} \left[(Z_{ji} - Z_{ki}) y_{jk} + Z_{ji} y_{jk}^{sh} \right] I_i \tag{4}$$

From complex power injection, the bus current can be written as

$$I_i = \frac{p^i - jq^i}{V_i^*} \tag{5}$$

Substituting the values of Ijk and Ii from equation (4) and (5) in the expression (1) and rearranging we get,

$$S_{jk} = \sum_{i=1}^{n} a_{jk}^i \left[p^i + jq^i \right] \tag{6}$$

Where $$a_{jk}^i = \frac{V_j \left[(Z_{ji} - Z_{ki}) y_{jk} + Z_{ji} y_{jk}^{sh} \right]^*}{V_i} \tag{7}$$

Therefore, the complex power flow Sjk through any line is obtained as function of power injections at all the buses, i.e. pi,qi, i=1,2,3,........n.

As the allocation is being done based on the active power injections, the active power through line jk is given by,

$$P_{jk} = \sum_{i=1}^{n} a_{jk}^i p^i \tag{8}$$

The above equation can be represented in matrix form as,

$$\begin{bmatrix} P_{12} \\ P_{13} \\ . \\ . \\ P_{jk} \\ . \\ P_{mn} \end{bmatrix} = \begin{bmatrix} a_{12}^1 & a_{12}^2 & a_{12}^3 & . & . & . & a_{12}^n \\ a_{13}^1 & a_{13}^2 & a_{13}^3 & . & . & . & a_{13}^n \\ . & . & . & . & . & . & . \\ . & . & . & . & . & . & . \\ a_{jk}^1 & a_{jk}^2 & . & . & a_{jk}^i & . & a_{jk}^n \\ . & . & . & . & . & . & . \\ a_{mn}^1 & a_{mn}^2 & . & . & a_{mn}^i & . & a_{mn}^n \end{bmatrix} \begin{bmatrix} p^1 \\ p^2 \\ . \\ . \\ . \\ . \\ p^n \end{bmatrix} \tag{9}$$

Where m, n are the number of nodes.

METHODOLOGY

In this section, a framework based on multiple transactions is presented. Consider a system with n number of buses and m number of transactions in which each load acts as a buyer to get its demands met through transactions with one or more sellers. Similarly, each generator acts as a seller and undertakes transactions with one or more buyers.

A bilateral transaction is characterized by specifying the seller, the buyer and the amount of real power. Every transaction m can be characterized by $T^{(m)}$, Which is composed of a set of sellers $S^{(m)}$, a set of buyers $B^{(m)}$ and the megawatt amount $t^{(m)}$, expressed as follows

$$T^{(m)} = \left\{t^{(m)}, S^{(m)} B^{(m)}\right\} \tag{10}$$

Where $t^{(m)}$ represents the transaction amount in MW and $S^{(m)}$ is given by

$$S^{(m)} = \left\{\left(S_j^{(m)}, \alpha_j^{(m)}\right) j = 1,2,3....N_s^{(m)}\right\} \tag{11}$$

Where $S_j^{(m)}$ represents the selling bus supplying $\alpha_j^{(m)}$ $t^{(m)}$ MW of the transaction amount. The fraction $\alpha_j^{(m)}$ must satisfy the condition $\sum_{j=1}^{N_s^{(m)}} \alpha_j^{(m)} = 1$, $N_s^{(m)}$ represent the number of selling buses. $B^{(m)}$ is given by

$$B^{(m)} = \left\{\left(b_k^{(m)}, \beta_k^{(m)}\right) k = 1,2,3....N_b^{(m)}\right\} \tag{12}$$

Where $B_k^{(m)}$ represents the buying bus receiving $\beta_k^{(m)}$ $t^{(m)}$ MW of the transaction amount. The fraction $\beta_k^{(m)}$ must satisfy the condition $\sum_{k=1}^{N_b^{(m)}} \beta_k^{(m)} = 1$, $N_b^{(m)}$ represent the number of buying buses.

The nodal power injection can be written as sum of individual transactions, we can express the amount of the power injection at any bus i=1,2……..n as follows

$$p_i = \sum_{m=1}^{m} \delta_i^{(m)} t^{(m)} \tag{13}$$

Where the components of the vectors $\delta^{(m)}$ are

$$\delta_i^{(m)} = \left\{ \begin{array}{l} \alpha_i^{(m)} \; if \; S_j^{(m)} = i, \; j = 1,2,3.....N_s^{(m)} \\ \beta_k^{(m)} \; if \; b_k^{(m)} = i, k = 1,2,3.....N_b^{(m)} \\ \alpha_i^{(m)} - \beta_k^{(m)} \; if \; S_j^{(m)} = b_k^{(m)} = i, \; j = 1,2,3..N_s^{(m)}, k = 1,2,3...N_b^{(m)} \\ 0, \; otherwise \end{array} \right\} \tag{14}$$

The active power through line jk is given by

$$P_{jk} = \sum_{i=1}^{n} \alpha^{i}_{jk} \, p_i \tag{15}$$

Substituting (13) in (15)

$$P_{jk} = \sum_{i=1}^{n} a^{i}_{jk} \sum_{m=1}^{m} \delta_i^{(m)} t^{(m)} \tag{16}$$

Power in the line j-k for each transaction T is given by

$$P^{T}_{jk} = \sum_{i=1}^{n} a^{i}_{jk} \, \delta_i^{(T)} t^{(T)} \tag{17}$$

The usage of a line by a particular transaction is set to zero if the power flow due to the transaction goes in the opposite direction of the net flow for the line.The line charge for each transaction 'i' is given by

$$F_{il} = \begin{cases} C_l \times P_{il} \times line length & if \; P_{il} > 0 \\ 0 & if \; P_{il} \leq 0 \end{cases} \tag{18}$$

The total network usage is given by

$$F_i = \sum_{l=1}^{nl} F_{il} \tag{19}$$

Cost allocation by ZCF method is given by

$$ZCF_i = K \frac{F_i}{\sum_{j=1}^{nl} F_j} \tag{20}$$

Where K is total embedded cost and nl is number of lines.

CASE STUDY

The evaluation of cost allocation by above methodology is performed on a sample six bus system shown in Fig.2, which is having six nodes, seven lines and three generators. The trading of the system is 350MW. The system is partitioned with three specified transactions and each transaction involves generator sources and load centres.

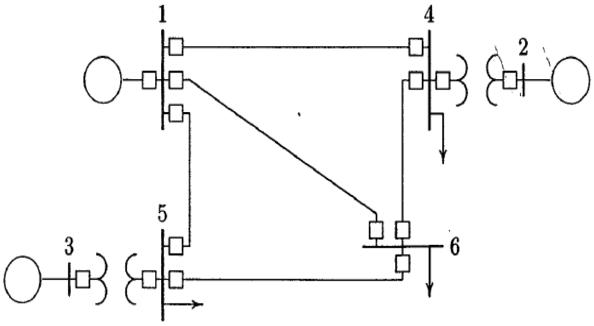

Figure 2: Six bus system

The transaction data for the sample six bus system is given in Table I. In the first transaction generators at buses 1 and 2 participate with a transaction amount of 100MW. Load at bus 4 is only participating in this transaction receiving the total transacted amount of 100 MW.

Table I: Transaction Data for 6 bus Test System

Transaction M	t(m) MW	s(m)	B(m) buying buses
1	100	(1, 15.2%), (2, 56.5%)	4
2	150	(1, 84.8%), (2, 43.5%)	5,6
3	100	(3,100%)	5,6
Total	350		

Similarly the other two transactions are represented based on the contracts between generators and loads. The methodology developed for cost allocation of wheeling transactions in multiple transaction framework is implemented using MATLAB. The results are tabulated in Table II, III and IV for a six bus system shown in Fig.2. The contribution of each transaction to each line is calculated by this method and accordingly the cost contributions of transactions are arrived. The total cost of each line will be equal to the sum of the contribution of all the transactions to that particular line.

RESULTS

The cost of each line shared by each transaction is the product of rate of each line and the power flow in that line due to transaction. The power flow in each line and the cost shared by each transaction is tabulated in Tables II, III and IV. It can be observed from Table II that the power flow due to transaction I in line 4 is more compared to other lines. But the cost shared by transaction I for line 6 is more because the cost shared by the transaction for each line is the product of power flow and the rate of that particular line.

Table II: Results of Transaction I

Line	Power (MW)	Cost($/hr)
1	0.1195	26.8946
2	0.2032	21.3320
3	0.1978	42.5217
4	0.5650	19.7750
5	0.0000	0.0000
6	0.4388	54.8485
7	0.1324	23.1681
Total Cost to be Bourne by transaction		188.5399

It can be observed from Table III that the transaction amount of transaction II is more and the power flow in each line is presented. The power flow in line 5 is zero as the transaction II is not utilizing line 5.

Table III: Results of Transaction II

Line	Power (MW)	Cost($/hr)
1	0.6669	150.0436
2	0.7968	83.6680
3	0.5883	126.4931
4	0.4350	15.225
5	0.0000	0.0000
6	o.4468	55.8485
7	0.2777	48.6056
Total Cost to be Bourne by transaction		479.8838

From Table IV, it can be observed that the cost of line 5 is borne by transaction III as no other transaction is utilizing that line and is completely utilized by transaction III.

Table IV: Results of Transaction III

Line	Power (MW)	Cost($/)
1	0.2136	48.0618
2	0.0000	0.0000
3	0.2139	45.9852
4	0.0000	0.0000
5	1.0000	42.0000
6	0.1144	14.3030
7	0.5899	103.2263
Total Cost to be Bourne by transaction		253.5763

CONCLUSION

A new methodology for transmission cost allocation based on multiple transaction framework is presented. This methodology relates the line flows with magnitude of transacted power between the selling and buying buses. The results have proven that the proposed methodology is an accurate one as it considers transacted power in allocating cost to generators and loads.

REFERENCES

[1] F.F.Wu and P.Variya,”co-ordinated multilateral Trades for electric power networks: Theory and implementation,”power report PWP-031,June 1995.

[2] D.kirschen,R.Allan and G.strbac,”contributions of individual generators to loads and flow,”IEEE Transactions Power systems,vol.12,no.1,pp.52-60,feb 1997.

[3] NERC, International operations services working group (IOS WG),”Defining interconnected operations services under open access, “Final report, March 7,1997.

[4] J.W.M.cheng ,F.D. Galiana,and D.T.Mc Gillis,”studies of bilateral contracts with respect to steady-state security in a degenerated environment,”in preceedings of the 20th PICA,may 11-16,1997,pp 31-36.

[5] George Gross,sha Tao,”A physical-flow-based approach to allocating transmission losses in a transaction frame work”,IEEE Transcationson power systems”,vol.15,No.2,May 2000,pp 631-637.

[6] Shn Tao,George Gross,”Transcations loss compensation in multiple transaction Networks”,IEEE Transcations on power systems,Vol.15,No.3,Aug 2000,PP 909-915.

[7] Z,Jing,X.Dhan,F.Wen,Y.Ni,and F.F.Wn,”Review of transmission fixed cost allocation methods,”in proc.IEEE Power eng.soc.General meeting,Toronto,on Canada,2003.

[8] Antonio J.conejo,Javier conireras,Delbris A.Lina,Antonio Padilha-Feltrin,”Z-bus Transmission Network cost allocation,”IEEE transactions on power systems,vol.22,No.1,Feb 2007.

[9] Rao M.S.S,Soman S.A.,chitkara p.,Gajbhiye R.K.,Hemachandtra N.,Menezes B.L.,”Min-Max Fair power flow tracing for transmission system usage cost allocation:A large system perspective”,IEEE transactions on power systems,vol.25,No .3,pp 1457-1468, Aug 2010.

[10] P.V. Satya ramesh, C.Radha Krishna,”Usage-based transmission loss allocation under open acess in deregulated power system”,IET Gener. Transm.Distrib.Nov.2010,vol.4,lssue11,pp.1261-1274.

[11] J. Nikonkar,M.R. Haghifam,”Transmission cost allocation based on the Use of system and considering the congestion cost”,Electrical power and Energy systems,vol.43,PP-961-968,July 2012.

[12] A.J. Wood and B.F. Wollen berg,Power Generation , Operation and control, 2nd ed: John Wiley & sons, Inc.;1996.