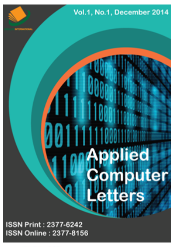
Applied Computer Letters (ACL)

DOI : http://doi.org/10.26480/acl.02.2017.01.05

ISSN: 2377-6242 (Print)
ISSN: 2377-8156 (Online)



COMPUTER RESEARCH OF THEORY LINE LOSS BASED ON GIS COMPONENT TECHNOLOGY

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ARTICLE DETAILS

Article History:

Received 7 February 2017
Accepted 10 March 2017
Available online 8 April 2017

ABSTRACT

The theoretical line loss data of distribution network is an important economical and technical index in Grid corporation routine work. This paper in view of the problems of theoretical line loss calculation in data integration and secondary development, analyze and calculate the relevant data sources by the study of the component development technology. Based on the method for theoretical line loss calculation and combined the geographic information topology, the paper optimizes key algorithm and achieves the design method for theoretical line loss calculation of distribution network based on the development of GIS components, and provides a good analysis and decision-making platform in reducing loss for Grid corporation management..

KEYWORDS

GIS, component, distribution grid, theoretical line loss

1. INTRODUCTION

The theoretical line loss data of distribution network is a comprehensive economic, technical index in Grid corporation routine work, which reflects the distribution management level of Grid corporation. Based on a study and judging from the technology, the level of line loss rate reflects the rationality of its grid structure, through which Grid corporation can explore the internal potential to provide economic benefits [1].

The theoretical line loss calculation data of distribution network is derived from the data of distribution line system, including the wire models of distribution line, the models and capacity of distribution transformer, and so on. These data aren't merely from the data of distribution system. The traditional calculation method is based on the GIS platform to achieve a complete calculation by inputting other parameters manually. This calculation exists the following drawbacks: (1) The data updates of Grid GIS and MIS are not synchronized, resulting in inaccurate data of line loss calculation. The common situation is that the line run data information lag in the GIS. (2) Some grid GIS integrates the data of MIS system, but because MIS database structure changes with the business logic, resulting in the large post-maintenance cost and low efficiency of MIS data integration in the GIS platform [2].

Under the above background, the calculation method of theoretical line loss based on GIS component technology can solve the above drawbacks of both, improving the data integration and the efficiency of secondary integrated development.

2. THE COMPONENT-BASED DEVELOPMENT TECHNIQUES

2.1 Component Development Technology Roadmap

Computer software technology is more and more widely applied in various industries. With the expansion of business applications, the scale of software systems is increasing, the structure is more complex, and the system maintenance is more difficult, so that business development gradually turn into the mode based on business logic encapsulation. Therefore, in the conditions of implementing functions, adopting a method which has a high efficiency of development and low cost of post- maintenance is the goal of application system development. In this context, the development model of component-based application gradually has been widely used in the development of industrial applications as in Reference [3].

Component technology development is based on object-oriented model, the traditional object-oriented development methodology can be used for component-based development, but the component development is mainly reflected in the separation of interface. And the complete function can be implemented by combining the interfaces provided by multiple components.

2.2 Development System Structure Based on Component

Component-based development is based solely on the functional modular and componentization design. The entire function is divided into sub-functions or functional interface, which is encapsulated by using component that is completely transparent relative to the integrated platform. And integrated platform achieves full functions through integrating function or common interface. Development system structure diagram based on Component is shown in Figure 1.

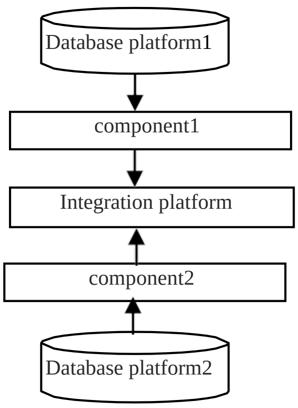

Figure 1: Development system structure diagram based on component.

3. MODEL DESIGN FOR THEORETICAL LINE LOSS CALCULATION

3.1 Analysis of Calculation Data Sources

According to calculation formula of the theoretical line loss, it shows that the process need to use the technical parameters of overhead lines, the technical parameters and operating parameters of distribution transformers and so on. The spatial and geographic data and the account for lines and transformers are taken as the most direct source of data to calculate the theoretical line loss. Through analyzing the calculation principles, the calculation model is built to realize the calculation process. Theoretical line loss calculation is realized comprehensively by multi-source data.

In the specific application to the data, the wire length of overhead line is from the electric GIS, and the wire models of the overhead line are from the account data of electric GIS or production MIS, the capacity of the transformer is from the account data of electric GIS or production MIS [4]. The active line power is from the AMRS MIS system, the reactive line power is from the AMRS MIS system, the power supply of the transformer is from electricity marketing of MIS system [5].

3.2 Calculation Model Design

The 6 KV or 10 KV distribution network mostly adapt the radiated distribution network, which can be treated as the tree node structure from the logical structure. In the process of theoretical line loss calculation, its topology of the spatial and geographic distribution line is the foundation of calculation model. According to a research, the topology is composed of the towers, overhead lines and transformers, but the transformers are attached to the towers, which can be represented by the towers on the logical structure [6].

According to a study, the line topology the poles can be divided into three types: (1) the outgoing pole: This type of tower is usually the first pole to qualify from the substation, and the first pole for the entire line either; (2) T junction pole: This type of tower can be the tower of the sub-lines. The sub- lines may be scattered from the tower, which is also the share of the load calculation in the line loss calculation; (3) Leaf type pole: This is the end pole tower of the line, in distribution network lines, each of the end pole tower has a distribution transformer [7].

In the GIS platform, distribution network circuit structure is shown in Figure 2, while the line topology and pole type are shown in Figure 3. In the GIS system, the topological relations between the pole lines are entirely reflected by the poles. The overhead lines are automatically erected based on the data of the device attributes from the rod and bar. The topological association between distribution transformers and lines is reflected by the number of poles in the transformer equipment accounts.

Figure 2: Distribution gride on GIS platform structure diagram.

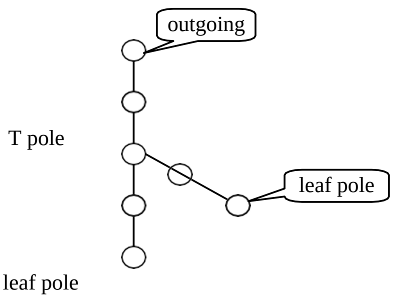

Figure 3: Distribution grid topology and the pole diagram

3.3 Calculation Process Design

The process of theoretical line loss calculation can be divided into four processes as a whole.

(1) Analysis of GIS data features
Analyze the geographic data and business attribute data in GIS system, and anatomize the system database according to the theoretical line loss calculation method [8].

(2) Establish the line loss calculation model
Based on the geographic information platform, design a efficient and accurate model of theoretical line loss calculation.

(3) Analysis of MIS system data
Based on the geographic data, combine the theoretical line loss calculation model, then analyze the data characteristics related to MIS business system.

(4) Line loss calculation
Based on the theoretical line loss model, use multi- source data communication strategy and complete the data extraction and calculation through various application components.

The active power and reactive power in overhead line loss calculation obtained by MIS component, the specific formula gives:

$$\Delta A_b = (A^2_{pg} + A^2_{qg}) \frac{K^2 R_{db}}{U^2 t_b} \times 10^{-3} (KW \cdot h) \quad (1)$$

Where, A_{pg} — line active power supply (KW.h)
A_{Qg} — line reactive power supply(KW.H)
K — characteristic coefficient of line load curve;
Rdd —the equivalent resistance of the wire (Ω). The equivalent resistance of the wire is shown as:

$$R_{dd} = \frac{\sum_{j=1}^{n} S_{ej} R_j}{\left(\sum_{i=1}^{m} S_{ei}\right)^2} \quad (2)$$

Where, S_{ej} R_j — the sum of the transformer rated capacity on each computing power lines (KV.A)
S_{ei} — the rated capacity of each distribution transformers running on the line (KV.A)

Transformer rated capacity can be acquired by accessing production MIS system data via MIS component, but also can be obtained through accessing the transformer attribute data via the GIS component. R_j can be obtained through the conductor model of GIS components and query interface.

The formula for calculating transformer load loss is given as:

$$\Delta A_b = (A^2 pg + A^2 qg) \frac{K^2 R_{db}}{U^2_{Rj} t_b} \times 10^{-3} (KW \cdot h) \quad (3)$$

The variable loss of line can be expressed as:

$$\Delta A_{kb} = (A^2 pg + A^2 qg) \frac{K^2 R_d}{U^2 R_j t_i} \times 10^{-3} (KW \cdot h) \quad (4)$$

The fixed loss

$$\Delta A_{kb} = \left(\sum_{i=1}^{m} \Delta P_{oi}\right) t_b \times 10^{-3} (KW \cdot h) \quad (5)$$

The total loss of the line is calculated as:

$$\Delta A = \Delta A_{kb} + \Delta A_{gd} + \Delta A_1 + \Delta A_b + \Delta A_{gd} (KW \cdot h) \quad (6)$$

Where, U_{pj} —the average operating line voltage in kV. For convenience, the rated line voltage can be obtained through GIS component.

t_1 — the actual run-time of the line

t_b — transformer integrated run-time on the line; these run-time can get transformer operating data in the remote meter reading system by MIS components

P_{oi} — No-load losses of each transformer in the line operation can be acquired by accessing properties of distribution transform in the GIS platform via the GIS component.

4. DESIGN AND IMPLEMENTATION OF THE THEORETICAL LINE LOSS CALCULATION BASED ON COMPONENT

4.1 System Structure Design

In the system structure of the theoretical line loss calculation based on component, the system design is divided into three levels: the database platform, component logic layer, integrated platform layer. The system structure is shown in Figure 4.

(1) The database platform

The database platform include two categories, GIS database and MIS databases. GIS data provides spatial and geographical information of distribution network lines (such as length of overhead line), and provides some attribute data (such as conductor type of overhead line, etc.). Based on a study, MIS database provides overhead lines, distribution transformers and other data in distribution network, and also provides network operation data, such as active power and reactive power of lines [9].

(2) Component logic layer

Component logic layer defines the data model and association rules of the entire calculation process [10].

Definition of the business logic is implemented by the database, data structures and other methods, For example association between trunk lines and the branch lines can be implemented through T junction pole, and the location and attribute of the distribution transformer are achieved by field definition.

After the logic is encapsulated, component provides external access interface, and complete the specificimplementation process within the component.

(3) Integrated platform layer

On the basis of the component layer providing various functions, applying the theoretical line loss calculation model, the calculation of the theoretical line loss can be made through sub-function or function interface.

In this integration platform layer, by passing parameters the specific data access can be achieved through internal functions of component.

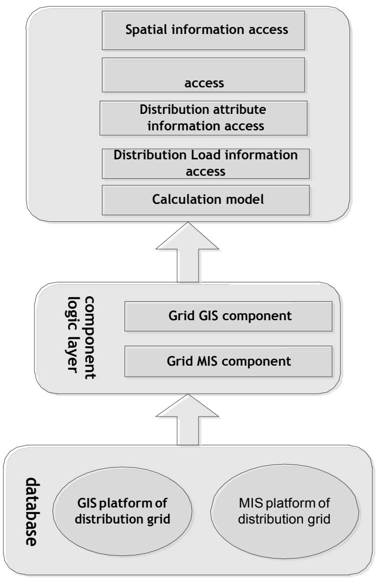

Figure 4: Design structure of calculation of theoretical line loss of distribution grid based on components.

4.2 Design of Implementation Process in Component

GIS component and MIS component achieve specific functions by encapsulating business logic. During the design, the various types of equipments are encapsulated into a specific class, such as the line class, distribution transformers class, grid operation class, etc. In each class the attributes and operation methods of equipments are defined, and the access between the various classes can be achieved through the interfaces. The process of implementing corresponding operation through line class *is shown in* Figure 5, distribution .transformers class, and towers class in the GIS component.

There is a general class used to access and manage other classes. In the example, LineLost is the class of line loss calculation, which has two properties: Overhead lines (TrollyList) and distribution transformers (TranseList). The corresponding atomic class is Trolly (overhead lines) and Transe (distribution transformers), the Init () method of LineLost is initialize class, GetTrollyType () method is used to get the overhead line models, GetTranseCont () method is used to get the capacity of the transformer, GetTranseType () method is used to get the distribution transformer model, IsPole () method is used to determine whether the distribution transformers belongs to the end tower of overhead lines.

In the Trolly atomic class of overhead line, LineCode represents the main line code, SubLineCode represents sub-line code, BeginPole represents the starting tower number, EndPoleIn represents the end tower number, Type represents conductors category of overhead lines, Len represents the span of overhead lines.

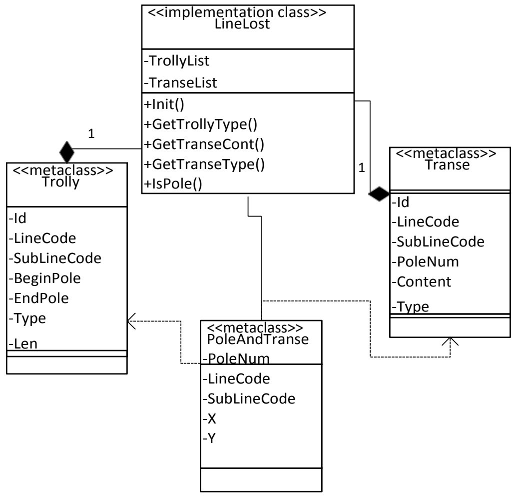

Figure 5: Example of component class.

Other classes are similar with overhead lines, which are both designed in accordance with the relevant attributes of the line equipment.

5. TECHNOLOGY OF THEORETICAL LINE LOSS CALCULATION FOR DISTRIBUTION NETWORK BASED ON THE COMPONENT

5.1 Model Implementation Process

After the calculation model is established, the data from power GIS system and other MIS system abstract pure computer data structure in the component, the main method of which includes the following aspects:

(1) Exclude unwanted poles data to identify each node of the tree structure; determine whether the pole is the starting tower of the line, that is the tree root. Thus build the line topology structure of distribution network through these steps:

function IsHeadNode(AGH: String): Boolean; Determine whether there is qualifying in the pole, that is tree T node, if so, turn back the number of the starting pole in the sub-line:

function IsT_Node (AGH: String; ChildRenList: TStringList): Boolean; Determine whether the poles exist on the map: function ISNullNode (AGH: String): Boolean;

(2) Generate tree structure

Generate the sub-tree at the root of a pole: procedure CreateSubTreeNode (Gh: String; LLen: Double);

```
Generate the simply process of the entire tree structure:
procedure CreateTree (Gh: String) begin
  / / ......
While Not ISNullNode (Gh) Do Begin
If IsT_Node (Gh, hildRenList) Then / / T junction
Begin
SetNodeMode (Gh); / / submit to the tree CreateSubTreeNode
(ChildRenStr, L1);
// ChileRen is the kids list, L1 is the distance between the
parent node andthe initial node
Gh: = TreeNS [TCount] NextNode;.
//Set the next pole in the sub-line as the current node
  End;
  If IsLeafNode (Gh) Then SetNodeMode (Gh); / /
submit to the tree
  / / ......
End;
```

5.2 Algorithm Selection and Optimization for the Load Capacity Calculation of Overhead Line

The load capacity calculation of overhead line is the complex process in the theoretical line loss calculation. There are two algorithms to calculate the load accounting to the above design model:

(1) Sequential accumulation method of load

From the current pole, the sub-tree traverses each node. According to the logic of the overhead line, traverse each distribution transformer in each overhead line, accumulate capacity of each distribution transformer and eventually acquire the load value of the entire line. Obviously, in the general distribution network lines, the number of distribution transformers is far less than the number of overhead lines, which leads to the accumulation of multiple access in a node (distribution transformer), resulting in the low computational efficiency .

(2) Reverse accumulation method of node: Do not access from the root as usual, and start to calculate from the node of distribution transformers. Backtrack until the root from down to up. It is obvious that this method of calculation calculate each leaf node only once, which is several times less in

time and has the higher efficiency than the first algorithm.

(3) The implementation of the optimization algorithm can be described as below:

a) Backtrack to find the parent node from the terminal node of distribution transformer. Every time backtracking a node, the empty volume of node load increases the capacity of distribution transformers.
b) The selection of backtracking node is progressive from the distribution transformer terminal to the power supply terminal, and ultimately implement the accumulation of the load capacity.

The optimization of backtracking algorithm from the distribution transformer terminal to the power supply terminal is based entirely on the reverse cumulative way from the child node to the parent node. The improvement of optimization algorithms can be shown in the following areas: optimization algorithm avoids the problem of duplicated counting multiple nodes from up to down as routine, which makes the higher computational efficiency in the transmission capacity of each node.

5.3 The Implementation of Multiple Components to Achieve Integration of Heterogeneous Data

MIS components and GIS components have separately the reading functions of the corresponding data. In reading the electricity marketing MIS, the lines, transformers and other information are included. The attribute data of GIS Application includes the line name, the branch name, the name of the transformer, the transformer code, transformer model, transformer capacity and other information. The marketing MIS includes the line name, the branch name, the name of the transformer, period for electricity, electricity consumption and so on.

Through the associated transformation between the two data analysis, the association can be achieved between the two, and the shared data taking the name of line transformer as the unique identification can be established.

GIS and MIS data converse into XML data file according to the index, so that the data communication between the two becomes possible. Because XML documents have the characteristics of the data querying and data storage. XML can realize the integration of the geographic information query and business information through all the operation, to further realize the calculation of the theoretical line loss.

5.4 Calculated Data Analysis

(1) Data analysis of the GIS component

Through entering the name of the substation and the line name in the line distribution network, GIS

component can analysis the GIS topology of the line, and the equivalent resistance of the wire can be calculated, as well as the equivalent resistance of transformers, circuit total equivalent resistance.

Input data includes substation (Orchard substation) and line name (Western Orchard line)

Get data from circuit topology of GIS platform:

a) 42 sub-lines; b) 102 towers in the main line, 925 towers in the sub-line, 43 end towers, 1037 overhead lines, and acquire the wire types and the wire cross- sections in every overhead line.

(2) Data analysis of the MIS component Accounting to the ID parameter of the distribution transformers transmitted by the GIS component, the data of transformers rated capacity, load loss, and no-load loss can be achieved;

According to the transmitted substation name and the line name, the active power is 68100 (KW*H) and the reactive power is 4250 (KW*H) in the stated period of time by reading the remote system.

(3) Analysis of the results

The power law is adapted in the calculation process, and the specific formula is referred in Reference 1.

Through calculation, the line parameter is as follows:

The equivalent resistance of the wire is 3.92Ω, the equivalent resistance of distribution transformer is 1.041Ω, the total equivalent resistance line is 4.973

Ω , variable loss is 336.99 KW.h, fixed loss is 5008.917 KW.H, the total loss is 5345.907 KW.H, the proportion of fixed loss is 93.696%, the economical load current is 22.107A, the economic load rate of the transformer is 20.81% , the theoretical line loss rate is 7.85%, and the best theoretical line loss rate is 3.816%.

5.5 The Component Integration effect in the Theoretical Line Loss Calculation of Distribution Network

The integration of calculation interface can be achieved on the basis of each application component in the theoretical line loss calculation of distribution Network based on component.

In the integrated interface, the operator can choose the line to calculate, and the period of the run-time, get active power and reactive power through marketing MIS component, and ultimately calculate the final result. The results include the intermediate parameters in the calculation process, such as the equivalent resistance of the wire, the equivalent resistance of the transformer, the total equivalent resistance line, total loss, economical load current, theoretical line loss rate, the best theoretical line loss rate. These parameters can provide a reference to reduce line losses for power supply enterprise.

6. CONCLUSION

In this paper, the component technology is used to generate the theoretical line loss calculation of the distribution network which solves the issue of multi- source parameters integration in the theoretical line loss calculation, implement data encapsulation access in grid GIS and MIS, and achieve the goal of real time data collection in the distribution grid lines. In this paper, the designed distribution network component can be applied to a variety of application systems in the field of distribution grid to improve the efficiency of system development, so that the data of distribution network can be accessed in the case that developers do not care database platform, which can improve the structuralization of system module, be easy to maintain and reduce development costs of the software platform.

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