Novel Approaches for Transmission System Expansion Planning-TCA

Mr.Luke John Baktha Singh Immaraju, ***Schollar,JNTUA,*** ***Ananthapuramu.Andhra Pradesh, INDIA.***

Dr.B.Venkata Prasanth, ***Professor & HOD/EEE*** ***QISCET, Ongole, INDIA***

Dr.V.Ganesh Research ***Professor/EEE,JNTUCEP*** ***Pulivendula, INDIA***

ABSTRACT: The "change" is the word which commonly effect daily in the technology. Without change, the world will be stop. Especially the use of electricity day by day increases and consumers expected reliability. Here we can define the reliability under this as the best for least. Hence the quality of power system is expected. For decades, transmission was developed in response to utility-by-utility needs to serve their own customers. Industry was vertically-integrated; transmission was planned and built by utility to move its generation to its load, or to move energy purchased from another vertically-integrated utility to its load. Costs were embedded in bundled rates to customers, or incrementally assigned to users of the system. Utilities must participate in a regional planning process that is open and transparent, with opportunities for all stakeholders to submit potential transmission needs for consideration. This paper presents an overview of transmission cost allocation methods.

Keywords: Deregulation, TCA, Power transmission system

I.INTRODUCTION

In the past years, the power system was bundled i.e. the power system which was followed by all the countries is known as Vertically Integrated unit(VIU). In this system, the main components of the power system are: Power Generation, Power Transmission and Power Distribution are combined together and act as a one unit. The final decision in this VIU is That country government. In this VIU, there was no other alternative to run the system and the government is one and only leader to regulate the system. This system is also known as regulated power system. In this VIU, any consumer has to get the power from Generation Companies through Transmission Company only. But, there are some disadvantages i.e. no possibility of getting the power directly from Generation Company, lack of competition as there is no competitor in the system. To avoid this, unbundled power system is introduced which is considered as deregulated power system.

In this system, the three entities of the system: Generation, Transmission and Distribution are open and act as separate companies. The main objective of this deregulated power system is to create the competition in the system and to provide the least cost services to the customers in fair and transparent manner as the layman can also understand the procedure behind the system.

The fig shows the block diagram representing the connectivity between the modules in restructured power system. Where,

GENCO: Generation unit/Companies

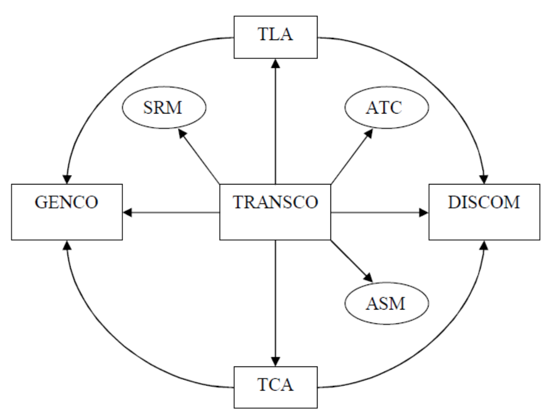
TRANSCO: Transmission unit/Companies

DISCOM: Distribution Unit/Companies

ATC: Available transfer Capability

TLA: Transmission Loss Allocation

TCA: Transmission Cost Allocation



ASM: All Security Management

SRM: System Reliability Management

Transmission cost allocation (TCA) is major module in deregulated electricity markets. Since the gencos are the inputs and discoms or customers are the outputs and all are connected as one network, regulation of participant can have significant effects on others making it difficult to estimate the cost, each participant is responsible for it. It is difficult to achieve an efficient transmission cost allocation scheme that could fit all market structures in different locations. As the research is going on transmission pricing indicates that there is no generalized agreement on pricing methodology. In practice, each restructuring model has chosen a method that is based on a particular characteristic of its network.

The main object of this paper is to go through the different methods for transmission cost allocation methods and from that conclusion for which method is supreme among all.

TCA Methods:

The following methods are discussed in this paper for the transmission cost allocation.

Those are:

1. PRO RATA Method
2. PROPORTIONAL SHARING Method
4. BUS wise Loss allocation Method

1.PRO RATA Method:

This method is also known as postage stamp method. In this procedure firstly, the total transmission cost is estimated and allocated to the consumers and generators as 50-50. First, the losses are assigned globally to generators and consumers, 50% losses to each case. Then, a proportional procedure is used: that is the losses allocated to the generators are proportional to the utilization. The PR procedure is easy to understand and implement. But it ignore the network.

$P_l = \sum_{i=1}^{n} P_l^{Gi} + \sum_{i=1}^{n} P_l^{Di}$

$P_l = P_l^G + P_l^D$ →(1)

Where P_l : Power usage of l^{th} line in

P_l^{Gi} : Power usage of l^{th} line to generator located at bus i

P_l^{Di} :Power usage of l^{th} line to consumer located at bus i

P_l^G : Power usage of l^{th} line to generator

P_l^D :Power usage of l^{th} line to consumer

All are in MW

Where L_j is the losses allocated to the j^{th} bus of load,

D_j is the power consumed by j^{th} bus,

And D is the total power consumption.

The drawback of this method is, if the two identical loads are connected to the one bus and those are located at the different distance this procedure will treat them equally. This is unfairness.

II. POSTAGE STAMP METHOD

The most common and simplest method for transmission loss allocation is postage – stamp method, which depends only on the amount of power transferred to the demand and the how much duration it is used, and it is not depend the supply and delivery points, distance of transmission usage. A consumer, who uses the transmission system less, actually subsidizes others who use the system bulk amount. The procedure is as follows.

Transmission loss allocation to the generator= $\frac{L}{2}\frac{Pi}{P}$

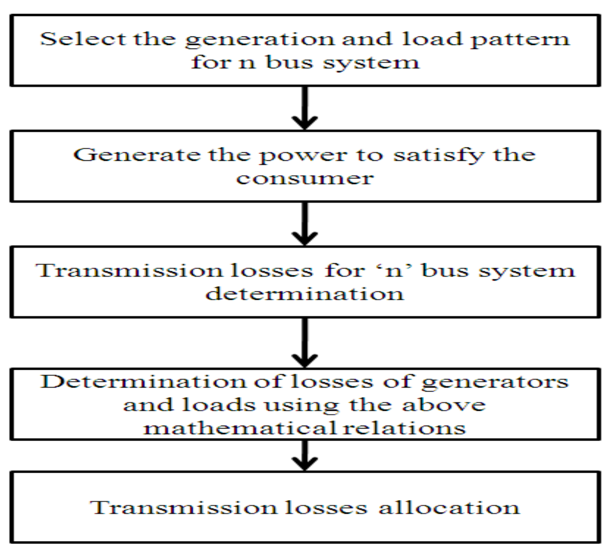
Where P_i is the power generated by i^{th} bus

P is the total power generated.

Transmission loss allocation to the load i.e. consumer = $\frac{L}{2}\frac{Di}{D}$

Where D_i is the power consumed by the i^{th} bus consumer and D is the total power consumption.

An algorithm for this method is as follows.



III. PROPORTIONAL SHARING METHOD

Proportional sharing method on top of electrical laws requires the assumption of the proportional sharing principle, which states the response of any system is directly proportional to its excitation. If we use this principle, the losses are allocated by means of linear. This allocation does not depend on slack bus. In order to allocate the losses we do consider the simple procedure, that is the losses with certain node in an electrical network proportionally shared by the all paths going electricity market.

Based on this, this method is considered as simple method for the loss allocation. There is no ideal procedure to allocate the transmission losses, the following properties are considered.

i. The losses to be constant with respect to the power flow

ii. The losses must depend on the energy which may be either produced or consumed.

iii. The allocated losses must be transparent.

iv. The allocated losses must approved the government such that politically no issues.

v. These losses provide correct conditional paths to the network.

TRANSMISSION LOSS ALLOCATION

$$P_{pq}(gross)=\frac{P_{pq}}{P_p}\sum[Au(p,q)]Pk \text{ for } q \text{ belongs to } \alpha_p^d$$

Where α_p^d is the set of nodes supplied from node p. P_p is the nodal power, K is the k^{th} bus i.e. at the generation side, P_k is the k^{th} bus power generation, P_{pq} is the real power flow (where p is the upstream q is downstream)

A_u is the upstream distribution matrix.

$[A_u]_{pq}$= 1 for p=q, $-\frac{|P_{qp}|}{pq}$ for $q\epsilon\alpha_p^u$, and 0 otherwise.

$$P_{pq}(gross)=\frac{P_{pq}}{P_p}\sum[Ad(p,q)]PDk \text{ for } q \text{ belongs to } \alpha_p^u$$

P_{DK} is the demand at k^{th} bus, P_{pq} is the real power flow (where q is the upstream p is downstream), A_d is the downstream distribution matrix.

$[A_d]_{pq}$= 1 for p=q, $-\frac{|P_{qp}|}{pq}$ for $q\epsilon\alpha_p^d$, and 0 otherwise.

In order to allocate the 50% losses to the generating stations and 50% losses to the load, the final generation and demand per bus are calculated as follows,

$P'_p=(P_{pq}(net)+P_p)/2$

$P'_{Dq}=(P_{pq}(gross)+P_{Dp})/2$

At last final the transmission losses allocation to the every generator bus and consumer bus are calculated as follows,

$L'_p = P_p - P'_p$

$L'_{Dp} = P'_{Dq} - P_{Dq}$

IV. BUSWISE ALLOCATION METHOD

In this method, it is not required to consider the assumptions and hence network laws will be considered. It will be based on true power injection and true power losses contribution factors of the buses. It does not require any assumptions in the network.

TRANSMISSION LOSS ALLOCATION:

In this method the load flow solution data will be considered as follows,

$S_{pq} = V_p I^*_{pq}$ ------→(1)

The voltage at node p is given by

$V_p = \sum_{k=1}^{n} Z_{pk} I_p$ -----→(2)

$I_{pq} = (V_p-V_q)/Z_{pq}+V_p/Z_{pq}^{sh}$ ----→(3)

Substituting equation (2) in equation (3)

$I_{pq} = (\sum_{k=1}^{n} Z_{pk}I_p-V_q)/Z_{pq}+(\sum_{k=1}^{n} Z_{pk} I_p)/Z_{pq}^{sh}$ ----→(4)

Substituting (4) in (1)

$S_{pq} = \sum_{k=1}^{n} factor1^k_{pq}$ ---→(5)

1^k_{pq} represents contribution of k^{th} bus to p-q line flow of power.

Similarly the complex power flow in line

$S_{qp} = \sum_{k=1}^{n} factor2^k_{pq}$ ----→(6)

Factor 2^k_{pq} represents contribution of the k^{th} bus to p-q line complex power

$S_{line\ loss} = S_{pq} + S_{qp} == \sum_{k=1}^{n} factor^k_{pq}$ →(7)

Where factor $^k_{pq}$ is the contribution of the k^{th} bus to the p-q line loss and also the power injected at p-q bus.

Let [R] matrix is the real part of $S_{line\ loss}$

Then by using [R] power losses allocated as follows

a. Determination of algebraic sum of the "absolute contribution of all buses to the real power loss of line p→q(say "p^{th}line") i.e. cumulative power loss "Cploss(p)" where

Cploss(p) = $\sum_{k=1}^{n} R(k,p)$ ---→(8)

b. To find the real power sponsored by the line p-q (l^{th} line) a power loss factor is given by

C(k,l) = $\frac{R(k,l)}{cploss(l)}$*rloss(l) --→(9)

c. At last final the total loss allocation of k^{th} bus is given as follows

LA(k) = =$\sum_{l=1}^{n\ lines} C(k,l)$ --→(10)

CASE STUDY

A case study of above methods on IEEE-5 bus system is illustrated to test the performance. This system is having two generators and four loads and is represented by the bus power injections. The solution of the power flow obtained by NR method. Let us assume the real power loss for 5 bus system is 9.602MW. Table–1 shows the results of loss allocation for the three methods of IEEE 5 bus system

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Table-1

Bus	Loss allocation in MW (total loss = 9.604MW)		
	2^{nd} method	3^{rd} method	4^{th} method
1	3.671	4.1768	4.26
2	1.7132	0.863	0.66
3	1.3098	1.3416	1.46
4	1.164	1.1892	1.3
5	1.746	2.0334	1.924
Total	**9.604**	**9.604**	**9.604**

Table-2 shows the results of transmission loss allocation for the three methods of IEEE 30–bus system

Table-2

Bus	Loss allocation in MW (total loss = 9.604MW)		
	2^{nd} method	3^{rd} method	4^{th} method
1	17.6628	18.7134	19.666
2	3.933	2.0644	1.088
3	0.1594	0.098	0.15
4	0.5048	0.407	0.486
5	6.2576	-17.2568	6.112
6	0	0	0
7	1.5146	25.5244	1.472
8	1.9928	1.1738	1.974
9	0	0	0
10	0.3852	0.3738	0.612
11	0.6642	0.6446	0.844
12	0.744	0.6	0.654
13	0.6642	0.5358	0.82
14	0.4118	0.3936	0.412
15	0.5448	0.5446	0.54
16	0.2324	0.216	0.212
17	0.5978	0.5986	0.552
18	0.2126	0.2358	0.218
19	0.631	-7.7496	0.616
20	0.1462	8.638	0.15
21	1.1624	1.2846	1.094
22	0	0	0
23	0.2126	0.2332	0.206
24	0.578	-2.9862	0.608
25	0	0	0
26	0.2324	-2.9646	0.324
27	0	0	0
28	0	0	0
29	0.1564	1.6352	0.232
30	0.7042	7.3872	1.248
Total	**40.30**	**40.30**	**40.30**

Observations:

a. 2nd method does not consider the network. It allocate the losses to the generators and loads marginally and it is independent of transmission line distance.
b. In proportional sharing principle method, with the consideration of network the looses were allocated.
c. In bus wise allocation method, losses were allocated by using the circuit laws.
d. In postage stamp method, the participant with more contribution will more benefited compared with others.
e. In proportional sharing principle method, the customers were not benefitted reasonably.
f. Hence bus wise allocation is the good method to allocate the transmission losses accurately compared with the remaining.

CONCLUSION

From the above four methodologies the following conclusions can be drawn

Pro rata method is similar to the postage stamp method. Postage stamp method is the simple and transparent to implement it does not take the network in to consideration and allocates the fixed real power loss to the participants irrespective of distance between the generators and loads.

Proportional sharing method takes the network in to consideration and allocates the real power losses proportionally to all the transactions. But here assumptions are made that the line inflows are equal to the line out flows. This method does not depend up on the choice of the slack bus.

Bus wise loss allocation method overcomes the all disadvantages and allocates the real power losses directly by using simple circuit laws. This method gives accurate results compared to the other two methods.

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About authors:

1.Mr.Luke John Baktha Singh Immaraju is currently a research scholar with the Department of Electrical and Electronics Engineering, JNTUA, Ananthapuramu, Andhra Pradesh, INDIA. His current research interests include Transmission System Expansion Planning, data mining application to power systems, smart grids and governing standards.

2.Dr.B.Venkata Prasanth is currently working as Professor and Head of the department with the Department of Electrical and Electronics Engineering, QIS College of Engineering and technology, Ongole, Andhra Pradesh, INDIA. His area of interest is Power Systems in deregulated environment. Under him Scholars are doing their research in various universities in INDIA.

3.Dr.V.Ganesh is currently working as Professor with the Department of Electrical and Electronics Engineering, JNTU College of Engineering, Pulivendula, Kadapa D.t., Andhra Pradesh, INDIA. His area of interest is Power Systems in deregulated environment. Under him Scholars are doing their research in various universities in INDIA.