Study on Loss Allocation of Power Distribution Network with Distributed Generation

Wei Li ming**, Lin Jun**
* Jilin Institute of Architecture and Civil Engineering, No.1129, Hongqi Street, Changchun, Jilin 130021, P.R.China
**Jilin University, No. 6, West Democratic Street, Changchun, Jilin 130061, P.R.China

Abstract—The introduction of distributed generation will bring new challenges to the theory of power electricity market. The problem of loss allocation is one of them. Firstly, a loss allocation method is presented for power distribution network with distributed generation. Secondly, the changes of loss allocation which introduction of distributed generation before and after brings about are analyzed and compared and relevant conclusions are obtained. Lastly, a typical mini-grid with a distributed generation is simulated. Simulation results prove the correctness and feasibility of the method.

Index Terms—distributed generation; network loss allocation; correction factor; power flow tracing

I. INTRODUCTION

As the contradiction between supply and demand of electricity is prominent in recent years, the cycle of building great grid is long and the gradual failure in the global primary energy and power companies is against the backdrop of deregulation, distributed generation is more and more attention. As a rapid and effective means the distributed generation can solve the electricity shortage. It will bring economic benefits when it is access to the distribution power system.

II. RESEARCH ON LOSS ALLOCATION CONNECTED WITH DISTRIBUTED GENERATION

In the paper, the following part will discuss how to allocate the loss of distribution network, in the process of allocation the impact of reactive power is necessary to take into account. The cross interaction items of loss are also allocated reasonably. Two assumptions are proposed: firstly, the user always have to share the power loss; followed by is that network losses caused by variation (increase or decrease the amount of volume) are allocated to the generator itself after distributed generators are joined the network. Current is a major factor to decide the network loss. In this paper contribution to the current real and imaginary parts of each branch can be obtained in the power flow tracing method[1]. Loss Allocation of Distribution System with Distributed Generator is conducted in two phases. The first phase is that loss of network without containing a distributed generator are allocated to the electricity consumers or their suppliers, the second phase is that loss changes of network arising from generators is allocated to each distributed generator.

A. Loss Allocation without Distributed Generators

At this stage, the network losses (without considering the case of a distributed generator) are all allocated to the electricity users; First of all, there is an infinite AC power when distributed generators are not considered, active and reactive power flow of each branch and voltages for each node are measured for of the, the real current and imaginary current parts of each branch can be calculated by power flow calculation software. The current of branch is defined as follows:

\[ I_i^p = I_i^{1p} + j I_i^{1q} \]  (1)

Each load j contributes on current of the real and imaginary parts of the branch i,

\[ I_i^j = \sum_{j=1}^{T} I_{ji}^{1p} + j \sum_{j=1}^{T} I_{ji}^{1q} \]  (2)

Therefore, the loss of branch i can be expressed as:

\[ P_{lossi} = R_i \left[ \left( \sum_{k=1}^{N} I_{ki}^{1p} \right)^2 + \left( \sum_{k=1}^{N} I_{ki}^{1q} \right)^2 \right] \]  (3)

Where \( R_i \) is resistance of branch i, \( N \) is the total number of that load.

From the equation (3), it can be seen that the impact on network loss by the load j is divided into two parts. First part is caused by the load j alone and the second part is interaction items caused by the other load of branch i and load j. These items of loss can be allocated in accordance with a lot of ways. Such as the commonly used proportional allocating method, method of square size, method of net loss sensitivity factor, method of assessed contributions, as well as other methods of assessment. The applied method in the paper is method of reference [1]-[2]. The allocated loss of load j by branch i can be expressed as:

\[ P_{lossi}^j = R_i \left[ \left( \sum_{k=1}^{N} I_{ki}^{1p} \right) I_{ji}^{1p} + \left( \sum_{k=1}^{N} I_{ki}^{1q} \right) I_{ji}^{1q} \right] \]  (4)

Obviously \( \sum_{j=1}^{N} P_{lossi}^j = P_{lossi} \). Therefore, the above method is correct. Allocated total loss of load j can be expressed as:

\[ P_{loss}^{j} = \sum_{i=1}^{T} P_{lossi}^j \]  (5)

In Equation (5), \( T \) is total number of branch.

B. Loss Changes Allocation after Introduction of Distributed Generation

After introduction of distributed generation, a new power flow will be generated with the emergence of distributed power generation. The real and imaginary...
parts of the changes of current are caused. The method described in the text [1-2] is applied. The size of the real and imaginary part of the branch currents can be calculated after joining the distributed generation. They are respectively \( I_{ji}^{p} \) and \( I_{ji}^{q} \). The following calculation is current variation for each load in each branch. These changes can be obtained from the (6):

\[
\Delta I_{ji}^{p} = I_{ji}^{p} - I_{ji}^{p1}
\]

\[
\Delta I_{ji}^{q} = I_{ji}^{q} - I_{ji}^{q1}
\]

(6)

The changes of branch \( i \) are caused by load \( j \). These changes are allocated to the generator \( g \).

\[
\Delta I_{ji}^{pg} = \frac{C_{j}^{pg}}{\sum_{k \in r} C_{j}^{pg}} \Delta I_{ji}^{p}
\]

\[
\Delta I_{ji}^{qg} = \frac{C_{j}^{qg}}{\sum_{k \in r} C_{j}^{qg}} \Delta I_{ji}^{q}
\]

(7)

Where, \( r \) is number of generator. The generators impact on the real and imaginary parts of current \( i \) and current of load \( j \). Changing value of each branch current allocated to each distributed generator can be calculated by the following formula:

\[
\Delta I_{ji}^{pg} = \sum_{j=1}^{N} \Delta I_{ji}^{pg}
\]

(8)

When considering distributed generators in the network, changes of the loss in branch \( i \) as follows:

\[
P_{loss} = R \left[ (I_{ji}^{p} + \sum_{j=1}^{E} \Delta I_{ji}^{pg})^2 + (I_{ji}^{q} + \sum_{g=1}^{E} \Delta I_{ji}^{pg})^2 \right]
\]

Where, \( E \) is the number of distributed generators. Similarly, loss changes of branch are allocated to every distributed generator \( g \).

It can be seen that the following results are as follows:

\[
\Delta I_{ji}^{pg} = R \left[ (I_{ji}^{p} + \sum_{k=1}^{E} \Delta I_{ki}^{pg}) \frac{I_{ji}^{p}}{E} + \Delta I_{ji}^{pg} \right]
\]

\[
+ (I_{ji}^{q} + \sum_{k=1}^{E} \Delta I_{ki}^{pg}) \frac{I_{ji}^{q}}{E} + \Delta I_{ji}^{pg} \right]
\]

Clearly, the above-mentioned equation satisfies principle of total volume. The allocation method is strictly correct. In order to allocate all loss variation, the above allocation process is needed to calculate all of the generators and the branches. From the above-mentioned equation, it can be seen that total loss of allocated to distributed generator \( g \) can be calculated as follows:

\[
P_{Gloss} = \sum_{i=1}^{I} P_{Glossi}
\]

III. SIMULATION ANALYSIS

The loss allocation of a simple small-scale distribution system after the introduction of distributed generators is calculated by the above method. Basic data is seen in the reference [3]. The generators G1 and G2 are sent out active power and reactive power of the peak-load. The apparent power is respectively as follows: \( S_{G1} = 3MVA \) and \( S_{G2} = 6MVA \). The total loss is allocated to loads when distributed generator is not introduced to the network. Loss is allocated to each distributed generator after considering distributed generators. The value of system losses is shown in Table I before and after the introduction of the distributed generators. From Table I it can be seen: 1) the contribution of each load to be distributed only their branch. 2) In some cases, only the reactive power and its own loss of some special branch are allocated to load. Before introduction of distributed generators the distribution system loss is 1345.77kW, after the introduction of two generators the loss is 584.69kW. The latter decreases 56.6% of the entire network loss. From Table II, it can be seen that the loss of branch connecting generators 27-8 and 28-15 respectively, is all assigned to the generators G1 and generator G2. This is a very realistic situation. Table 2 shows that each generator can help to reduce network losses, but most arises from generators G1. Because of the generators G1's location it can reduce the additional network loss. Addition to its own branch 28-15, generator G2 increases current of 13-10, 14-13, 15-14. These currents result in an increase of those losses of above branches. From the above it can be seen that the allocation is in line with actual situation and can provide correct economic signal to encourage the entire network to reduce losses. It is important significant for fair and rational losses allocation.

<table>
<thead>
<tr>
<th>Number</th>
<th>Branch</th>
<th>Loss before the introduction of distributed generation (kW)</th>
<th>Losses after the introduction of distributed generation (kW)</th>
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<tr>
<td>1</td>
<td>1-2</td>
<td>326.88</td>
<td>52.34</td>
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<tr>
<td>2</td>
<td>1-3</td>
<td>115.11</td>
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<td>4</td>
<td>2-15</td>
<td>15.11</td>
<td>10.39</td>
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<td>5</td>
<td>3-9</td>
<td>81.53</td>
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</table>

Total losses (before) 1345.77
**IV. Conclusions**

By the calculation a simple of examples with distributed generators in distribution network method described in the paper proves the correctness and feasibility. The calculation is simple and loss allocation of distribution network will enable a more fair and reasonable. After the introduction of multiple distributed generation contribution to the change of loss caused by each power supply is not the same. It has great relationship with the location of their specific access and in the presence of ring network. In addition to losses of its own branch connecting to the network increases, loss of other branch in the loop can increase.

**Reference**


