

# A quick method to estimate low voltage problem

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**Abstract.** In order to solve the problem in the prediction of low voltage problem in distribution network, a method of estimating low voltage problem is proposed from two aspects: network simplification and load simplification. In the basis of the difference construction of the backbone and branch line, a backbone-branch network simplified model is proposed, and also the large input parameters problem is solved through the parameter estimation. In the basis of the division of the trunk that a branch load model is structured to realize a rapid distribution of the load. And finally, by using the voltage drop theoretical, a simple and practical low voltage loss quick check is formed to make it easy for grassroots staffs to use.

## 1. Introduction

Under the dual action of the continually improvement of national economy and the strong support for agriculture, the rural economy has developed rapidly and the living standard of the peasants has been significantly improved. However, the contradiction of incompatible between the development of power and the economic development especially for the problem of low voltage becomes more and more prominent, which has seriously impact on the normal production and consumption of rural areas and restricted the further development of rural power. Therefore, a scientific, reasonable and practical low voltage problem quantification method needs urgently to be studied and promoted to solve the problem of low voltage effectively.

The load moment theory is widely used in low voltage problem prediction. In literature [1], it proposes method of the rapid determination of low-voltage lines in zone area based on the load moment theory in accordance with the actual situation of production and related design rules and regulations. In literature [2], the load moment is used to analyse the intrinsic relationship between the line load moment and the cross section of the wire, and the different diameters are normalized to determine the optimal section for the wire diameter replacement in zone area. Literature [3] studies about the selection problem of calculating coefficient related to voltage of power supply system and wire material happening at the time of load moment calculation. Literature [4] puts forward the concept of equivalent load moment and tests the rationality of the concept according to the actual project.

The judging method of low voltage problem based on the load moment to a certain degree solves the problem of large demand for data based on the voltage loss data completely calculated but still can't solve the following problems: 1) The load moment method dose not fundamentally reduce its requirement for the line account, load and other data which is actually difficult to obtain. 2) The load moment method has a complete theoretical logic that requires high about the user's theoretical quality



in practical use, which brings only wake effect in rural areas with a salient problem of low voltage. 3) Professional software and computers and other equipment are needed in the use of the load moment method, and this brings an inconvenience for grass-roots staffs to use in the field survey and review.

In order to solve the problem in the prediction of low voltage problem in distribution network, a method of estimating low voltage problem is proposed from two aspects: network simplification and load simplification. In the basis of the difference construction of the backbone and branch line, a backbone-branch network simplified model is proposed, and also the large input parameters problem is solved through the parameter estimation. In the basis of the division of the trunk that a branch load model is constructed to realize a rapid distribution of the load. And finally, by using the voltage drop theoretical, a simple and practical low voltage loss quick check is formed to make it easy for grassroots staffs to use.

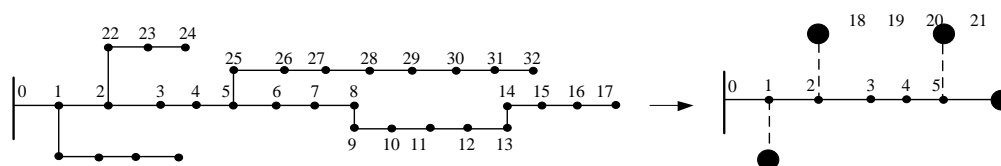
## 2. Backbone-Branch Network Model

### 2.1. Model construction

The load (line current) of any branch of the medium and low voltage network in the non-distributed power is determined by its own branch load and has no relationship with any other branch, and the voltage drop of one branch is only decided by its head voltage and electrical characteristics. While, the voltage drop of the trunk line in the network is affected by load of all branches. In the basis of characters stated above, the backbone-branch network model shall be constructed at the moment of conducting medium-low voltage analysis in the medium and low voltage networks.

The method for constructing backbone-branch network model as below: simplify the original distribution network into a network that is constructed by the branch element which composed by each branch line and the trunk component composed by trunk line.

According to above analysis, any medium and low voltage network can be simplified.



**Figure.1** Simplified network of the trunk-branch model

### 2.2. Parameter estimation

Main parameters of trunk-branch network model's parameter estimation includes: trunk line length, trunk line diameter, branch line length and branch line diameter.

Estimation of the length of trunk line means to estimate the length of the trunk line, which can be completed more accurately by checking the accounting data or by the rough estimation from the grassroots operating personnel experience.

Estimation of the trunk line diameter means to estimate its average diameter, which can be obtained by checking the accounting data and calculating the average diameter or be gotten from grass-roots staff's estimation of the length of kinds of line diameter and calculations on them.

Estimation of the length of branch line means to estimate the length of the branch line, which can be obtained more accurately by checking the accounting data or by the rough estimation from the grass-roots operating personnel experience.

Estimation of the branch line diameter means to estimate the average diameter of it, which can be obtained by checking the accounting data and calculating the average diameter or be gotten from grass-roots staff's estimation of the length of kinds of line diameter and calculations on them.

### 3. Branch Load Model

#### 3.1. Category of the medium branch load

According to the different types of power supply of the medium-voltage lines, medium voltage lines are divided into two categories as urban and rural.

According to the characteristics of the power load, the urban areas subdivided into three categories as industrial type, residential type and commercial type, among which the industrial type means urban area power supply mainly with industrial electricity load, the residential type means urban area power supply mainly with residential electricity load and the commercial type means urban area power supply mainly with commercial electricity load.

The rural areas according to economic development and production and living standards are divided into three categories as class I village group, class II village group, and class III village group, among which class I village group means generally town, township government seat, urban and rural areas or relying type economic development zone, the class II means generally small processing industry or more developed areas of agricultural production and the class III means all apart areas of rural basic production and living.

#### 3.2. Category of the low branch load

According to the different types of power supply, the low voltage branch load is divided into three categories as life class, production category and commercial category, among which the life class electricity supply load means mainly about residents living electricity load, the production one means mainly about electricity load of small processing industry, aquaculture, irrigation and small mining (digging) and the commercial one means mainly about commercial electricity load.

#### 3.3. Load distribution coefficient

Load distribution coefficient refers to the proportion of each branch loading the line or zone area, the branch load distribution coefficient has the following characteristics:

$$\begin{cases} 0 \leq \sigma_B \leq 1 \\ \sum \sigma_B = 1 \end{cases} \quad (1)$$

Accurate load distribution coefficient must be collected and calculated through load measurement on the same time, but actually the measurement is not necessary because it is difficult to be realized under the situation of many branches and low degree automation or to reflect the line load distribution

Characteristics over a period of time. This paper is estimating load distribution coefficient  $\sigma_{S_i}$  of each branch through methods stated below:

$$\sigma_{S_i} = \bar{\mu}_{S_i} \cdot t_{S_i} \cdot \frac{P}{T_{S_i}} \quad (2)$$

In this formula,  $t_{S_i}$  is the estimated capacity of the branch  $S_i$ ,  $T_{S_i}$  is the total capacity of the line (or zone),  $P$  is the active load for the line (or zone),  $\bar{\mu}_{S_i}$  equals to the normalized load category factor which is calculated by the load factor of all branches:

$$\bar{\mu}_{S_i} = \frac{\mu_{S_i}}{\sum \mu_{S_i}} \quad (3)$$

In this formula, the load classification factor is the load characteristics of different load categories. The larger the load factor, the greater the corresponding load, otherwise vice versa. The load factor is not static but changed along with the actual situation of each branch and can be estimated through the experience of grass-roots operators.

### 3.4. Load distribution strategy

The load  $P_B$  at the maximum load time point of each branch can be obtained by calculating the maximum load  $P_{\max}$  of the line (or zone area) and the load distribution coefficient of the branch, which is:

$$P_B = \sigma_B \bullet P_{\max} \quad (4)$$

## 4. Analysis process

In the basis of the abovementioned trunk-branch simplification network model and branch load model, the practical method of rapid estimation of low voltage problem is constructed as below:

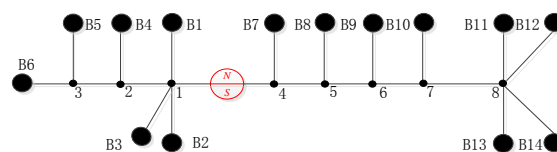
- 1) Construct the trunk-branch network simplified model of a line (or zone) according to the situation of the backbone and branch line;
- 2) Estimate the main line length, main line diameter, branch line length, branch line diameter and other parameters;
- 3) Determine the load category of each branch and the load category factors;
- 4) Calculate the load distribution coefficient of each branch;
- 5) Estimate the numbers of the users of the low voltage according to the quick check manual of voltage drop;
- 6) Calculate the quantitative impact of the project on the low voltage problem.

## 5. Typical examples

For the sake of verifying the validity of the method proposed in this paper, the zone area of Shizishan village will be analysed. By parallel comparing and analysing the voltage loss of Power System Calculation and Drawing Software Package developed by Zhengzhou Defang Company, the model is calculated.

### (1) Network simplification

According to the method proposed in this paper, backbone-branch network simplified model is firstly constructed, comparing to backbone-branch network simplified model of the zone area as shown in Figure2.



**Figure.2** Backbone-branch network

### (2) Parameter estimation

It is to use the experience of the grassroots operating personnel to estimate the length of the trunk line, the main line diameter, branch line length, branch line diameter and other parameters. As can be seen from the data in Table1, there is no deviation between the estimated data of the branch line diameter and the actual data. As for branch line length, the maximum and minimum deviation is 23 meters and 0 meter and the maximum error rate is 8.3%. The total error is 57 meters and the total error rate is only 1.6%, which means a small range of error between the actual data and estimated data.

According to the model proposed in this paper, the load category and load size of each branch is determined. Table1 shows the load category and load size of each branch.

**Table.1** Load category and load size of each branch

Branch	Power supply type	Maximum load	Branch	Power supply type	Maximum load
B1	Commercial type	5.5	B8	Commercial type	24.6
B2	Commercial type	5.5	B9	Commercial type	10.9
B3	Commercial type	16.4	B10	Residential type	3.3
B4	Residential type	14.7	B11	Industrial type	7.1
B5	Residential type	14.7	B12	Industrial type	46.1
B6	Residential type	3.3	B13	Industrial type	28.4
B7	Commercial type	5.5	B14	Industrial type	14.2

## (3) Deviation analyze

In Table 2, it states the comparison between the proposed method and the voltage loss calculation method (VLC method). According to the data in the table, there are two branches have deviation after separately calculating by the proposed method and by VLC method, besides, other branches' results have consistent results. Among which, the maximum error of branch 12 is two users who were found to truly have a low voltage situation at the peak load period after communicating with these two users. The main reason for miscalculation of voltage loss calculation method is its analysis only on single load state while the method proposed in this paper has overcome this limitation.

**Table.2** Comparison between the proposed method and VLC methods

Branch	Proposed method	VLC method	Branch	Proposed method	VLC method
B1	0	0	B8	0	0
B2	0	0	B9	0	0
B3	0	0	B10	0	0
B4	0	0	B11	0	0
B5	5	4	B12	8	6
B6	1	1	B13	0	0
B7	0	0	B14	4	4
Total	18	15			

**6. Conclusion**

In order to solve the problems in the prediction of low voltage problem in distribution network, a method of estimating low voltage problem is proposed from two aspects: network simplification and load simplification. In the basis of the difference construction of the backbone and branch line, a backbone-branch network simplified model is proposed, and also the large input parameters problem is solved through the parameter estimation. In the basis of the division of the trunk that a branch load model is structured to realize a rapid distribution of the load. And finally, by using the theoretical analysis of voltage drop, a simple and practical low voltage loss quick check is formed to make it easy for grassroots staffs to use.

**Acknowledgments**

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**References**

- [1] Fengchao, Qianjing, Huang Hong sheng. Distribution line planning and distribution transformer location optimization based on load moment [J]. Zhejiang electric power, 2015, 02:5-8.
- [2] Zhengpeixiang, Xuanjuqin, Wang kai. Government of low voltage area based on normalized load moment for distribution networks [J]. Journal of electric power science and technology, 2015, 02:80-86.

- [3] Baolifang, Li wen. Discussion on calculation coefficient in calculation of voltage loss via load moment [J]. Building electricity, 2012, 04:31-33.
- [4] Li binghua, Yueyuntao, Wang likun. Research and application of equivalent load moment [J]. Building electricity, 2012, 12:3-9.