An Approach for Transmission Usage & Loss Allocation by Graph Theory

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Abstract: - Restructuring of Electricity supply industry introduced many issues such as transmission pricing, transmission loss allocation and congestion management. Many methodologies and algorithms were proposed for addressing these issues. In this paper a power flow tracing based method is proposed which involves Matrices methodology for the transmission usage and loss allocation for generators and demands. This method provides loss allocation in a direct way because all the computation is previously done for usage allocation. The proposed method is simple and easy to implement in a large power system. Further it is less computational because it requires matrix inversion only a single time. Results are shown for the sample 6 bus system and IEEE 14 bus system.

Key-Words: - Modified Kirchhoff Matrix, Power flow tracing, Transmission Pricing, Transmission Loss Allocation

1 Introduction

Restructuring of Electricity Supply Industry (ESI) has taken place around the world. The main aim behind this restructuring is to introduce competition to increase efficiency and quality of services in the electricity supply industry. This restructuring consists of various new aspects such as transmission embedded cost allocation, transmission loss allocation, congestion management etc. These all issues raise problems and challenges in front of the utilities of ESI. After restructuring, competition is introduced in the distribution sector. But it is difficult to introduce competition in the transmission sector due to its monopolistic nature. In transmission sector it is not possible to build a separate transmission line for every generation facility. Hence transmission cost allocation is very complicated task in the deregulated environment. Further issues like the fair and equitable allocation of the transmission charges should be addressed.

In the same way transmission loss allocation in an open access market is very significant issue. It is very well known fact that when the electrical power is transmitted through a network it will cause power losses in the network. The generator must compensate for the loss by generating more power but under competitive electricity market no generator would want to generate more power to compensate this loss as it will increase their generation cost. From an economic point of view both generators and loads are supposed to pay for losses because they both use the network and thus are responsible for losses incurred. The problem of allocating transmission active power loss among the various participants has become more important with the increase in competition level in the electricity market.

The main transmission pricing methodologies are classified in figure 1:

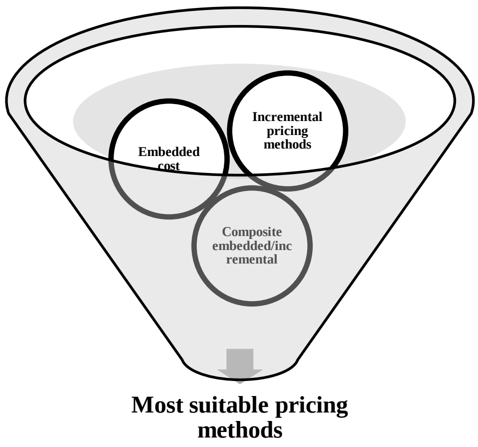

Figure 1. Various Transmission Pricing Methods

Further the incremental pricing methods are subdivided into following categories shown in figure 2:

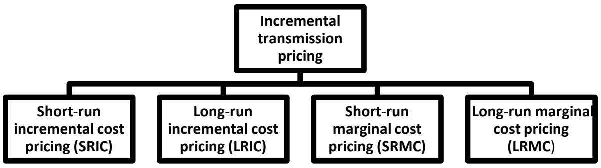

Figure 2. Types of Incremental Transmission Pricing Methods

Colombia, UK and Brazil, have used long run marginal cost (LRMC) methodology due to its easy implementation.

Embedded Transmission Pricing Methods allocate the embedded system costs i.e., fixed cost among transmission system users. Classification of these methods shown in figure 3:

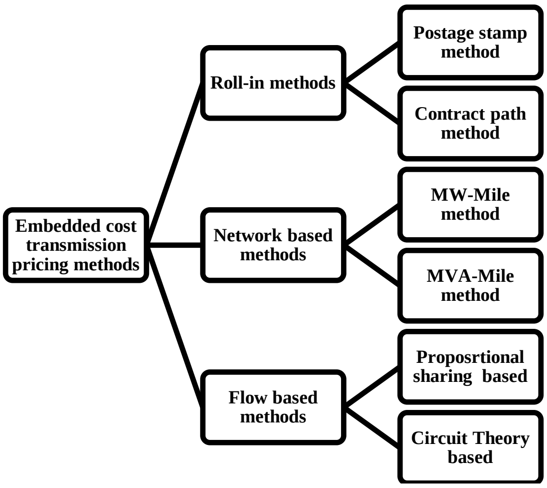

Figure 3. Types of Embedded Transmission Pricing Methods

Selection of the slack bus greatly influenced the pricing methodologies, such as use of a fixed “slack bus” is adequate in countries where most of the load is concentrated in a single center, such as the cities Buenos Aires (Argentina) and Santiago (Chile). Hence the marginal participation method is applied in countries like Argentina, Chile and Panama.

There are various transmission pricing methodologies which are used across the world for allocation of transmission charges to users. These are mainly classified into the embedded cost and market based pricing methodologies. Embedded Cost Pricing methods are based upon determining a utility’s total cost of providing the transmission services. It includes typically service related cost, asset related, and operation & management costs, while market based pricing methodologies are driven by a competitive bidding process which results in prices that are influenced by the demand of services.

Power flow tracing provide us a complete view of usage allocation problem which is very important for transmission cost allocation. When usage allocation is known it is straightforward to allocate the transmission cost to generators and loads. The first attempt to trace power flows was done by Bialek et al. when Topological Generation Distribution factors based Power flow tracing were proposed in March 1996 [2] which explained the method for tracing generator's output. They introduce a simple topological method of tracing the flow of real and reactive power in transmission networks. In Feb 1997, Kirschen et al. [3] explained a power flow tracing method based on the proportional sharing assumption which introduces the concept of domains, commons, and links. In Nov 2000, Gubina et al. [4] described the method to determine the generators’ contribution to a particular load by using the nodal generation distribution factors. In Aug 2000, Wu et al. [5] explained the use of graph theory to calculate the contributions of individual generators and loads to line flows and the real power transfer between individual generators and loads. In 2009 Xie et al.[6] proposed and explained the power flow tracing algorithms founded in the extended incidence matrix considering loop flows. In Feb 2007, Conejo et al. [7] explained a method of network cost allocation based on Z-bus matrix. In Aug 2006 Abhyankar et al. [8] proposed real power flow tracing method based on optimization approach. In Aug 2010, Rao et al. [9] explained the Min-Max fair allocation criteria for transmission system usage allocation.

Similarly many different loss allocation schemes have been proposed for transmission loss allocation. The existing transmission loss allocation methods may be classified into prorata method, marginal methods, power flow tracing-based methods, and circuit theory based methods [1]. Prorata method is one of the classical methods which are easy to implement and understand. It is characterized by the allocation of electric losses proportionally to the power delivered by each generator and each load. It is also assumed an equal allocation 50% to generator and 50% of the loads [10]. In marginal procedure incremental transmission coefficients are used for allocation of transmission losses to demands and generators [11]. The use of power flow tracing methods for allocation of transmission losses is proposed in [12]. In this work proportional sharing principle is combined with load flow results. The methods based on circuit theory are simple and easy to implement. In this category method based on Z- bus matrix is proposed by A. J. Conejo et al. This method presents a new procedure for allocating transmission losses to generators and loads in the context of pools operated under a single marginal price derived from a merit-order approach [13]. The main difficulty in allocating losses to load or generators to bilateral contracts by circuit theory is that, despite approximations the final allocations always contain a certain degree of arbitrariness. Recently several new algorithms and methods are also proposed such as in [14] a method based on complex power flow tracing is proposed. This method topologically determines the contribution of generators and loads to losses in transmission lines. In [15] author decomposed transmission losses into three components. Analytical proofs of the proposed loss decomposition are presented along with methods of allocating each component to the parties contributing to it. In [16] a new algorithm is proposed for transmission loss allocation which is used path integral and based on transaction strategy. A new path integral method is developed by integrating the partial differential of the system loss along a path reflecting the transaction strategy. A usage based transmission loss allocation method is proposed in [17]. This new method calculates the portion of real power transmission loss contribution from the generators and simultaneously the portion of the real power transmission loss allocated to the loads using their contract obligations with the generators in the open access environment. In [18] method based on circuit theory and the concept of orthogonal projection for pool based electricity market is proposed.

This paper presents a model of usage and loss allocation based on the concept of the matrices methodology. In the proposed method modified Kirchhoff matrix is developed for usage allocation. After that loss allocation matrix is formed for transmission loss allocation to loads and generators. The paper is organized as follows: section two presented the proposed methodology. The procedure of usage and loss allocation is presented in section three. Results and discussion are presented on sample 6 bus and IEEE 14 bus system in section five followed by a conclusion.

2 Proposed Matrices Methodology

Let consider a simple diagraph G showed in figure 4.

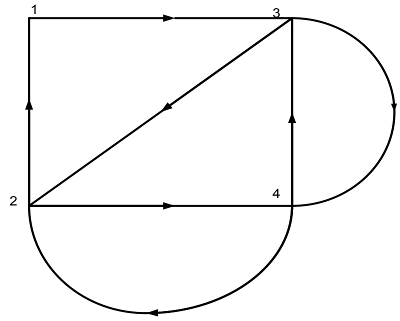

Figure 4. Simple Diagraph G

The Kirchhoff matrix of above diagraph is given by Eq. 1.

$$K(G) = \begin{bmatrix} 1 & 0 & -1 & 0 \\ -1 & 2 & 0 & -1 \\ 0 & -1 & 2 & -1 \\ 0 & -1 & -1 & 2 \end{bmatrix}$$

Hence from the above example for a simple digraph G of n vertices, an n by n matrix called the Kirchhoff matrix $K(G)$ or $K = [k_{ij}]$ is defined as [1],

$$K = \begin{cases} d^-(v_i) & \text{for } i = j \\ -x_{ij} & \text{for } i \neq j \end{cases} \qquad (1)$$

Where $d^-(v_i)$ = in-degree of the ith vertex

$-x_{ij}$ = (i,j)th entry in the adjacency matrix

This matrix is the basis of the proposed methodology.

First Authors construct a power flow matrix from the Newton Raphson load flow. This matrix gives a complete overview of power flows in the system. It is formed between nodes of the system. Diagonal elements give net flows at nodes and off diagonal elements give the actual flows and counter flows in the system. The proposed matrix is defined as follows: active power in branch $i-j$ from bus i to bus j as p_{ij} (> 0) and total inflow at bus i as p_{Ti}

$$pf_{ij} = \begin{cases} -p_{ij} & \text{for } i \neq j \text{ and } p_{ji} > 0 \\ p_{ij} & \text{for } i \neq j \text{ and } p_{ij} > 0 \\ p_{Ti} & \text{for } i = j \end{cases} \qquad (2)$$

Where p_{Ti} = net flows on the nodes

From the above matrix and using Eq. 1 the Modified Kirchhoff matrix is constructed as follows:

Denoting Modified Kirchhoff matrix of a Power Network as $K_m = (k_{ij}^m)_{n\times n}$, authors define the following expression for elements of the Modified Kirchhoff matrix:

$$k_{ij}^m = \begin{cases} -p_{ij} & \text{for } i \neq j \text{ and } p_{ij} > 0 \\ p_{Ti} & \text{for } i = j \\ 0 & \text{otherwise} \end{cases} \quad (3)$$

Now from the above Modified Kirchhoff matrix, Kirchhoff loss matrix can be formed as follows:

$$kl_{ij} = \begin{cases} p_{ij}^l & \text{for } i \neq j \text{ and } p_{ij} > p_{ji} \text{ and } p_{ji} < 0 < p_{ij} \\ p_{ji}^l & \text{for } i \neq j \text{ and } p_{ji} > p_{ij} \text{ and } p_{ij} < 0 < p_{ji} \\ 0 & \text{otherwise} \end{cases}$$

(4)

Where

$p_{ij}^l = p_{ij} + p_{ji}$, and $p_{ji}^l = p_{ji} + p_{ij}$

p_{ij}^l= transmission loss in line i-j in actual direction

p_{ji}^l= transmission loss in line i-j in counter direction

2.1 Properties of Modified Kirchhoff matrix

Property1. The sum of all elements in row j of a Modified Kirchhoff matrix equals the active load power at bus j. This property is mathematically expressed as:

$$K_m I = P_L \quad (5)$$

Property2. The sum of all elements in column j of a Modified Kirchhoff matrix equals the total active power of generators at bus j. This property is mathematically expressed as:

$$I^T K_m = (P_G)^T \quad (6)$$

The above equation can be rewritten as follows

$$K_m^T I = P_G \quad (7)$$

From equation (5) and (7) we have

$$I = {K_m}^{-1} P_L \quad (8)$$

$$I = ({K_m}^T)^{-1} P_G \quad (9)$$

Eq. (9) can be rewritten as

$$I = ({K_m}^{-1})^T P_G \quad (10)$$

From the above matrix we get the inverse of Modified Kirchhoff matrix (${K_m}^{-1}$) which is used for power flow tracing and loss allocation. In the next section procedure for power flow tracing and loss allocation is described.

3 Procedure for Tracing Power Flow and Loss Allocation

In this paper authors adopt the tracing procedure which is proposed in [6]. But authors modified this tracing algorithm for transmission loss allocation.

3.1 Model for Power flow Tracing

When Let ln=1........n represents the total number of lines in the system. M=1........m is the total number of generators and $D = 1 \ldots\ldots d$ is the total number of loads in the system.

Again let $P_{GG} = \text{diag}\,(P_{G1}, P_{G2}, \ldots, P_{Gm})$ represents the number of generators in diagonal matrix. Thus

$$I^T P_{GG} = (P_G)^T \text{ or } P_G = P_{GG} I \quad (11)$$

Combining eqs. (11) and (8)

$$P_G = P_{GG} {K_m}^{-1} P_L \quad (12)$$

Matrix $P_{GG}{K_m}^{-1}$ is named supply factor matrix. The supply factor matrix is denoted by $T = (t_{ij})$, i.e.,

$$T = P_{GG} {K_m}^{-1} \quad (13)$$

and from Eq. (9)

$$P_{Gi} = \sum_{j=1}^{n} t_{ij} P_{Lj} \quad (14)$$

Where $t_{ij}P_{Lj}$ denotes the active power distribution of generation output at bus i to the load situated at bus j [6].

$$P_{i\to j} = t_{ij} P_{Lj} \quad (15)$$

Thus Eq. (15) gives the generator's share to loads in the system.

On the same line for calculating the generators shares to lines flow Eq. (15) is modified by replacing load power from the lines flow as shown in Eq. (16). It is assumed that a a_g: a_l (23:77) split in the transmission usage occurs between generators and demand [20].

For example the generator share situated as bus s to the line s-t is given by

$$P_{i\rightarrow s-t} = t_{is}P_{st}a_g \qquad (16)$$

Hence Eq. (15) and (16) gives the generators share in loads and lines flows. Similarly, the usage allocated to a load for the use of all lines can be defined by using a_l instead of a_g.

For calculating the loads shares in line flows and generated power same procedure is followed:

Considering dual of Eq. (9)

$$P_L = P_{LL}({K_m}^{-1})^T P_G \qquad (17)$$

Where the diagonal matrix $P_{LL} = \mathrm{diag}\,(P_{L1}, P_{L2}, \ldots\ldots, P_{Ld})$ and R= $P_{LL}({K_m}^{-1})^T$ is the extraction factor matrix of loads from generators [6].
By using an extraction factor matrix, loads share in generating power and line flows is calculated.

3.2 Model for Transmission Loss and Cost Allocation

For transmission loss allocation to generator considers Eq. (16). In this equation line flows P_{st} is replaced by the transmission Loss in lines which is coming from the elements of the Kirchhoff loss matrix p^l_{ij} and p^l_{ji}.

Hence transmission losses of line s-t allocated to generator located at bus i is given by:

$$P^l_{i-s\rightarrow t} = t_{is}p^{\,l}_{\,st} \qquad (18)$$

Similarly transmission losses of line s-t allocated to load situated at bus j is given by:

$$P^l_{j\rightarrow s-t} = r_{js}p^{\,l}_{\,st} \qquad (19)$$

From the equations (18) and (19) losses are allocated to generators and loads respectively. This method of loss allocation is said to be direct because all the calculation is already done for usage allocation.

If the usage cost of the line is denoted as C_{s-t} (in Rs/MW) then loss cost allocated to users is given by:

For generators

$$c^{G_i}_{s-t} = \frac{P^l_{i\rightarrow s-t}}{p_{s-t}} \times C_{s-t} \qquad (20)$$

Where $c^{G_i}_{s-t}$=Transmission Loss cost allocated to generator i for line s-t.

p_{s-t}= Power Loss in Transmission Line s-t.

Total transmission loss cost allocated to generators

$$C^{G_i} = \sum_{ln=1}^{n} c^{G_i}_{ln} \qquad (21)$$

Where C^{G_i} =Transmission Loss cost allocated to generator i for all the lines.

Similarly for Loads

$$c^{L_T}_{s-t} = \frac{P^l_{j\rightarrow s-t}}{p_{s-t}} \times C_{s-t} \qquad (22)$$

Where $c^{L_T}_{s-t}$= Transmission Loss cost Allocated to Load T for line s-t.

p_{s-t}= Power Loss in Transmission Line s-t.

Total transmission loss cost allocated to generators

$$C^{L_T} = \sum_{ln=1}^{n} c^{L_T}_{ln} \qquad (23)$$

Where C^{L_T} = Transmiaaion Loss Cost Allocated to Load for all the Lines

4 Results and Discussion

The proposed matrices methodology is applied to the sample 6 and IEEE 14 bus power system to demonstrate the feasibility and effectiveness of the methodology. A computer program coded in MATLAB is developed.

4.1 IEEE 6 Bus System

4.1.1 Transmission Usage Allocation and Pricing

The sample 6 bus power system is used to illustrate the proposed methodology. The summation of powers extracted by the load buses from all the generators equals the total load demand similarly the addition of powers contributed by the generator buses to all the demands equals the total generation power. For example load at bus 4 is 0.7 pu in which 0.53 is supplied by Generator 1 and remaining 0.2 pu is supplied by generator 2. Table 1 and Table 2 gives the generators and load contributions to line flows. These tables also provide the transmission charge allocation to generators and loads.

TABLE I
TRANSFERRED POWER AND CHARGE ALLOCATED TO GENERATORS FOR THE 6 BUS SYSTEM

Line	Flow (pu)	Cost (Rs/hr)	Supplied by Gen. 1	Supplied by Gen.2	Supplied by Gen.3	Charge allocated to Gen.1(Rs/hr)	Charge allocated to Gen.2(Rs/hr)	Charge allocated to Gen.3(Rs/hr)
1	0.29	223.61	0.29	0.00	0.00	51.43	0.00	0.00
2	0.44	206.16	0.44	0.00	0.00	47.42	0.00	0.00
3	0.36	310.49	0.36	0.00	0.00	71.41	0.00	0.00
4	0.03	254.95	0.01	0.02	0.00	21.84	37.50	0.00
5	0.33	111.80	0.12	0.21	0.00	9.58	16.45	0.00
6	0.16	316.23	0.06	0.10	0.00	27.08	46.50	0.00
7	0.26	211.90	0.10	0.17	0.00	18.15	31.16	0.00
8	0.19	286.36	0.00	0.01	0.18	1.16	2.01	62.79
9	0.44	101.98	0.01	0.01	0.42	0.41	0.71	22.36
10	0.04	447.21	0.03	0.01	0.00	77.63	29.63	0.00
11	0.02	316.23	0.01	0.00	0.00	45.78	11.98	18.82

TABLE II
EXTRACTED POWER AND CHARGE ALLOCATED TO LOADS FOR THE 6 BUS SYSTEM

Line	Flow(pu)	Cost(Rs/hr)	Extracted by Load 4(pu)	Extracted by Load5(pu)	Extracted by Load6(pu)	Charge allocated to Load4(Rs/hr)	Charge allocated to Load5(Rs/hr)	Charge allocated to Load6(Rs/hr)
1	0.29	223.61	0.14	0.12	0.03	84.02	69.64	18.52
2	0.44	206.16	0.21	0.18	0.05	77.44	64.19	17.11
3	0.36	310.49	0.17	0.14	0.04	116.58	96.70	25.72
4	0.03	254.95	0.01	0.01	0.01	79.18	45.15	72.64
5	0.33	111.80	0.13	0.08	0.12	34.56	19.67	31.85
6	0.16	316.23	0.06	0.04	0.06	97.71	55.61	90.17
7	0.26	211.90	0.11	0.06	0.10	65.51	37.27	60.38
8	0.19	286.36	0.00	0.06	0.14	0.00	66.03	154.46
9	0.44	101.98	0.00	0.13	0.31	0.00	23.54	54.99
10	0.04	447.21	0.04	0.00	0.00	324.68	18.86	0.82
11	0.02	316.23	0.00	0.02	0.00	0.00	237.77	5.73

4.1.2 Transmission Loss Allocation and Pricing

Table 3 and 4 gives a transmission loss allocation to loads and generators. Total system losses occurred in the system is 0.084697 pu from which 23% is allocated to generators and 77% is allocated to demands.

TABLE III
TRANSMISSION LOSS ALLOCATION TO LOADS FOR IEEE 6 BUS SYSTEM

Lines	Loss(pu)	L4(pu)	L5 (pu)	L6 (pu)
1	0.01	0.00	0.00	0.00
2	0.01	0.00	0.00	0.00
3	0.01	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00
5	0.02	0.01	0.00	0.00
6	0.01	0.00	0.00	0.00
7	0.01	0.00	0.00	0.00
8	0.01	0.00	0.00	0.01
9	0.01	0.00	0.00	0.01
10	0.00	0.00	0.00	0.00
11	0.00	0.00	0.00	0.00
Total	0.08	0.02	0.02	0.02

TABLE IV
TRANSMISSION LOSS ALLOCATION TO GENERATORS FOR IEEE 6 BUS SYSTEM

Lines	Loss(pu)	G1(pu)	G2 (pu)	G3(pu)
1	0.01	0.00	0.00	0.00
2	0.01	0.00	0.00	0.00
3	0.01	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00
5	0.02	0.00	0.00	0.00
6	0.01	0.00	0.00	0.00
7	0.01	0.00	0.00	0.00
8	0.01	0.00	0.00	0.00
9	0.01	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00
11	0.00	0.00	0.00	0.00
Total	0.08	0.01	0.00	0.01

4.2 IEEE 14 Bus System

4.2.1 Transmission Usage Allocation and Pricing

The proposed method is also applied on IEEE 14 bus system [20]. Authors assume that cost of the line is proportional to the length of the line. After this the share of each generator (load) in load (generator) and line flows is calculated. Table 5 and 6 gives generators and loads shares to various line flows respectively.

TABLE V

TRANSFERRED POWER ALLOCATED TO GENERATORS FOR THE IEEE 14 BUS SYSTEM

Line	Flow(MW)	Cost(Rs/hr)	Supplied by Gen.1(MW)	Supplied by Gen.2(MW)
1	141.27	62.26	141.30	0.00
2	71.83	229.49	71.80	0.00
3	73.85	203.47	67.90	8.10
4	58.71	185.65	54.00	6.50
5	44.53	182.97	41.00	4.90
6	23.77	183.69	23.50	1.70
7	27.73	44.18	27.50	1.90
8	16.06	209.12	15.90	1.10
9	59.44	556.18	60.00	2.40
10	44.71	252.02	45.20	1.80
11	7.58	220.41	7.70	0.30
12	7.93	283.81	8.00	0.30
13	18.00	146.10	18.20	0.70
14	0.00	176.15	0.00	0.00
15	27.73	110.01	27.50	1.90
16	5.07	90.29	5.00	0.40
17	9.22	298.77	9.10	0.60
18	3.97	208.86	4.10	0.20
19	1.73	297.92	1.80	0.10
20	5.92	387.73	6.10	0.20

TABLE VI

EXTRACTED POWER ALLOCATED TO LOADS IN THE IEEE 14 BUS SYSTEM

Line	Flow (MW)	Cost(Rs/hr)	L3	L4	L5	L6	L9	L10	L11	L12	L13	L14
1	141.27	62.26	55.02	28.44	4.62	6.80	17.55	5.47	2.16	3.74	8.34	9.14
2	71.83	229.49	27.98	14.46	2.35	3.46	8.92	2.78	1.10	1.90	4.24	4.65
3	73.85	203.47	38.36	14.14	1.22	1.80	8.73	2.14	0.57	0.99	2.21	3.69
4	58.72	185.65	30.50	11.24	0.97	1.43	6.94	1.70	0.45	0.79	1.76	2.93
5	44.53	182.97	23.13	8.53	0.74	1.09	5.26	1.29	0.34	0.60	1.33	2.22
6	23.77	183.69	4.99	9.81	0.00	0.00	6.06	1.03	0.00	0.00	0.00	1.88
7	27.73	44.18	5.82	11.44	0.00	0.00	7.06	1.20	0.00	0.00	0.00	2.20
8	16.06	209.12	3.37	6.63	0.00	0.00	4.09	0.70	0.00	0.00	0.00	1.27
9	59.44	556.18	6.72	13.20	3.98	5.87	8.15	3.53	1.86	3.23	7.19	5.71
10	44.71	252.02	5.05	9.93	3.00	4.41	6.13	2.65	1.40	2.43	5.41	4.29
11	7.58	220.41	0.00	0.00	0.00	1.90	0.00	0.69	0.60	1.05	2.32	1.03
12	7.93	283.81	0.00	0.00	0.00	1.98	0.00	0.72	0.63	1.09	2.43	1.07
13	18.00	146.10	0.00	0.00	0.00	4.50	0.00	1.64	1.43	2.48	5.52	2.43
14	0.00	176.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15	27.73	110.01	0.00	0.00	0.00	0.00	18.72	3.18	0.00	0.00	0.00	5.83
16	5.07	90.29	0.00	0.00	0.00	0.00	3.42	0.58	0.00	0.00	0.00	1.07
17	9.22	298.77	0.00	0.00	0.00	0.00	6.22	1.06	0.00	0.00	0.00	1.94
18	3.97	208.86	0.00	0.00	0.00	0.00	0.00	2.13	1.85	0.00	0.00	0.00
19	1.73	297.92	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.35	0.27	0.12
20	5.92	387.73	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.11	1.81

4.2.2 Transmission Loss Allocation and Pricing

Table 7 and 8 presents the transmission loss allocation between generators and Loads respectively. Total system losses occur in IEEE 14 Bus system is 15.87016 MW. 23% of total losses i.e. 3.70114478 MW is allocated to generators and 77% i.e. 12.16902 is allocated to loads.

TABLE VII
TRANSMISSION LOSS ALLOCATION TO GENERATORS FOR IEEE 14 BUS SYSTEM

Line	Losses(MW)	Supplied by Gen.1(MW)	Supplied by Gen.2(MW)
1-2	4.18	0.96	0.00
1-5	3.30	0.76	0.00
2-3	2.98	0.55	0.16
2-4	2.26	0.41	0.12
2-5	1.31	0.24	0.07
4-3	0.44	0.09	0.02
4-7	0.00	0.00	0.00
4-9	0.00	0.00	0.00
5-4	0.54	0.12	0.01
5-6	0.00	0.00	0.00
6-11	0.11	0.02	0.00
6-12	0.10	0.02	0.00
6-13	0.30	0.07	0.01
7-8	0.00	0.00	0.00
7-9	0.00	0.00	0.00
9-10	0.01	0.00	0.00
9-14	0.14	0.03	0.01
11-10	0.03	0.01	0.00
12-13	0.01	0.00	0.00
13-14	0.10	0.02	0.00
Total	15.87	3.31	0.39

TABLE VIII
TRANSMISSION LOSS ALLOCATION TO LOADS FOR IEEE 14 BUS SYSTEM

Line	Losses(MW)	L3	L4	L5	L6	L9	L10	L11	L12	L13	L14
1	4.18	1.22	0.64	0.10	0.16	0.39	0.13	0.06	0.10	0.19	0.23
2	3.30	0.96	0.51	0.08	0.13	0.30	0.10	0.05	0.08	0.15	0.18
3	2.98	1.17	0.44	0.05	0.07	0.28	0.07	0.02	0.02	0.07	0.11
4	2.26	0.89	0.33	0.03	0.05	0.21	0.05	0.02	0.02	0.05	0.09
5	1.31	0.52	0.19	0.02	0.03	0.12	0.03	0.01	0.01	0.03	0.05
6	0.44	0.07	0.14	0.00	0.00	0.09	0.01	0.00	0.00	0.00	0.03
7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	0.54	0.05	0.09	0.03	0.04	0.06	0.02	0.01	0.02	0.05	0.04
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	0.11	0.00	0.00	0.00	0.02	0.00	0.01	0.01	0.01	0.03	0.01
12	0.10	0.00	0.00	0.00	0.02	0.00	0.01	0.01	0.01	0.02	0.01
13	0.30	0.00	0.00	0.00	0.06	0.00	0.02	0.02	0.03	0.07	0.03
14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
17	0.14	0.00	0.00	0.00	0.00	0.07	0.01	0.00	0.00	0.00	0.02
18	0.03	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00
19	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
20	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.02
Total	15.87	4.88	2.34	0.30	0.58	1.52	0.48	0.22	0.31	0.72	0.82

4 Conclusion

In the proposed work authors presents a combined methodology for the transmission usage and loss allocation which is based on the matrices methodology. Furthermore transmission loss allocation by this method is direct because all the calculation previously done for usage allocation. This method requires less calculation as compared to other methods such as Topological generator distribution factors proposed by Bialek [4] because matrix inversion is required only one time. Also the proposed matrix has a huge number of zero elements hence it is highly sparse in nature. Results are shown for the sample 6 bus system and IEEE 14 bus system.

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