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Tracing Generators' Output in Transmission Open Access

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Abstract--**Over the past few years, the electric power utility industries around the world have experienced a strong drive towards deregulation. Based on the experience of deregulation of the communication, natural gas and airline industries, the deregulation of electric utilities is necessary for high efficiency and energy saving. In developed countries, after decades of government regulation and protection, the traditional vertical integrated electric utilities have been criticized as ineffectively monopoly sectors. Customers have to pay expenses to utilities due to low efficiency operation and improper policy. However, deregulation may bring fair pricing and open access to all users. Regardless of market structure, it is important to know the contribution of particular generator to particular load and line flow. Due to nonlinear nature of power flow, it is difficult to determine transmission usage in the network accurately. Thus, models and tracing algorithms will become very heuristic in order to allocate the power flow and loss in transmission networks. This paper discussed a method for tracing the power flow and loss in the deregulated transmission system. Based on converged load flow, basic circuit theories including superposition theory, equivalent impedance and equivalent current injection are applied in developing this method. Then, the voltages, currents, power flows and losses contributed by every generator in the system could be traced. An IEEE-14 bus test system has been used and the results found to be effective in testing this method. Result comparisons of previous method is also been discussed.**

Index Terms**-- Deregulation, Power Flow Tracing, Proportional Sharing Principle, Superposition Law, Open Access.**

I. INTRODUCTION

IN transmission open access, it is interesting to know, which power plants supply a particular line flow and how much its contribution to the loads. The studies of this area are enhanced and developed year by year to give the opportunity to researchers to come out the algorithms for power tracing. Since the nonlinear nature of power flow, it is difficult to trace the power flow and loss in the meshed network accurately. In this paper, an algorithm that uses basic circuit theories including superposition theory, equivalent impedance and equivalent current injection are applied. To date several tracing algorithms have been proposed in the literatures [1]-[11].

In [2]-[5], a novel tracing method that use proportional sharing assumption is presented. In this paper, two tracing algorithms were proposed, upstream-looking and downstream-looking algorithm. The upstream-looking algorithm will apportion the losses to the loads and allocate the supplement charge to the generators while downstream-looking algorithm will apportion the losses to the generators and allocate the supplement charge to the loads. Even though the approach is conceptually simple, it requires inverting a sparse matrix of the rank equal to number of networks nodes.

The method based on organization of the buses and branches of the network into homogenous group was proposed in [6, 7]. In the method, the network characteristics including 'domains', 'commons' and 'links' need to be defined first and then the contribution of a load or generator to a line can be obtained. The disadvantage of this method is the share of each generator in each 'common' is assumed to be same. In addition, since the topology of 'common' could radically change even the case of slight change in power flows, this concept can lead into problems.

The method that uses real and imaginary currents to trace the generators' output was proposed in [8]. This technique does not require modeling line losses and automatically becoming lossless real and imaginary current networks. However, the method still involves the disadvantages of concept in [6, 7]. In [9, 10], proposal of the charging of transmission losses under trading arrangement is reported. This method makes some modification of the method that proposed in [2]-[5]. One of the modifications is introduction of decoupled power flow of line instead of additional fictitious node. However, the size of the matrix is still large if this method is applied to large system.

In [11], three-bus oriented schemes based on generalized generation distribution factors (GGDFs) and generalized load distribution factors (GLDFs) were proposed to allocate the transmission losses to market participants. This bus-oriented method is aimed to reducing the distribution factor computation and reflecting the activity in a competitive market.

Basically, the algorithm's development in this paper is referred to [1]. In [1], the concerned of the author is regarding singular characteristic of full admittance matrix that will brings the additional formulas to overcome the singular problem. From [1] also, the equations are reviewed and improved.

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II. APPROACH

This paper will emphasize on the method that has been proposed in [1]. Based on [1], equations are reviewed and reduced to meet the requirement of power tracing algorithm. This method is named as Superposition theory method due to usage of superposition law as a foundation in this algorithm's development.

After power flow solution is obtained, we can identify voltage magnitudes, angles, total real power and reactive power for each bus in the network. The bus system then can be identified as slack bus, generator bus (PV bus) and load bus (PQ bus). The generator bus (including slack bus) can be treated as equivalent current injection and load bus as equivalent impedance. The apparent power of a generator bus *n* and its corresponding equivalent current injection can be expressed as [1]:

$$S_{n,G} = \left(P_{n,G} + jQ_{n,G}\right) \tag{1}$$

$$I_{n,G} = \left(\frac{P_{n,G} + jQ_{n,G}}{V_{n,G}}\right) \tag{2}$$

Where n is number of generator, $V_{n,G}$ is the generator bus voltage, $P_{n,G}$ is the real power and $Q_{n,G}$ is the reactive power for the generator bus. Those elements can be obtained from load flow study.

In a power system, generators and loads are not the only sources and/or sinks of complex power. Static Var Compensators (SVCs), transformer, shunt capacitors/reactors and line charging capacitances play a vital role in transferring power between suppliers and customers. Thus, in this paper will take this effect into corresponding equivalent impedance that derived from [1]. For a load bus i,the corresponding equivalent impedance ($Z_{i,L}$) can be derived as:

$$Z_{i,L} = \frac{V_{i,L}}{I_{i,L}} = \frac{\left|V_{i,L}\right|^2}{P_{i,L} - j\left(Q_{i,L} - Q_c\right)} \tag{3}$$

Where $V_{i,L}$, $I_{i,L}$ and $S_{i,L} = [P_{i,L} - j(Q_{i,L} - Q_c)]$are the voltage, current and apparent power of load bus i including effect of injected MVAR that obtained from the converged load flow solution respectively. After the equivalent impedance is integrated into the admittance matrix, the relation between bus voltage and bus current injection can be expressed as [1]:

$$V_{BUS} = Z_{MATRIX} I_G \tag{4}$$

Where $V_{BUS,}$, I_G and Z_{MATRIX} are the bus voltage vector, current injection vector and impedance matrix including the effect of the equivalent impedance respectively. The effect of slack bus is also included in this equation.

III. TRACING THE VOLTAGE AT BUS FROM EACH GENERATOR

To trace the voltage at each bus, we use superposition law as a foundation of this method's development. By using superposition law, only one generator is connected to the system and at the same time the other generators in the system are open circuit. By taking the generators into account one by one, we can express the voltage contribution of each generator to each bus as [1]:

$$\begin{bmatrix} \Delta v_1^n \\ \vdots \\ \Delta v_n^n \\ \vdots \\ \Delta v_N^n \end{bmatrix} = \begin{bmatrix} z_{11} & \cdots & z_{1n} & \cdots & z_{1N} \\ \vdots & \ddots & \vdots & \iddots & \vdots \\ z_{n1} & \cdots & z_{nn} & \cdots & z_{nN} \\ \vdots & \iddots & \vdots & \ddots & \vdots \\ z_{N1} & \cdots & z_{Nn} & \cdots & z_{NN} \end{bmatrix} \begin{bmatrix} 0 \\ \vdots \\ I_{n,G} \\ \vdots \\ 0 \end{bmatrix} \tag{5}$$

From the expression above, voltage at bus i contributed by generator bus n (Δv_i^n) and the voltage of bus i contributed by all generator buses can be written as [1]:

$$\Delta v_i^n = z_{in} * I_{n,G} \tag{6}$$

$$V_i = \sum_{n=1}^{N_G} \Delta v_i^n \tag{7}$$

From these equations, it can be seen that the voltage contributions of each generator to each bus can be calculated easily. This information is very important to calculate the power flow and loss allocation.

IV. TRACING THE CURRENT THROUGH EACH LINE

Based on the circuit theory concept and referring to figure 1, the current flow at each line in deregulated network can be determined as:

$$\Delta i_{ij}^n = \left(\Delta v_i^n - \Delta v_j^n\right)\left(g_{ij} + jb_{ij}\right) + \left(jc/2\right)\left(\Delta v_i^n\right) \tag{8}$$

$$\Delta i_{ji}^n = \left(\Delta v_j^n - \Delta v_i^n\right)\left(g_{ij} + jb_{ij}\right) + \left(jc/2\right)\left(\Delta v_j^n\right) \tag{9}$$

Where $y_{ij} = (g_{ij} + jg_{ij})$ is the line admittance from bus i to j and $c/2$ is the line charging susceptance. Δi^n_{ij} and Δi^n_{ji} are the line currents, produced by generator bus n, from bus i to bus j and from bus j to bus i, respectively.

V. TRACING POWER FLOW AND LOSS

Since the voltage and current at the bus has been identified, the power flow at every line and the loss in the system can be calculated. The power flow from bus i to bus j and the loss produced by generator n at each line can be expressed [1]:

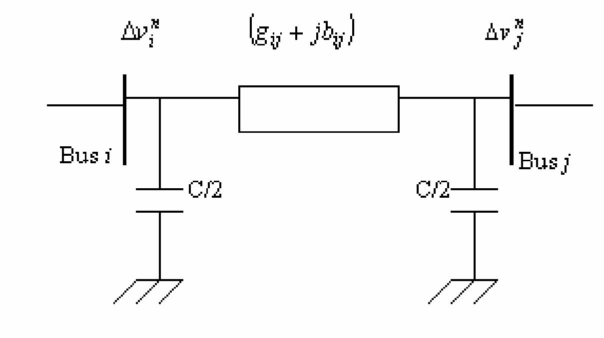


Fig. 1 A Transmission line section model

$$\Delta s_{ij}^{n}=V_i\left(\Delta i_{ij}^{n}\right)^{*} \tag{10}$$

$$P_{ij,Loss}^{n}=\mathrm{Re}\left(\Delta s_{ij}^{n}\right)+\mathrm{Re}\left(\Delta s_{ji}^{n}\right) \tag{11}$$

The power from generator to a load also can be calculated by the same procedure, which is:

$$\Delta i_{i,L}^{n}=\frac{\Delta v_i^{n}}{Z_{i,L}} \tag{12}$$

Where $\Delta i^{n}_{i,L}$ is the current injection of a load bus contributed by generator bus n. Therefore the power of load bus i contributed by generator bus n can be written as:

$$\Delta s_{i,L}^{n}=V_i\left(\Delta i_{i,L}^{n}\right)^{*} \tag{13}$$

The correctness of this method can be verified by comparing the results obtained by expressions above with the converged power solution.

VI. PROPORTIONAL SHARING METHOD IN SHORT

Proportional sharing method is proposed in [2]-[5]. This method is based on proportional sharing principle and aims at tracing the flows of electricity through power networks. It allows quantifying how much of the active and reactive power flows from a particular source to specific load. It also allows quantifying the contribution from each generator or load to flows and losses in a given line.

Tracing the generators' output that proposed in [2]-[5] consists of several algorithms. The simplest algorithm is using average line flows. This algorithm is to average the line flows over sending and receiving-end values and adjusted correspondingly the nodal injections. The other approaches are to consider gross flows that are flows that would exist if no power were lost in the network and the approach to consider the net flows when all the losses are removed from the network. While to trace the reactive power, the additional fictitious line node is introduced. To do some comparison with Superposition theory method, we will discuss the novelties of gross flows.

A. Tracing real power using gross flows

The gross nodal power, when looking at the inflows (upstream-looking algorithm), can be expressed as [3, 5]:

$$P_i^{(gross)}=\sum_{j\in\alpha_i^{(u)}}\left|P_{i-j}^{(gross)}\right|+P_{Gi}\quad \text{for } i=1,2,3\ldots,n \tag{14}$$

Where α_i^{u} is set of nodes supplying directly node i (i.e, power must flow towards nodded i in the relevant lines), P_{Gi} is the generation in node i and P_{i-j} is the line flow into node i in the line j-i. Then, we can say that $|P_{ij}^{(gross)}| = |P_{ji}^{(gross)}|$.The line flow $|P_{ij}^{(gross)}| = |P_{ji}^{(gross)}|$ can be related to the nodal flow at node j by substituting $|P_{ij}^{(gross)}| = c_{ji}^{(gross)}.P_j^{(gross)}$, where $c_{ji}^{(gross)} = |P_{ji}|/P_j$, to give:

$$P_i^{(gross)}=\sum_{j\in\alpha_i^{(u)}}c_{ji}^{(gross)}.P_j^{(gross)}+P_{Gi} \tag{15}$$

This, on rearrangement becomes:

$$P_i^{(gross)}-\sum_{j\in\alpha_i^{(u)}}c_{ji}^{(gross)}.P_j^{(gross)}=P_{Gi}\ \text{ or }\ A_uP_{gross}=P_G \tag{16}$$

Where A_u is the $(n\ x\ n)$ upstream distribution matrix, P_{gross} is the vector of nodal through-flows and P_G is the vector of nodal generations. The (i, j)-th element of A_u is equal to [2]-[5]:

$$\left[A_u\right]_{ij}=\begin{cases}1 & for\quad i=j\\ -c_{ji} & for\quad j\in\alpha_i^{(u)}\\ 0 & otherwise\end{cases} \tag{17}$$

Note that A_u is sparse and non-symmetric. If A_u^{-1} exists, then $P_{gross} = A_u^{-1}P_G$ and i-th element is [3]:

$$P_i^{(gross)}=\sum_{k=1}^{n}\left[A_u^{-1}\right]_{ik}P_{GK}\qquad \text{for } i=1,2,3\ldots,n \tag{18}$$

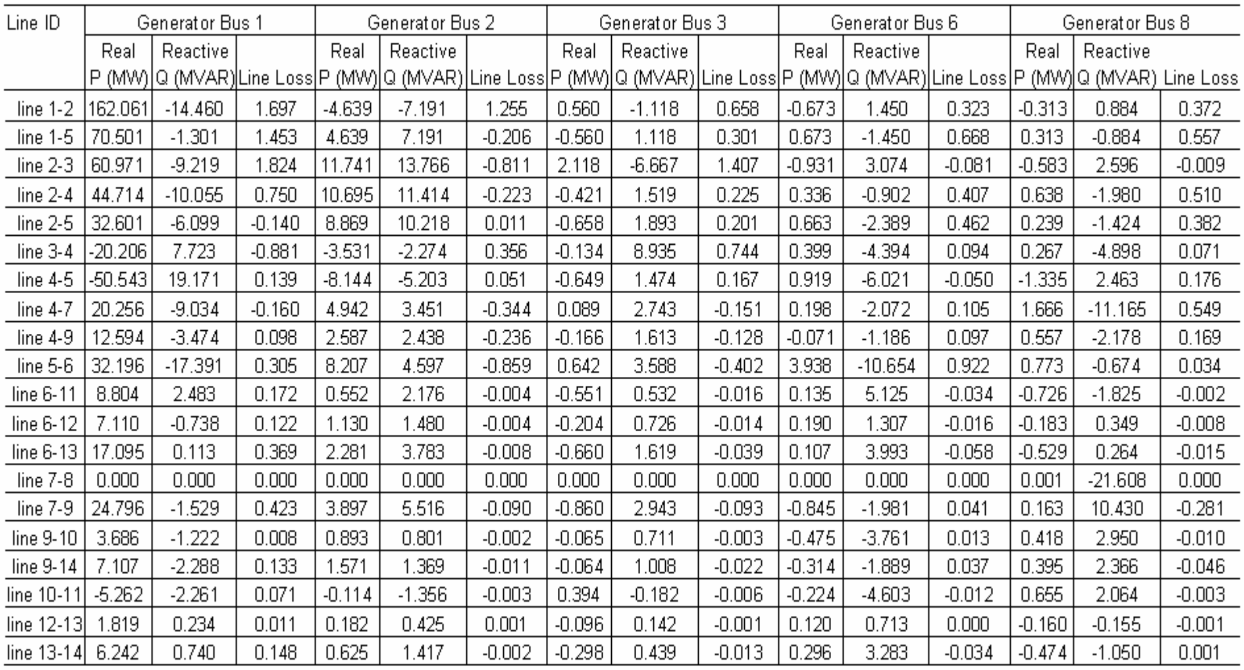
This equation shows that the contribution of the k-th system generator to i-th nodal power is equal to $[A_u^{-1}]_{ik}.P_{GK}$. It can be seen that the same $P_i^{(gross)}$ is equal to the sum of the load demand, P_{Li} and outflows in lines leaving the node i. A line outflows in line i-$l^{(gross)}$ from node i can be therefore calculated. And by using proportional sharing principle, the line flow can be expressed as [5]:

$$P_{i-l}^{(gross)}=\frac{\left|P_{i-l}^{(gross)}\right|}{P_i^{(gross)}}\sum_{k=1}^{n}\left[A_u^{-1}\right]_{ik}P_{GK} \tag{19}$$

Where $\frac{\left|P_{i-l}^{(gross)}\right|}{P_i^{(gross)}}\sum_{k=1}^{n}\left[A_u^{-1}\right]_{ik}$ is called topological distribution factor that is indicating the proportion of power that generator

TABLE I

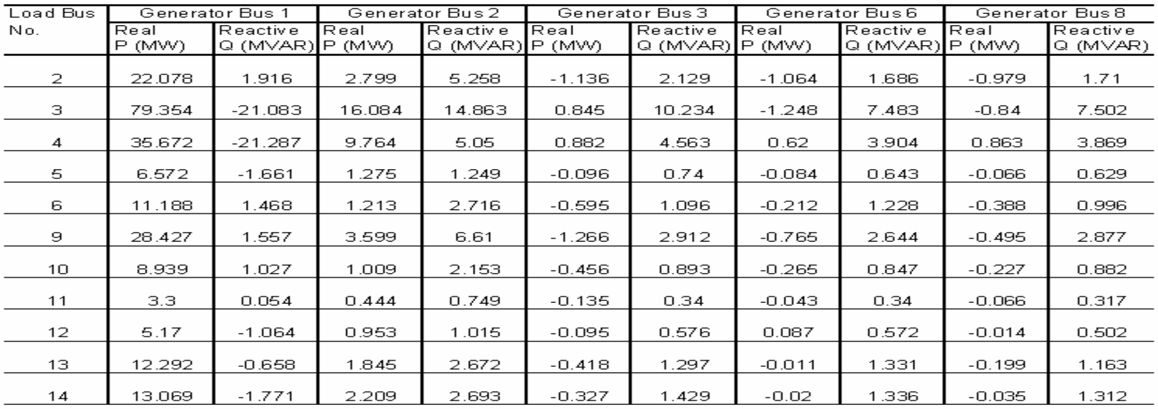
RESULT OF CONTRIBUTION OF INDIVIDUAL GENERATORS TO LINE FLOWS AND ITS LOSSES



Line ID	Generator Bus 1			Generator Bus 2			Generator Bus 3			Generator Bus 6			Generator Bus 8		
	Real P (MW)	Reactive Q (MVAR)	Line Loss	Real P (MW)	Reactive Q (MVAR)	Line Loss	Real P (MW)	Reactive Q (MVAR)	Line Loss	Real P (MW)	Reactive Q (MVAR)	Line Loss	Real P (MW)	Reactive Q (MVAR)	Line Loss
line 1-2	162.061	-14.460	1.697	-4.639	-7.191	1.255	0.560	-1.118	0.658	-0.673	1.450	0.323	-0.313	0.884	0.372
line 1-5	70.501	-1.301	1.453	4.639	7.191	-0.206	-0.560	1.118	0.301	0.673	-1.450	0.668	0.313	-0.884	0.557
line 2-3	60.971	-9.219	1.824	11.741	13.766	-0.811	2.118	-6.667	1.407	-0.931	3.074	-0.081	-0.583	2.596	-0.009
line 2-4	44.714	-10.055	0.750	10.695	11.414	-0.223	-0.421	1.519	0.225	0.336	-0.902	0.407	0.638	-1.980	0.510
line 2-5	32.601	-6.099	-0.140	8.869	10.218	0.011	-0.658	1.893	0.201	0.663	-2.389	0.462	0.239	-1.424	0.382
line 3-4	-20.206	7.723	-0.881	-3.531	-2.274	0.356	-0.134	8.935	0.744	0.399	-4.394	0.094	0.267	-4.898	0.071
line 4-5	-50.543	19.171	0.139	-8.144	-5.203	0.051	-0.649	1.474	0.167	0.919	-6.021	-0.050	-1.335	2.463	0.176
line 4-7	20.256	-9.034	-0.160	4.942	3.451	-0.344	0.089	2.743	-0.151	0.198	-2.072	0.105	1.666	-11.165	0.549
line 4-9	12.594	-3.474	0.098	2.587	2.438	-0.236	-0.166	1.613	-0.128	-0.071	-1.186	0.097	0.557	-2.178	0.169
line 5-6	32.196	-17.391	0.305	8.207	4.597	-0.859	0.642	3.588	-0.402	3.938	-10.654	0.922	0.773	-0.674	0.034
line 6-11	8.804	2.483	0.172	0.552	2.176	-0.004	-0.551	0.532	-0.016	0.135	5.125	-0.034	-0.726	-1.825	-0.002
line 6-12	7.110	-0.738	0.122	1.130	1.480	-0.004	-0.204	0.726	-0.014	0.190	1.307	-0.016	-0.183	0.349	-0.008
line 6-13	17.095	0.113	0.369	2.281	3.783	-0.008	-0.660	1.619	-0.039	0.107	3.993	-0.058	-0.529	0.264	-0.015
line 7-8	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	-21.608	0.000
line 7-9	24.796	-1.529	0.423	3.897	5.516	-0.090	-0.860	2.943	-0.093	-0.845	-1.981	0.041	0.163	10.430	-0.281
line 9-10	3.686	-1.222	0.008	0.893	0.801	-0.002	-0.065	0.711	-0.003	-0.475	-3.761	0.013	0.418	2.950	-0.010
line 9-14	7.107	-2.288	0.133	1.571	1.369	-0.011	-0.064	1.008	-0.022	-0.314	-1.889	0.037	0.395	2.366	-0.046
line 10-11	-5.262	-2.261	0.071	-0.114	-1.356	-0.003	0.394	-0.182	-0.006	-0.224	-4.603	-0.012	0.655	2.064	-0.003
line 12-13	1.819	0.234	0.011	0.182	0.425	0.001	-0.096	0.142	-0.001	0.120	0.713	0.000	-0.160	-0.155	-0.001
line 13-14	6.242	0.740	0.148	0.625	1.417	-0.002	-0.298	0.439	-0.013	0.296	3.283	-0.034	-0.474	-1.050	0.001

TABLE II

LOAD TRACING RESULTS OF IEEE 14-BUS SYSTEM



Load Bus No.	Generator Bus 1		Generator Bus 2		Generator Bus 3		Generator Bus 6		Generator Bus 8	
	Real P (MW)	Reactive Q (MVAR)	Real P (MW)	Reactive Q (MVAR)	Real P (MW)	Reactive Q (MVAR)	Real P (MW)	Reactive Q (MVAR)	Real P (MW)	Reactive Q (MVAR)
2	22.078	1.916	2.799	5.258	-1.136	2.129	-1.064	1.686	-0.979	1.71
3	79.354	-21.083	16.084	14.863	0.845	10.234	-1.248	7.483	-0.84	7.502
4	35.672	-21.287	9.764	5.05	0.882	4.563	0.62	3.904	0.863	3.869
5	6.572	-1.661	1.275	1.249	-0.096	0.74	-0.084	0.643	-0.066	0.629
6	11.188	1.468	1.213	2.716	-0.595	1.096	-0.212	1.228	-0.388	0.996
9	28.427	1.557	3.599	6.61	-1.266	2.912	-0.765	2.644	-0.495	2.877
10	8.939	1.027	1.009	2.153	-0.456	0.893	-0.265	0.847	-0.227	0.882
11	3.3	0.054	0.444	0.749	-0.135	0.34	-0.043	0.34	-0.066	0.317
12	5.17	-1.064	0.953	1.015	-0.095	0.576	0.087	0.572	-0.014	0.502
13	12.292	-0.658	1.845	2.672	-0.418	1.297	-0.011	1.331	-0.199	1.163
14	13.069	-1.771	2.209	2.693	-0.327	1.429	-0.02	1.336	-0.035	1.312

k contributes to line *i-l*. Finally, for load demand share, we can express as [3, 5]:

$$\left|P_{Li}^{(gross)}\right| = \frac{\left|P_{Li}^{(gross)}\right|}{P_i^{(gross)}} \sum_{k=1}^{n} \left[A_u^{-1}\right]_{ik} P_{GK} \tag{20}$$

To obtain the losses, we calculate the difference between the gross demand and actual demand [5]:

$$P_{loss} = P_{Li}^{(gross)} - P_{Li} \tag{21}$$

The exact derivation of other algorithms can be found in [2]-[5].

VII. NUMERICAL EXAMPLES AND DISCUSSION

A number of simulations have been carried out to demonstrate the validity of the method. The method was implementing using Matlab programming language. A load flow program that developed by [12] is used to obtain the system status. The result of IEEE 14-bus test system is presented. Converged bus solution and line parameter data for IEEE 14-bus test case is attached in Appendix.

The active and reactive power flow tracing result is shown in Table 1. The implicit result obtained from (10) is shown here. It can be seen that every generator bus has contribution to the line flows. Note that the contributions from the generator bus 3, 6 and 8 to the line flows. Even though these buses generation of reactive power, it is still have some

TABLE III
REAL POWER CONTRIBUTION FROM INDIVIDUAL GENERATORS TO LOADS

Bus No.	Load (MW)	Superposition Method						Bialek's method			
		Supply Generator Bus					Total (MW)	Supply Generator Bus		Total (MW)	Loss (MW)
		1	2	3	6	8		1	2		
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	21.70	22.08	2.80	-1.14	-1.06	-0.98	21.70	17.68	4.50	22.19	0.48
3	94.20	79.35	16.08	0.85	-1.25	-0.84	94.20	79.28	20.19	99.47	5.27
4	47.80	35.67	9.76	0.88	0.62	0.86	47.80	40.60	10.34	50.93	3.13
5	7.60	6.57	1.28	-0.10	-0.08	-0.07	7.60	8.38	-0.61	7.77	0.17
6	11.20	11.19	1.21	-0.60	-0.21	-0.39	11.21	12.35	-0.90	11.45	0.25
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	29.50	28.43	3.60	-1.27	-0.77	-0.50	29.50	25.05	6.38	31.43	1.93
10	9.00	8.94	1.01	-0.46	-0.27	-0.23	9.00	7.65	1.95	9.60	0.60
11	3.50	3.30	0.44	-0.14	-0.04	-0.07	3.50	5.17	-1.63	3.54	0.04
12	6.10	5.17	0.95	-0.10	0.09	-0.01	6.10	6.79	-0.50	6.30	0.20
13	13.50	12.29	1.85	-0.42	-0.01	-0.20	13.51	15.09	-1.10	13.99	0.49
14	14.90	13.07	2.21	-0.33	-0.02	-0.04	14.90	14.52	1.37	15.89	0.99

contribution to the real power of each line. This result is expected because of the effect of equivalent impedance of the systems. From this table also we can see the loss obtained at each line contributed from each generator by using (11). Table 2 shows the load tracing results obtained using (13). Again, it can be seen the contribution of generator bus 3, 6 and 8 to the real power of each load.

The active power at load bus is presented in Table 3 along with the result obtained through the procedure proposed by Bialek [2]-[5] that we discussed above. Note that the result obtained by superposition method is compared well with the results of [2]-[5]. From Table 3, we can see the result of superposition method is complying with the load demand by using (13). While for Bialek's method, the load demand share is obtained using (20) and the loss is obtained using (21). The disadvantage of this method is we do not know the loss is contributed from which generator.

VIII. CONCLUSION

In this paper, the superposition theory method for tracing generators' output is reported. The method can determine the amount of real and reactive power output from a particular generator to a particular load. The loss allocation of each line, which produced by each generator, can also be obtained. The algorithm is simple and accurate. Accordingly, a small, illustrative network was selected as test case to show simplicity of the method. The method could be used to resolve some difficult pricing and costing issues to ensure fairness and transparency in the power system industry.

IX. APPENDIX

TABLE IV
BUS DATA OF IEEE 14-BUS SYSTEM

Bus No.	Voltage Mag.(V)	Angle (Degree)	Load		Generation		Injected
			MW	Mvar	MW	Mvar	Mvar
1	1.0600	0.0000	0.0000	0.0000	232.5719	-15.7590	0.0000
2	1.0450	-4.9865	21.7000	12.7000	40.0000	46.1735	0.0000
3	1.0100	-12.7397	94.2000	19.0000	0.0000	25.7260	0.0000
4	1.0147	-10.2597	47.8000	-3.9000	0.0000	0.0000	0.0000
5	1.0176	-8.7690	7.6000	1.6000	0.0000	0.0000	0.0000
6	1.0700	-14.4302	11.2000	7.5000	0.0000	21.9583	0.0000
7	1.0488	-13.2538	0.0000	0.0000	0.0000	0.0000	0.0000
8	1.0849	-13.2565	0.0000	0.0000	0.0000	22.3577	0.0000
9	1.0328	-14.8338	29.5000	16.6000	0.0000	0.0000	0.1900
10	1.0318	-15.0474	9.0000	5.8000	0.0000	0.0000	0.0000
11	1.0472	-14.8555	3.5000	1.8000	0.0000	0.0000	0.0000
12	1.0537	-15.2974	6.1000	1.6000	0.0000	0.0000	0.0000
13	1.0469	-15.3194	13.5000	5.8000	0.0000	0.0000	0.0000
14	1.0210	-16.0746	14.9000	5.0000	0.0000	0.0000	0.0000
Total			259.0000	73.5000	272.5719	100.4566	0.1900

TABLE V
LINE PARAMETER DATA OF IEEE 14-BUS SYSTEM

Line No.	From	To	R (pu)	X (pu)	B (total)
1	1	2	0.01938	0.05917	0.05280
2	1	5	0.05403	0.22304	0.04920
3	2	3	0.04699	0.19797	0.04380
4	2	4	0.05811	0.17632	0.03740
5	2	5	0.05695	0.17388	0.03400
6	3	4	0.06701	0.17103	0.03460
7	4	5	0.01335	0.04211	0.01280
8	4	7	0.00000	0.20912	0.00000
9	4	9	0.00000	0.55618	0.00000
10	5	6	0.00000	0.25202	0.00000
11	6	11	0.09498	0.19890	0.00000
12	6	12	0.12291	0.25581	0.00000
13	6	13	0.06615	0.13027	0.00000
14	7	8	0.00000	0.17615	0.00000
15	7	9	0.00000	0.11001	0.00000
16	9	10	0.03181	0.08450	0.00000
17	9	14	0.12711	0.27038	0.00000
18	10	11	0.08205	0.19207	0.00000
19	12	13	0.22092	0.19988	0.00000
20	13	14	0.17093	0.34802	0.00000

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