International Journal of u- and e- Service, Science and Technology
Vol.9, No. 11 (2016), pp.1-14
http://dx.doi.org/10.14257/ijunesst.2016.9.11.01

The Research on network Losses Allocation of Power Market based on Improved REI Network Numerical Equivalence

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Abstract

The main purpose of this paper is how to allocate network losses of power market, and takes this as objective function of this paper. Then we have conducted an in-depth analysis and discussion to the commonly-used algorithm of network losses allocation of each country. On this basis, we have chosen power flow tracking algorithm, and carried on in-depth analysis, then found out the shortcomings and areas for improvement. For the shortcomings, we have introduced REI network numerical equivalence method, and applied it to the improved power flow tracing algorithm of this paper. Moreover, we have verified four-node and three-machine nine-node network system, and proved the rationality of the model. Therefore, the proposed method in this paper was applied to bidirectional network losses allocation model. Generator and load undertook network losses of each electronic component according to certain proportion. In this paper, complex power flow tracing algorithm was applied to four-node system and the western U.S. power grid WSCC three-machine nine-node system, verifying the validity and correctness of this algorithm.

***Keywords**: Network losses allocation of power market; Improved REI network equivalent method; Power flow tracing algorithm*

1. Introduction

How to allocate fairly and reasonably network losses to each user is Power Company's actual production demand. However, the existing power flow tracking algorithm for network losses allocation of power market is always from one aspect or a point of view, violating the principle of fairness [1]. So, this paper proposes a new algorithm-based on improved power flow tracing algorithm's network losses allocation method [2].

With the process of the current electric power industry development, the electric power industry monopoly pattern in the traditional way is being replaced by the market mechanism. Electric power market reform becomes important direction. More and more people care transmission losses allocation in the process. It not only affect the power user's economic interests, but also the electric power market health and development, So how to allocate loss to every user fairly and reasonably has become one of the hottest research for many scholars and electricity companies. How to fast and effective and open the loss allocation to every user is a problem. So this paper proposes trend based on the loss of allocation problem.

Under actual conditions, there is no common standard for the calculation of loss in the world. So network loss calculation method of different countries and different regions is different, and then it has caused the difference of allocate network losses

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ISSN: 2005-4246 IJUNESST
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of the user, which violate the principle of fairness. Furthermore, the smooth development of the power market and the power industry also has brought about the hidden trouble. Therefore, fairly and reasonably allocate network losses is the key problem for the development of the power market, and it also concerns the economic interests of the market players. Whether it is in terms of national security or the benign development of the power industry, economic efficiency, and even power users, allocation of network losses reasonably and fairly are of vital significance for them.

Prorated principle is firstly proposed by J. Bialek in 1996. This principle shows that power of one node is how to allocate, it reflects equality of opportunity and principle of fairness. Based on this principle, many algorithms of power flow tracing are proposed [3].

When calculated the network loss of current power market, the Radial Equivalent Independent method is inducted to this article. With to solve the problem of large amount of calculation, the Radiation to coming Equivalent Independent method (REI) used in the network with loss allocation. To simplify the original network equivalence, we can divide into the node to retain the node and node. We use the improved gauss elimination method to eliminate useless node in order to make the calculation simple and shorting time of target.

2. Power Flow Tracing Algorithm Principle-the Prorated Principle

Prorated principle belongs to topology analysis method. In power system, power flow of flowing into node is all equal, which flow direction is arbitrary, and prorated principle can be expressed in Figure (1).

In Figure (1), a and, b are two input lines, c and d are two output lines and they are interconnected via node o. Power flow flows into from the input line, outflows from the output line, and the arrows represent flow direction. Power flow of each output line is decided by voltage difference of the adjacent nodes and impedance of this line. Therefore, power flow doesn't relate to node o. Node o is merely a connection point. We can assume that input and output power flow of each branch circuit have the same ratio. Power flow of each branch circuit, in accordance with the prorated principle, can be expressed as:

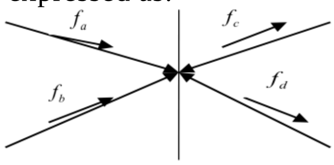

Figure (1). The Prorated Principles

$$f_c = f_c \frac{f_a}{f_a + f_b} + f_c \frac{f_b}{f_a + f_b} \tag{1}$$

$$f_d = f_d \frac{f_a}{f_a + f_b} + f_d \frac{f_b}{f_a + f_b} \tag{2}$$

It can be seen from formula (1) how much power flow the input power flow f_a from the input branch a supply to the output power flow f_c and how much power flow the input power flow f_b from the input branch b supply to the output power flow f_c. The same as the formula (2). The essence is that the injected power flow of each input branch mixes by node o and then distributes to each output

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branch, so output power flow of each output branch is equal to the sum of the proportion that each input branch accounts for total input power flow.

3. Rei Equivalent Methods

The main content of REI (Radial Equivalent Independent) network numerical equivalent method is described below, its equivalent changes as shown in Figure (2).

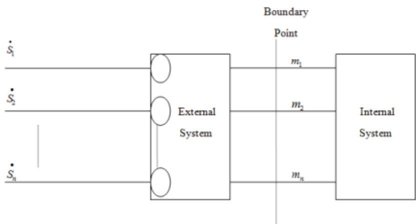
According to electric current calculation method, for unimportant nodes in power system, we need to eliminate them and the electric current $\dot{I}_k$ is calculated as follows:

$$\dot{I}_k = \frac{\overset{*}{S}_k}{\overset{*}{U}_k} \quad (k = 1,2,3......) \tag{3}$$

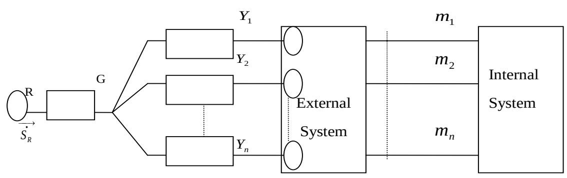
In this formula, S_k is the first node power in power system, $\overset{*}{S}_k$ is the conjugate of active node S_k and $\overset{*}{U}_k$ is the conjugate of complex voltage U_k of original network node.

Virtual node instead of active node of original network, and electric current can be expressed as:

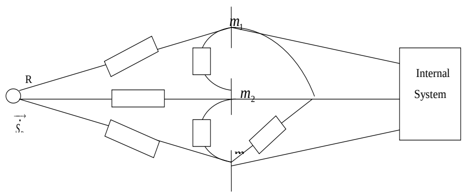
$$\dot{I}_R = \sum_{k=1}^{n} \dot{I}_k = \sum_{k=1}^{n} \frac{\overset{*}{S}_k}{\overset{*}{U}_k} \tag{4}$$



(a)The original network



(b) The original network using REI numerical equivalent method



(c) The equivalent circuit by Gaussian elimination method

Figure (2). Simplified Procedure of REI Network Equivalent Method

When simplifying the original network by REI method, we need to keep each node power of the original network the same, as shown in Fig. (2b). After constructing the original network by REI method, its node G and admittance Y_k of active node that we need to eliminate in the original network require to meet the following formula:

$$Y_k = \frac{\dot{I}_k}{\dot{U}_G - \dot{U}_k} \quad (k = 1,2,3,......,n) \tag{5}$$

When we simplify the network by REI method, network losses must remain consistent, so you can arrive at the following formula:

$$\dot{S}_R = \sum_{k=1}^{n} \dot{S}_k \tag{6}$$

$$\dot{U}_R = \frac{\dot{S}_R}{\overset{*}{I}_R} = \frac{\dot{S}_R}{[\sum_{k=1}^{n} \frac{\dot{S}_k}{\dot{U}_k}]} \tag{7}$$

$$Y_R = \frac{\dot{I}_R}{\dot{U}_k - \dot{U}_G} \tag{8}$$

Y_R is an admittance between R and G . Under normal circumstances, we make $U_G = 0$, so that we can make equivalent effect achieve the optimal. In this case, we can get a unique REI value network. To simply formula (7) and (8), we can get:

$$Y_k = -\dot{I}_k / \dot{U}_k = -\overset{*}{S}_k / U_k^2 \tag{9}$$

$$Y_R = \dot{I}_R / \dot{U}_R = \overset{*}{S}_R / U_R^2 \tag{10}$$

We can eliminate these uninterested nodes by Gaussian elimination after constructing REI value network, as shown in above Figure (2c).

3.1. Application of Gaussian Elimination Method in this Article

First, we can assume that, node system has n nodes in power industry.

According to the formula: $Y = G + jB$

In the formula, Y is node admittance, unit is *Siemens* (S). G is conductance, it represents the ability of certain conductor transmission electric current [4-5]. B is susceptance. By calculation, we can establish admittance matrix.

Then defines i , j , k three nodes, merges network and establishes one $3 \times n$ matrix C ,which corresponds to admittance matrix , as shown in the following formula:

$$C = \begin{bmatrix} 0 & \cdots & 1 & 0 & \cdots & \cdots & \cdots & \cdots & \cdots & 0 \\ 0 & \cdots & \cdots & \cdots & 1 & 0 & \cdots & \cdots & \cdots & 0 \\ 0 & \cdots & \cdots & \cdots & \cdots & \cdots & 1 & 1 & \cdots & 0 \end{bmatrix}$$

In power network, before eliminating, Setting electric current and voltage of each injected node are I and V respectively. After transforming equivalently, electric current and voltage become I_1 and V_1 separately, the formula is as follows:

$$VY = I \tag{11}$$

$$V_1 = CV \tag{12}$$

$$I = C^T I_1 \tag{13}$$

Putting formula (11) into formula (13), by calculating, we can get:

$$-YV + C^T I_1 = 0 \tag{14}$$

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Combine with (14) and (12):

$$\begin{bmatrix} -Y & C^{T} \\ C & 0 \end{bmatrix} \begin{bmatrix} V \\ V_1 \end{bmatrix} = \begin{bmatrix} 0 \\ V_1 \end{bmatrix} \tag{15}$$

Firstly, eliminating the former N columns of coefficient matrix in formula (15) by Gaussian elimination method, then, simplifying negative matrix $-Y$, eventually, forming upper triangular matrix.

$$V_1 = Z_1 I_1 \tag{16}$$

In formula (16), Z_1 is the node impedance matrix after simplifying the original network. First, simplifying formula (15) by Gaussian elimination method eliminates the former N columns of coefficient matrix. Then it will generate a coefficient matrix corresponding to N -order matrix after eliminating, and the coefficient matrix is Z_1. Finally, finding out inverse matrix of Z_1 by inverse operation, we can get node-admittance matrix Y_1 of equivalent transformation of power system. According to the formula: $y_{ij} = -Y_{ij}$

You can access the required node branch admittance after eliminating:

$$y_{i0} = y_{ii} + \sum Y_{ik} \ (k \neq i) \tag{17}$$

y_{ij} is the admittance between different nodes i and j . y_{i0} is the branch admittance of equivalent network node i to the ground.

4. Improved Complex Power Flow Tracing Method

In power system, each node branch will have losses, so when simplifying the original network into a lossless network, we need to introduce a non-existent node, which can equivalently replace network losses from each branch in the node system. In this paper, we calculate the apportionment of network losses in the active and reactive power un-decoupling condition [6-7]. Therefore, in full consideration of the influence of reactive power to active power, the result of the calculation and the actual are more consistent. In this way, we not only consider the influence of each node to power system network, but also allocate network losses from the entire network to generators and loads, making calculation more convenient and shorter hours.

4.1. Downstream Tracking

In power system, along the path of power flow flowing, adopting downstream tracing mode to network losses of the whole network, its network losses are completely undertaken by the load side. In the process of complex power downstream tracing, in order to maintain the stability of the system and the voltage, we regard load node and generator node as our internal systems, its equivalent circuit is shown in Figure (3).

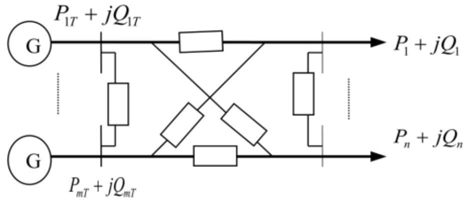

Figure (3). Downstream Tracking Models

First, the original network is replaced equivalently, and then we use virtual nodes instead of our equivalent external node, finally, the losses network is transformed equivalently into a lossless network.

Generally, it is assumed that in equivalent circuit if there are N nodes, L slip roads, so after adding virtual node, the number of nodes is $N+L$, then number the added virtual node, followed by $N+1, N+2, \ldots\ldots, N+L$.

For load nodes, its node injected complex power is shown by formula (18).

$$S_{Gi} = -S_{Li} \tag{18}$$

The total power flow through node i is:

$$S_i = \sum_{j \subset L_{i+}} S_{ij} + S_{Li} = \sum_{j \subset L_{i+}} C_{ij} \times S_j + S_{Li} \left(i = 1,2,\ldots\ldots, N+L\right) \tag{19}$$

In this formula, we can make $C_{ij} = \frac{S_{ij}}{S_j}$.

The formula (19) can be transformed into:

$$S_i - \sum_{j \subset L_{i+}} C_{ij} \times S_j = S_{Li} \tag{20}$$

$$B_d S = S_L \tag{21}$$

In this formula, B_d is $(N+L)\times(N+L)$ matrix, S is the power flow vector that every node flows into, S_L is the vector that each load node flows into load power in simplified network of power systems.

Therefore, matrix B_d can be expressed as:

$$[B_d]_{ij} = \begin{cases} -C_{ij} = -\frac{S_{ji}}{S_j} & J \in L_{i+} \\ 1 & i = j \\ 0 & Others \end{cases} \tag{22}$$

According to formula (21), vector S can be expressed:

$$S_i = \sum_{k=1}^{n+m} \left[B_d^{-1}\right]_{ik} S_{LK} \left(i = 1,2,\ldots\ldots, N+L\right) \tag{23}$$

As can be seen from the above formula, complex power that load K flows into node i is:

$$S_{i.LK} = [B_d^{-1}]_{ik} S_{LK} \tag{24}$$

According to complex proportion sharing principle, on the circuit $i-j$, generator S_{Gi} provides power for loads LK:

$$S_{Gi.Lk} = \frac{S_{Gi}}{S_i} \times S_{i.Lk} = \frac{S_{Gi}}{S_i} [B_d^{-1}]_{ik} S_{LK} \qquad (J \in l_+) \tag{25}$$

In the downstream tracking model, network losses of each branch are replaced by the losses of virtual nodes, which is equivalent to put power in the circuit. For the losses of the whole network of this system, we only need to calculate out network losses of each virtual node and get its sum.

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From formula (25), we can obtain network losses that loads require to undertake, as follows:

$$\Delta S_{LK} = \sum_{i=n+1}^{n+m} \frac{S_{Gi}}{S_i} [B_d^{-1}]_{ik} S_{LK} \ \left(k = 1,2\cdots\cdots,n\right) \tag{26}$$

This method is called complex power downstream tracing method.

4.2. Countercurrent Tracking

In countercurrent tracking, we allocate all network losses which are produced in the node system to the generator side. If the network has one and only one node between generators and loads, it can't be replaced by virtual node. Instead, it should be the same as the generator node as an internal node, and then set up a virtual active node R to deal with the original network [8-9]. After processing, the equivalent circuit is shown in Fig. (4):

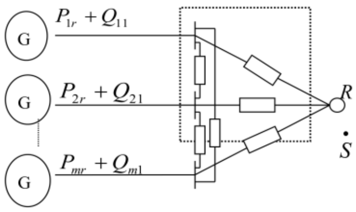

Figure (4). Network Losses Allocated to the Generator Side

Dealing with the original power system network and replacing equivalently with REI method [10]. Setting the number of nodes is n, the number of branches is m, adding virtual active nodes in the branch, followed by $n+1, n+2, ..., n+m$, meanwhile, setting the flow direction of active power of node system as reference direction of the whole network power flow. The total power of node i is:

$$S_i = \sum_{j \subset L_{i-}} S_{ji} + S_{Gi} \quad (i = 1,2,......,n+m) \tag{27}$$

In this formula, L_{i-} is the incoming line set of node i, S_{Gi} is the injected power of the generator pouring into node i, S_{ji} is the power flow of circuit $j-i$.

By calculating, we can get:

$$S_i - \sum_{j \subset L_{i-}} \frac{S_{ji}}{S_j} \times S_{Gi} = S_{Gi} \tag{28}$$

$$A_u S = S_G \ or \ S = A_u^{-1} S_G \tag{29}$$

In formula, A_u is $(n+m)\times(n+m)$ matrix; S is the sum of complex power of flowing into each node; S_G is the vector of complex power that each generator node injects the node system.

For A_u positive matrix, it meets the following conditions:

$$[A_u]_{ij} = \begin{cases} -\frac{S_{ji}}{S_j} & J \in L_{i-} \\ 1 & i = j \\ 0 & Others \end{cases} \tag{30}$$

By formula (29), vector S can be calculated, the value is:

$$S_i = \sum_{k=1}^{n+m} \left[A_u^{-1}\right]_{ik} S_{GK} \quad (i = 1,2,......,n+m) \tag{31}$$

That is to say, generator S is able to provide $[A_u^{-1}]_{ik} S_{GK}$ power flow for node i. According to principles of complex power flow tracing-complex proportion sharing principle, we can get the power that generator S_{GK} provides to load S_{Li} of node i, as follows:

$$S_{Li.Gk} = \frac{S_{Li}}{S_i} \times S_{i.Lk} = \frac{S_{Li}}{S_i} [A_u^{-1}]_{ik} S_{GK} \tag{32}$$

In the countercurrent tracing, all network losses are undertaken by the generator. Therefore, when calculating, we only need to calculate out power that the generator contributes to the virtual node, and then sum its node power. The losses that the generator should undertake are:

$$\Delta S_{GK} = \sum_{i=n+1}^{n+m} \frac{S_{Li}}{S_i} \left[A_u^{-1}\right]_{ik} S_{GK} \quad (k = 1,2,......,n) \tag{33}$$

4.3. The Bi-Directional Tracking Model in Network Losses Allocation

Downstream tracing allocates losses to the load side; Countercurrent tracking only allocates all network losses to the generator. However, in actual work operation, the generator side and load side effect mutually, they have all made their own contribution to the network losses of the system. If the location of the generator and load changes, the network losses will also change [11-12]. However, the above two algorithms can't reflect the change.

In this case, this paper puts forward complex power flow tracing algorithm of bi-directional allocation. Its specific algorithm is as follows: We regard network losses of components as a whole and give the generator of using the line provide losses allocation of γ share. So, the load through this line occupies ($1-\gamma$) share. When $\gamma = 0$, it's downstream tracing; When γ =1, its countercurrent tracing. However, when $0 \prec \gamma \prec 1$, network losses of power grid operation are undertaken by both the generator side and the load side, reflecting the common effect of the generator side and the load side. Under normal circumstances, in order to save hours and fair principle, we generally pick $\gamma = 0.5$, generator side and load side bear equally network losses of each component of the power grid.

After simplifying power grid equivalently, we can calculate virtual load component S_{Li} $(i = n+1, n+2,......,n+m)$ by countercurrent tracing method. The whole network losses that the generator k should bear are:

$$\Delta S_{Gk} = \sum_{i=n+1}^{n+m} \frac{\gamma S_{Li}}{S_i} \left[A_u^{-1}\right]_{iK} S_{Gk} (k = 1,2,3,......,n) \tag{34}$$

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To the virtual power component $S_{Gi}(i = n+1, n+2, \cdots\cdots n+m)$ of power grid, the load of node k that determined by downstream tracking method is $S_{Gi,Lk}$, so network losses that the load should bear are $(\gamma - 1) \cdot S_{li,Gk}$. To sum all the components of the power grid, we can gain network losses of the whole power transmission that the load k should bear, as follows:

$$\begin{aligned} \Delta S_{LK} &= \sum_{i=n+1}^{n+m} S_{Gi,Lk} \\ &= \sum_{i=n+1}^{n+m} \frac{-(1-\gamma) S_{Gi}}{S_i} \left[B_d^{-1} \right]_{ik} S_{LK} \left(k = 1,2,3,\ldots\ldots, n \right) \end{aligned} \tag{35}$$

5. Numerical Examples

5.1. Four-Node Network System

For comparison, we use the four-node network as an example, the diagram as follows:

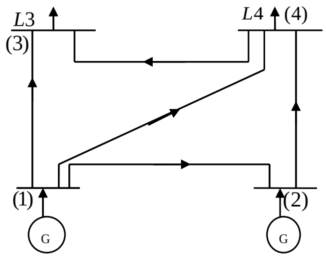

Figure (5). Four-Node Systems

The basic line and reactance parameters as follows:

Table 1. Basic Parameters of the Four-Node System

Line	1-2	1-3	1-4	2-4	4-3
R_{ij}/Ω	0.127	0.06	0.117	0.035	0.057
X_{ij}/Ω	0.97	0.695	0.96	0.308	0.58

In this paper, we pick $\lambda = 0.5$, and the specific results as follows:

Table 2. Improved Complex Power Flow Tracing Algorithm

Method	G1	G2	L3	L4
Countercurrent	0.1303-0.2400j	0.0097-	0	0
Downstream	0	0	0.0856+0.1159j	0.0544-
Bidirectional	0.0651-0.1200j	0.4900-	0.0428-	0.0272-

Comparing the improved algorithm and power flow tracking algorithm based on active and reactive power decoupling, the literature has given the calculating process of the latter, and the network losses as follows[13]:

Table 3. Unimproved Power Flow Tracing Algorithm

Method	$G1$	$G2$	$L3$	$L4$
Countercurrent method	0.1228	0.0172	0	0
Downstream tracing	0	0	0.0976	0.0424

From the above tables, we can see obviously, to generator $G1$, network losses by the improved method are higher than that of traditional methods, but the numerical value that generator $G2$ obtains drops. This is mainly caused by generators of different power factor. Checking the power factors of generator $G1$ and $G2$, we can find the power factor of generator $G1$ is lower than that of generator $G2$. And we know that the influence of reactive power to active power, it can cause active power network losses. Relatively speaking, losses allocation numerical value of generator $G1$ increases, and that of generator $G2$ correspondingly declines [14-15]. Therefore, the improved algorithm can improve the accuracy of the results of network losses allocation.

From Table 2, we can see that when we adopt downstream tracing or countercurrent tracing method, only the generator side or the load side conducts losses allocation without considering the influence of the other party, and the bi-directional allocation mode is a good solution to this problem.

5.2. WSCC9 Node System

We select the western U.S. power grid WSCC three-machine nine-node system as the test system. The system includes three generators, three load points and six transmission lines, in Fig. (**6**):

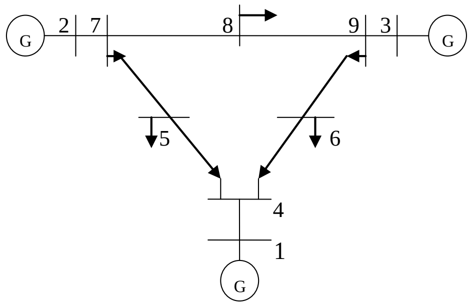

Figure (6). Three-Machine Nine-Node System of Western U.S. Power Grid WSCC

Node1 is the balance node and reference value of generators is $S = 100MVA$, and $U = 230KV$. In the power system, the total network losses of the power grid are $0.0464 - 0.09216j$ and the system parameters are shown in Table 4.

According to Table 5, we adopt average network losses allocation method, power flow tracing method and the improved method, calculating results are shown in Table 6.

Table 4. Line Parameters of the Three-machine Nine-node System

Head-end node number	Terminal node number	R/Ω	X/Ω	$B/2/S$
4	1	0	0.0576	0
7	2	0	0.0625	0
9	3	0	0.0586	0

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8	7	0.0085	0.0720	0.149
9	8	0.0119	0.1008	0.209
5	7	0.0320	0.1610	0.306
6	9	0.0390	0.1700	0.358
5	4	0.0100	0.0850	0.176
6	4	0.0170	0.0920	0.158

Table 5. Generator Parameters

Generator label	Reference value	x_l	r_a	x_d	$x_d^{'}$	$\frac{x_d^{'}}{s}$	x_q	$x_q^{'}$	$T_{q0/s}^{'}$	$\frac{H}{S}$
1	100	0	0	0.1460	0.0608	8.96	0.0969	0.0969	0.310	23.64
2	100	0	0	0.8958	0.1198	6.00	0.8645	0.1969	0.535	6.40
3	100	0	0	1.3125	0.1813	5.89	1.2578	0.2500	0.600	3.01

Table 6. Losses Allocation of Generator Side

Name of Generator	The average losses allocation method	Flow Tracing Method	The improved method
1	$0.0023 - 0.5595j$	$0.0043 - 0.2819j$	$0.0051 - 0.3766j$
2	$0.0292 - 0.1375j$	$0.0277 - 0.1536j$	$0.0263 - 0.1827j$
3	$0.0149 - 0.2246j$	$0.0144 - 0.4861j$	$0.0148 - 0.3610j$
Total network losses	$0.0464 - 0.9216j$	$0.04664 - 0.9216j$	$0.0462 - 0.9218j$

Table 7. Losses Allocation of Load Side

Name of Load	The average losses allocation method	Flow Tracing Method	The improved method
4	$0.0184 - 0.4007j$	$0.0258 - 0.2516j$	$0.0238 - 0.2019j$
5	$0.0133 - 0.2404j$	$0.0082 - 0.4283j$	$0.0101 - 0.3959j$
6	$0.0147 - 0.2805j$	$0.0124 - 0.2417j$	$0.0125 - 0.3243j$
Total network losses	$0.0464 - 0.9216j$	$0.0124 - 0.9216j$	$0.0464 - 0.9221j$

Table 8. The Bi-Directional Losses Allocation

Name	The average losses allocation method	Flow Tracing Method	The improved method
1	0.0013-0.2798j	0.0020-0.1049j	0.0026-0.1883j
2	0.0146-0.6681j	0.0138-0.0678j	0.0132-0.0914j
3	0.0075-0.1123j	0.0072-0.2430j	0.0074-0.1807j
4	0.0092-0.2004j	0.0129-0.1258j	0.0119-0.1010j

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5	0.0066-0.1202j	0.0041-0.2142j	0.0050-0.1979j
6	0.0073-0.1403j	0.0062-0.1209j	0.0063-0.1621j
Total network losses	0.0465-0.9218j	0.0464-0.9216j	0.0466-0.9222j

From Table 6, we can see the calculated network losses of three methods and the total network losses are equal. But to generators, the calculated results by these three methods are different. By the average method and power flow tracing method, we calculate that the network losses of the generator 1, 2, 3 respectively are 0.0023,0.0043, 0.0292,0.0277, 0.0149,0.0144. But the network losses by the improved algorithm respectively are 0.0051, 0.0263, and 0.0148. We can see clearly that the result of using the improved method make the network losses of generator1 allocating improve, that of generator 2 reduce, and that of generator 3 reduce a bit, because power factor of different generators is different. In comparison, the power factor of generator1 is much smaller than that of generator 2 and 3; the power factor of generator 3 is slightly smaller than that of generator 2. So the network losses ratio of generator 1 increases, generator 2 and 3 reduce accordingly, the volatility of generator 3 is relatively small. Because in actual power grid, reactive power has influence on active power, so using improved complex power tracing method can obtain more accurate and reasonable results.

From Table 6, and 7, we can see that they all merely calculate network losses allocation of a single direction of the power system without considering the interaction between them [16]. If we adopt downstream tracing method, then we automatically ignores the generator side, its network losses should automatically become zero and network losses of power grid operation is completely compensated by the load side. If we adopt countercurrent tracking method, the result is the same.

From Table 8, we can see that, adopting the bi-directional allocation method can make up for the lack of losses allocation caused by countercurrent or downstream tracing method, the losses allocation is undertaken together by the generator and the load.

6. Conclusions

This paper analyzed and studied the current existing problems in power flow tracking algorithm. With the problem of long hours and large amount of calculation, REI (Radial Equivalent Independent) network numerical equivalent method was applied to network losses allocation. In order to achieve simpler calculation and shorter hours, we simplified the original network equivalently; Nodes were divided into preserved and not preserved; the latter were eliminated by improved Gaussian elimination method. We point out that power flow tracing method based on active and reactive power decoupling isn't suitable for network losses allocation. Thus, we propose that complex power flow tracing algorithm based on active and reactive power un-decoupling. Considering the influence of generator side and load side to network losses, if we allocate network losses from a single aspect, it will cause one side compensate the other side.

(1) We have analyzed and discussed the current algorithm of network losses allocation. For the long hours and complicated calculating issues of the current power flow tracing algorithm, we have applied REI method to network losses allocation algorithm, and simplified equivalently original network to save hours.

(2) In the process of REI method being applied to network losses allocation, because there is a link between node number of equivalent network, when we eliminate node by Gaussian elimination method, elimination of each node will generate a new matrix, and it makes calculation complicated. Therefore, we have

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improved Gaussian elimination method, and the method doesn't have to generate a new admittance matrix.

(3) On the basis of complex proportional sharing principle, we have considered the influence of reactive power to active power in power market, and proposed complex power flow tracing algorithms. This method is more reasonable and practical than traditional method. On the basis of complex power flow tracking algorithm, we also have proposed the bi-directional allocation mode. In this mode, losses allocation is undertaken by the generator and the load jointly.

Conflict of Interest

The authors confirm that this article content has no conflicts of interest.

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