Power Tracing And Loss Allocation In A Power System By Using Bialek's Algorithm

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***Abstract*— In electric power system a fair transmission pricing scheme is an important issue. The issue of power tracing helps to evaluate a fair and transparent tariff. A power tracing method would make it possible to charge the generators and consumers on the basis of actual transmission used. It can determine which the most economical line is to supplies the consumer. Power tracing method helps to find which line is having more transmission losses. Power tracing helps and supports efficient operation of power system. Heavily loaded line having the more number of losses, so that loss calculation is the important problem which reduces the power transmission performance. The application of the technique is explained using 5 bus test system.**

***Keywords*— Power Tracing, loss calculation power system economics, Bialek's tracing methods, deregulated power system**

I. INTRODUCTION

Power system operation in electricity supply systems has been experiencing dramatic changes due to the ongoing restructuring of the industry. The changing of operation from regulated power system to re-regulation or deregulations is to increase competition and bring consumers economic benefits and new choices. In deregulated power system all the functions in power like; generation, transmission, distribution and retail sales are different companies devoted to each function. For the consumers the electricity bill now involves at least two components: one from the distribution and transmission network- operator responsible for the network and services, and the other from the system that generates the electrical energy.The regulated power industry is changed to deregulated power system which led to an important increase in power wheeling transactions. In market structure a transmission system uses multiple generation and load entities that do not enclose the transmission system. In deregulated power system it is very important to know the function of individual generators and loads to transmission lines and power transfer between individual generators to loads.

This tracing method helps to find the power transfer between individual generators to loads. Tracing method determines the contribution of transmission users to transmission usage. Tracing methods is also used for transmission pricing and recovering fixed transmission costs.

The power flow tracing algorithm is a mechanism for tracing the contribution of each user on a transmission system to allocate charges for using the transmission line. Its work is based on the concepts of Kirchhoff's current law and proportional sharing principle. In deregulated power system using Bialek's power tracing technique, describes which generators are supplying a particular load, how much use each generator is making of a transmission line and what is each generator's contribution to the system losses. The technique is not limited to incremental changes and is applicable to both active and reactive power. From the starting of a power flow solution, first identify the busses and then find the set of busses supplied to the same generators. It is possible to calculate the contribution of each generator to the load and flows by using proportional sharing principle.

II. POWER TRACING

It is very important to know the function of individual generators and loads to transmission lines and power transfer between individual generators to load in a power system. The power tracing methods helps to know the power transfer between individual generator to loads. Tracing methods determine the contribution of transmission user to transmission usage. It is also used for transmission pricing. The methods proposed for tracing the power flow are upstream and downstream algorithms[1].

A .Power Tracing Methods:

- Node method
- Graph method
- Method of common
- Bialek's tracing algorithm

III. NODE METHOD

In a meshed transmission network there are number of possible routes by which electrical power can flow from sources to sinks. It is possible to determine relation between the generators/loads and the flows in transmission lines by means of sensitivity analysis, that is by determining how a change in nodal generation/demand influences the flow in a particular line.[2].

A. Characteristics of Nodal Method:

(i) Before the application of this method the transmission losses must be removed from the lines.
(ii) Nodal method is a very slow process.
(iii) Matrix calculation is more complex for a big network.
(iii) This method only suitable for system with loop flows can handle cyclic flows in the system
(iv) For reactive power tracing this method requires the artificial nodes. [5].

IV. GRAPH METHOD

This method assumes that a generator has the priority to provide power to the load on the same bus. The remaining power will enter the network to supply other loads in the network to avoid unnecessary losses. According to a transaction contract a generator does not sell electricity to the local load and based on the following graph theory[2][12].

(i) Lines carrying the outflows for a generator bus with all incident.

(ii) Lines carrying inflows for a load bus with all incident. [12].

A. *Characteristics of Graph Method :*

(i) Before the application of this method the transmission losses must be removed.
(ii)Using graph method Extraction factor, Contribution factor matrices and sparse calculation is very simple.
(iii)This method does not handle loop flows, but is able to detect loop flows.
(iv) A generator has the priority to provide power to the load on the same bus[5] .

V. METHOD OF COMMON

This technique can be applied to both active and reactive power. The objective is to calculate the contribution, the percentage of a given flow or load in the network supplied by a certain generator. These calculations are based on the concept of proportionality.

A. *Characteristics of Method of Common:*

(i) The transmission losses can be directly accounted for and the contributions to them calculated.
(ii)The contribution factors and the outflows of a load are constant to all loads.
(iii)Easy to implement for large system.
(iv)The size and shape of a Common is subjected to change radically even with a small change in the direction of line flows.[2][5].

VI. BIALEK'S TRACING METHOD

In Bialek's tracing method, it is assumed that nodal inflows are shared proportionally among nodal outflows. This method determines the contribution of individual generators or loads to every line flow based on the calculation of topological distribution factors. This method can deal with both dc and ac power flows that is, it can be used to find contributions of both active and reactive power flows.

Bialek's tracing method is used to determine how much of a particular generators output supplies a particular load or how much of a particular load is supplied by a particular generator. Topological distribution factors calculated in this method are always positive; therefore this method eliminates the counter flow problem. The main principle used to trace the power flow will be that of proportional sharing principle. This method uses either the upstream looking algorithm or the downstream looking algorithm.[3][5].

VII. DOWN STREAM

(FLOW TRACING FROM A GENERATOR TO LOAD)

In downstream looking algorithm the transmission usage/supplement charge is allocated to individual loads and losses are allocated to generators. [7-10].

VIII. UP STREAM

(FLOW TRACING FROM A LOAD TO GENERATOR)

In the upstream looking algorithm the transmission usage/supplement charge is allocated to individual generators and losses are allocated to the load [4][7-10].

IX. PROPORTIONAL SHARING PRINCIPLE:

The proportional sharing principle is based on Kirchhoff's current law. It deals with a general transportation problem and assumes that the network node is a perfect mixer of incoming flows. Practically the only requirement for the input data is that Kirchhoff's current law must be satisfied for all the nodes in the network. In this respect the method is equally applicable to ac as well as dc power flow. The nodal sum i.e. total incoming and total outgoing power at node is equal.

The main principle used to trace the flow of electricity will be that of proportional sharing is shown in Fig1. In this, four lines are connected to node **a,** with two inflows and with two with outflows.

The total power flow through the node is Pa = 40 + 60 = l00MW of which 40% is supplied by line *j-a* and 60% by line *k-a*.

According to proportional sharing principle.

The 70MW outflowing in line a-m consists of

$$70 * \frac{40}{100} = 28MW$$ supplied by line *j-a* and

$$70 * \frac{60}{100} = 42MW$$ supplied by line *k-a*.

Similarly the 30MW outflowing in line *a-n* consists of

$$30 * \frac{40}{100} = 12MW$$ supplied by line *j-a* and

$$30 * \frac{60}{100} = 18MW$$ supplied by line *k-a*.

The proportional sharing principle basically amounts to assuming that the network node is a perfect ‘mixer’ of incoming flows so that it is impossible to tell which particular inflowing electron goes into which particular outgoing line. The principle is fair as it treats all the incoming and outflowing flows in the same way.

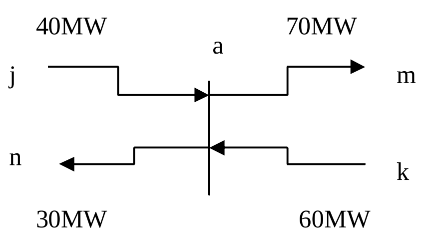

Fig.1 Proportional sharing principle

X. FLOW TRACING FROM A GENERATOR TO A LOAD (DOWN STREAM TRACE)

In the upstream looking algorithm the transmission usage/supplement charge is allocated to individual generators and losses are allocated to loads. Upstream tracing gives the information about the contribution of each generator to each transmission line and the load. When the distribution of power flow has been assigned, starting from the load node, according to a user’s power flow paths and the contribution factor of each node, the relation between load and line flow can be conformed, as well as that between load and generator output[1][7-10].

The total flow Pi, the outflow to the ith bus, is the sum of all the outflows through the lines connected to the bus and the local bus load

$$P_i = \left(\sum_{l\varepsilon\mu} |P_{i-l}|\right) + P_{Li} \qquad \text{For i=1,2,….n} \qquad (1)$$

where μ is the set of nodes directly supplied from node *i*, implying power flowing from the ith node. If the line losses are neglected, then $|P_{l-i}| = |P_{i-l}|$ .Equation (1) can be further expanded into:

$$P_i = \left(\sum_{l\varepsilon\mu} \left|\frac{P_{l-i}}{P_l}\right| P_l\right) + P_{Li} \qquad \text{For i=1,2,…n} \qquad (2)$$

Where $C_{li} = \frac{|P_{l-i}|}{P_l}$ expressing relationship between line flow and the nodal flow at the lth node and using proportional sharing principle, $|P_{l-i}| = C_{li} P_l$. Substituting this in (2) which gives

$$P_i - \sum_{l\varepsilon\mu} C_{li} P_l = P_{Li} \qquad (3)$$

(Or)

$$A_d P = P_L$$

P is the vector of net nodal powers; PL is the vector of nodal load demands, while Ad is called the Downstream matrix

$$[A_d]_{il} = \begin{cases} 1 \\ -C_{li} = -\dfrac{|P_{l-i}|}{P_l} \\ 0 \end{cases} \qquad (4)$$

Where,

1	for i=l
C_{li}	for all possible cross flows
0	for otherwise

The ith element of $P = A_d^{-1} P_L$ shows the distribution of the ith nodal power between all the loads in the system. In summation form

$$P_i = \sum_{K=1}^{n} \left[A_d^{-1} \right]_{ik} PLK \quad \text{for i=1,2,....n} \quad (5)$$

The inflow to node *i* from line *i-l* can be calculated using the proportional sharing principle as

$$P_{i-l} = \frac{|P_{l-i}|}{P_l} \sum_{K=1}^{n} \left[A_d^{-1} \right]_{ik} PLK \quad \text{for i=1,2,…n} \quad (6)$$

this equation allows to determine how the line flows supply individual loads. The generation at a node is also an inflow and can be calculated using the proportional sharing principle as

$$P_{Gi} = \frac{P_{Gi}}{P_i} \sum_{k=1}^{n} \left[A_d^{-1} \right]_{ik} PLK \quad \text{for i=1,2,…n} \quad (7)$$

$$P_{Gi} = \frac{P_{Gi}}{P_i} P_i$$

This equation again shows that the share of the output of the generator used to supply the load demand.

XI FLOW TRACING FROM A LOAD TO A GENERATOR (UPSTREAM TRACE)

In downstream looking algorithm the transmission usage/supplement charge is allocated to individual loads and losses are allocated to generators. Downstream tracing provides the information about the amount of load power shared by the transmission line and the generator. When the distribution of the power flows has been assigned, starting from the generator, according to the paths of the generator's output and the contribution factor of each node, the relationship between the generator output and line power flow or load can be determined, as well as branch loss that each generator should allocate[4][7-10].
The total flow , the inflow to the ith bus, is the sum of all the inflows through the lines connected to the bus and the local bus injection.

$$P_i = \left(\sum_{j \varepsilon \Re} |P_{i-j}| \right) + P_{Gi} \quad \text{for i=1,2,….n} \quad (8)$$

Where gamma is the set of nodes directly supplying node *i*, implying Power flow towards ith node. If the line losses are neglected, then $|P_{j-i}| = |P_{i-j}|$. Equation (8) can be further expanded to

$$P_i = \left(\sum_{j \varepsilon \Re} \left| \frac{P_{j-i}}{P_j} \right| P_j \right) + P_{Gi} \quad \text{for i=1,2,…n} \quad (9)$$

Where $C_{li} = \frac{|P_{j-i}|}{P_j}$ to express relationship between line flow and the nodal flow at the Jth node, using proportional sharing principle $|P_{j-i}| = C_{ji} P_j$, substituting this in (2) which gives

$$P_i - \sum_{j \varepsilon \Re} C_{ji} P_j = P_{Gi} \qquad (10)$$

(or)

$$A_u P = P_G$$

P is the vector of gross nodal flows; PG is the vector of nodal generations, while $Au$is called the Upstream matrix,

$$\left[A_u \right]_{ij} = \begin{cases} 1 \\ -C_{ji} = -\dfrac{|P_{j-i}|}{P_j} \\ 0 \end{cases} \qquad (11)$$

Where,

1	for i=j
C_{li}	for all possible net flows
0	for other wise

The ith element of $P = A_u^{-1} P_G$ shows the participation of the ktgeneration to the ith nodal flow and determines the relative participation of the nodal generations in meeting a retailer's demand, given as:

$$P_i = \sum_{K=1}^{n} \left[A_u^{-1} \right]_{ik} PGK \quad \text{for i=1,2,....n} \quad (12)$$

A line out flow in line *j-i* from node *i* can be therefore calculated using proportional sharing principle ,as

$$P_{j-i} = \frac{|P_{j-i}|}{P_i} \sum_{K=1}^{n} \left[A_u^{-1} \right]_{ik} PGK \quad \text{for i=1,2,…n} \quad (13)$$

Finally, load demand at the ith bus, applying the proportional methodology is given by:

$$PLi = \frac{PLi}{Pi} \sum_{k=1}^{n} \left[A_u^{-1} \right]_{ik} PGK \quad \text{for i=1,2,…n} \qquad (14)$$

$$PLi = \frac{PLi}{Pi} Pi$$

This equation shows the contribution of the ith system generator to the kth load demand and can be used to trace where the power of a particular load comes from.

XIII.PROPORTIONAL SHARING OF LOOSES

Total loss=actual demand-cross demand for upstream algorithm.
Total loss=actual demand-net demand for downstream algorithm.

XIV. RESULT AND DISCUSION

The 5-bus system is simulated in power world simulator which involves different transaction locations. The power flow tracing method directly provides the contribution of each generator to the corresponding line. This resulting in lesser number of generators participating in the process of rescheduling is to reduce the transmission pricing as well as provide fair and fixed transparent tariff to the consumer and generators. The proportional sharing approach via upstream and downstream algorithm has been tested on 5-bus system using MATLAB programing. Power flow tracing algorithm gives better optimal solution and results and the loss allocation of individual generator and individual loads are tabulated.

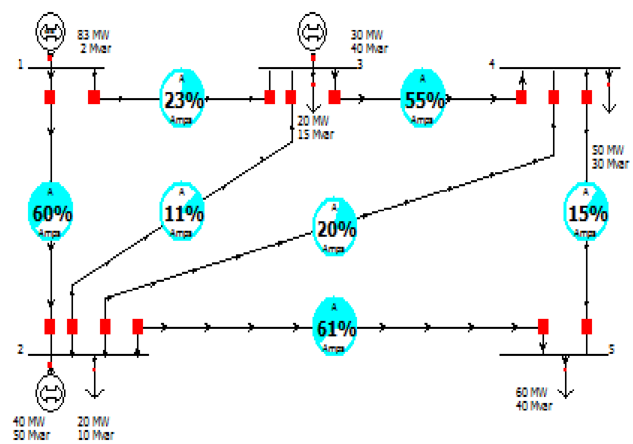

Fig.2.5-Bus power world simulation

Table 1.Bus records

Bus Records							
Number	PU Volt	Volt (kV)	Angle (De	Load MW	Load Mvar	Gen MW	Gen Mvar
1	1	138	0			83.48	1.61
2	0.98758	136.287	-2.08	20	10	40	50
3	0.97649	134.756	-3.16	20	15	30	40
4	0.96247	132.82	-3.77	50	30		
5	0.92803	128.068	-5.01	60	40		

Table 2.Load flow results

Load flow results							
From no	To No	MW From	Mvar From	MVA From	% of MVA	MW Loss	Mvar Loss
1	2	60.2	0.2	60.2	60.2	0.72	-0.79
1	3	23.3	1.4	23.3	23.3	0.44	-1.12
2	3	11	1.6	11.1	11.4	0.08	-1.69
2	4	18.2	7	19.5	19.7	0.24	-1.17
2	5	50.2	32.5	59.9	59.9	1.49	3.09
3	4	43.8	30.8	53.5	53.5	0.3	-0.03
4	5	11.4	8.9	14.5	15.4	0.2	-1.63

Table 3.Line data for the test system

Line data for the test system								
From No	To No	Status	Branch	Xfrmr	R	X	B	Lim A
1	2	Closed	Line	NO	0.02	0.06	0.03	100
1	3	Closed	Line	NO	0.08	0.24	0.025	100
2	3	Closed	Line	NO	0.06	0.18	0.02	100
2	4	Closed	Line	NO	0.06	0.18	0.02	100
2	5	Closed	Line	NO	0.04	0.12	0.015	100
3	4	Closed	Line	NO	0.01	0.03	0.01	100
4	5	Closed	Line	NO	0.08	0.24	0.025	100

Table 4. Bus power(i-j)

Power transfer from(i-j)			
S.no	From no	To no	p(i-i) trans
1	1	2	60.2
2	1	3	23.3
3	2	3	11
4	2	4	18.2
5	2	5	50.2
6	3	4	43.8
7	4	5	11.4

Table 5.Result for upstream-looking algorithm.
(contribution of load to generator)

LOAD/GEN	G1	G2	G3	TOTAL	LOSS
L2	12.09	8.04	0	20.13	0.13
L3	9.3931	1.387	9.408	20.188	0.1881
L4	25.8333	8.444	16.895	51.172	1.172
L5	36.27	22.112	3.852	62.234	2.234

Table 6.Results for downstream-looking algorithm.
(contribution of generator to load)

GEN/LOAD	L2	L3	L4	L5	TOTAL	LOSS
G1	11.958	9.286	25.17	34.764	81.178	2.302
G2	8.04	1.387	8.329	21.447	39.203	0.797
G3	0	9.48	16.774	3.756	30.01	0.01

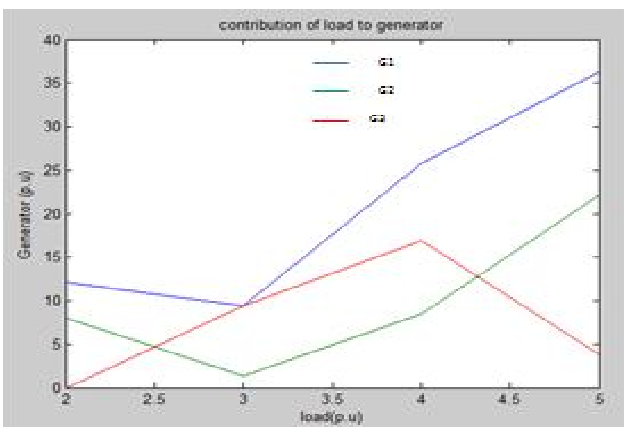

Fig. 3.contribution of load to generator

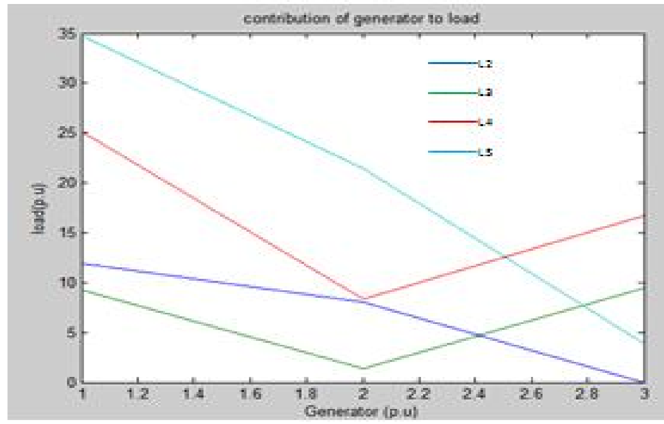

Fig.4.contribution of generator to load

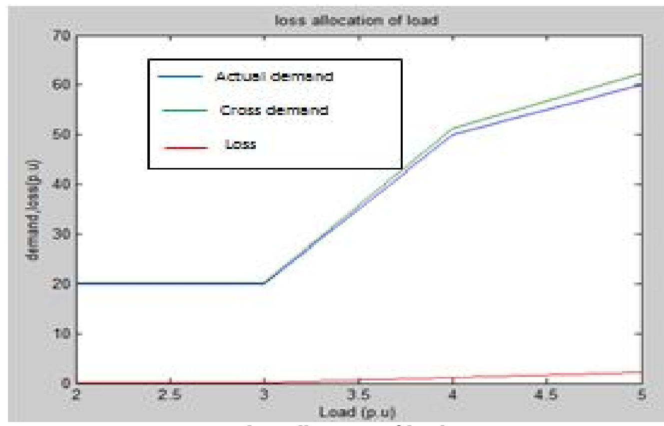

Fig.5.loss allocation of load

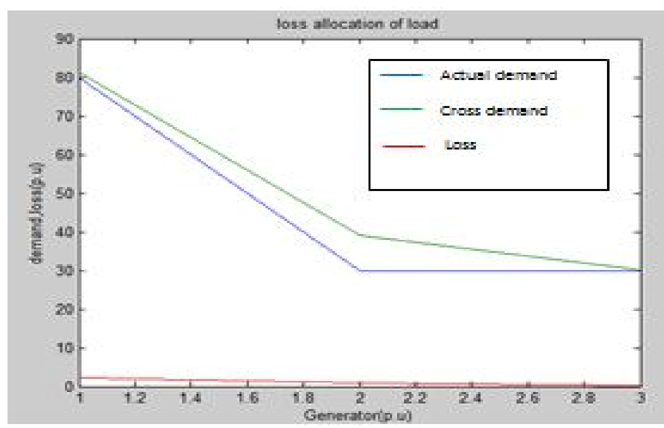

Fig.6.loss allocation of generator

XV. CONCLUTION

In deregulated power system, generation, transmission, and distribution are individual activities. This method is applied to the real power flow, results in two different algorithms applicable for two different purposes. The upstream-looking algorithm determines the gross power flow which shows how the power output from each of the generators would be distributed between the loads if the network was lossless. For each load, the difference between the gross and the actual power demand gives a transmission loss associated with supplying this load. A dual to that is the downstream-looking algorithm resulting in the net power flow. This shows how the actual demand of each of the loads would be distributed between individual generators if the network was lossless. For each generator, the difference between the actual and the net generation gives the transmission loss associated with the generator. The results corresponding to the bialek's tracing algorithm (upstream and downstream looking algorithm) are shown in table.

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