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LOSS CALCULATION METHOD FOR DISTRIBUTION NETWORK BASED ON MEASURED DATA

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Abstract:-To calculate theory line losses has significant sense for the distribution network programming and operation. The broad application of Terminal Unit gave loss calculation for distribution network a convenience with distribution automation improvement due to richer and richer data collection. The loop current method and current-voltage method are proposed to calculate theory line losses in this paper. The double methods used enough measured data and depended not upon topology analysis or equipment parameters, are unearthly method to calculate Theory line losses for distribution network.

Keywords*:* -distribution automation; line losses; theory line losses;

1. INTRODUCTION

Line losses rate index in electric power system examined the power supply enterprise operation condition, is an important technology economic indicator. Loss calculation for distribution network is an important basic measure to determine power system planning, operation ways, equipment service, and network technological transformation and so on.

Line losses for distribution network can be divided into two kinds, management line losses and theory line losses. Some literature[1] also divide line losses into statistic line losses, theory line losses, management line losses, economic line losses and quota line losses and so on. The literature[2] divided line losses into statistic line losses and theory line losses, and pointed out their main differences cause by the measurement alignment error, omission in copying, wrong in copying, violation of power consumption, electric larceny to use electricity and to steal electricity and so on factors. Line losses, the wastage of electric energy in the transmission process, is composed of fixed loss, variable loss and other losses. The fixed loss is the no-load loss approximately, has nothing to do with the element or the distribution network load; But the variable loss can be considered as the load loss, relates with element or distribution network load, changes along with the magnitude of load.

The main difficulty of theory line losses calculation for distribution network is the variable loss computation. The former method like as the root-mean-square current method and the average current method and so on, carries on the computation by the entire feeder line as the unit, uses feeder line head end measured data, so the computation precision is low, also is complex. The broad application of Terminal Unit gave loss calculation for distribution network a convenience with distribution automation improvement due to richer and richer data collection. The literature [4] adopted theory line losses computational method based on the live terminal unit, whereas, this method not only needs measured data of each node on the line but also needs the detailed network information, relatively have troubles in the analysis and computation. The computational method based on power flow in literature [5] is too complex to used.

The loop current method and current-voltage method are proposed to calculate theory line losses in this paper. The double methods used enough monitor terminal unit (FTU, TTU) measured data, took the sector as the unit to calculate theory line losses. These two methods depend not upon topology analysis or equipment parameters. Loop current method needs TTU measured data and calculates precisely. But current-voltage method only needs the data which measured by FTU at the head end of sector, the computation is rough, but simple and practical.

2. LOOP CURRENT METHOD

The traditional calculation of theory line losses needs feeder line head end RTU measured data in electric substation and take feeder line as unit to calculate. There have the multi- spots on the feed line to be measured and can take the sector as the unit to calculate the line losses with feeder line automation and distribution automation improvement due to use of a mass of FTU. Moreover, along with the massive uses of TTU, node data on the feed line can be measured. To make full uses of these data may greatly improve the precision and efficiency of the calculation of theory line losses.

Take a sector in distribution network as example to explain the computation process of loop current method. In the sector two branches joint two distribution transformer and corresponding TTU respectively as Fig.1 shows. After gathering each of node voltage and branch current, we can divide the entire sector into 3 loops, take the loop terminal branch current i_1, i_2, i_e as loop 1 current, loop 2 current, loop 3 current respectively. According to iteration theorem, the formula of entire sector invariable line losses is:

$$\Delta s = \Delta p + j\Delta q = \sqrt{3} u_{s1} \overset{*}{i_1} + \sqrt{3} u_{s2} \overset{*}{i_2} + \sqrt{3} u_{se} \overset{*}{i_e} \qquad (1)$$

$$u_{s1} = u_s - u_1$$
$$u_{s2} = u_s - u_2$$
$$u_{se} = u_s - u_e \qquad (2)$$

Where, i_1, i_2, i_e is respectively current vector of branch 1, branch 2 and branch e; u_1, u_2, u_s, u_e is respectively voltage vector of node 1, node 2, node s and node e; superscript $*$ denote conjugate.

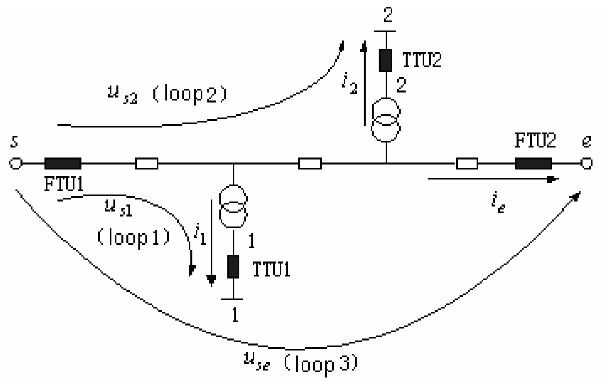

Fig. 1 Figure of a section

Therefore, suppose a sector includes N branches, each branch installs a TTU, then the number of loops in the sector is $N+1$, the line losses of the sector is:

$$\Delta s = \sum_{i=1}^{N+1} \Delta s_i \qquad (3)$$

Where, Δs_i is line losses of the i-th loop,

$$\Delta s_i = \begin{cases} \sqrt{3}(u_s - u_i)\overset{*}{i_i} & i \le N; \\ \sqrt{3}(u_s - u_e)\overset{*}{i_e} & i = N+1; \end{cases} \qquad (4)$$

Where, u_s denotes the voltage vector in sector head end; u_e denotes the voltage vector in sector terminal; i_e denotes the terminal branch current vector measured with sector terminal FTU; $u_i (i = 1,2,\cdots,N)$ denotes each branch line terminal node voltage vector respectively.

Suppose,

$$\begin{aligned} i_s &= I_s\angle\theta_s \quad u_s = U_s\angle\alpha_s \\ i_e &= I_e\angle\theta_e \quad u_e = U_e\angle\alpha_e \\ i_i &= I_i\angle\theta_i \quad u_i = U_i\angle\alpha_i \end{aligned} \tag{5}$$

Then,

$$\Delta p_i = \begin{cases} \sqrt{3}U_s I_i\cos(\alpha_s-\theta_i)-\sqrt{3}U_i I_i\cos(\alpha_i-\theta_i) & i\le N \\ \sqrt{3}U_s I_e\cos(\alpha_s-\theta_e)-\sqrt{3}U_e I_e\cos(\alpha_e-\theta_e) & i=N+1 \end{cases} \tag{6}$$

$$\Delta q_i = \begin{cases} \sqrt{3}U_s I_i\sin(\alpha_s-\theta_i)-\sqrt{3}U_i I_i\sin(\alpha_i-\theta_i) & i\le N \\ \sqrt{3}U_s I_e\sin(\alpha_s-\theta_e)-\sqrt{3}U_e I_e\sin(\alpha_e-\theta_e) & i=N+1 \end{cases} \tag{7}$$

In the above computation process, the data which needs merely is the measured value of current and voltage. Line losses computation beforetime often needs detailed network topology analysis and makes the computation process become much more complex. In the loop current method, so long as confirm the voltage and current at sector head and terminal, can definitely simplify the line losses computation using upload data by TTU and equation (6) ~ (7).

Must pay attention to the practical application, this method will produce big error if the TTU quantity is few on the scene.

3. CURRENT-VOLTAGE METHOD

Loop current method depends on data acquisition integrity for each FTU and TTU, so line losses theoretical calculation based on data acquisition with TTU is not feasible when the system do not install TTU or has fewer TTU and data acquisition is not integrity by TTU. This paper still takes the sector as unit of theory line losses calculation, proposes one kind of approximate calculation practical method for theory line losses, namely current-voltage method.

Fig. 2 The figure of a section predigestion

Fig. 2 shows predigestion circuit diagram for Fig. 1 and lists the sector head and terminal FTU only. Suppose that line load along the line evenly distributes, then mean current on the line approximately is :

$$i_{av} = \beta\left(i_s - \frac{i_s - i_e}{2}\right) = \beta\left(\frac{i_s - i_e}{2} + i_e\right) = \beta\left(\frac{i_s + i_e}{2}\right) \tag{8}$$

In the equation (5), i_s is sector head FTU actual measured current value; i_e is sector terminal FTU actual measured current value; β is line load coefficient; the line node voltage had known when confirms the line mean current, then the line voltage drop is:

$$\Delta u = u_s - u_e \tag{9}$$

Then the sector line losses are:

$$\Delta s = \beta\sqrt{3}\Delta u\, \overset{*}{i}_{av} \tag{10}$$

$$\begin{aligned} \Delta s &= \beta\sqrt{3}(\Delta p + j\Delta q) \\ &= \beta\sqrt{3}\left(\frac{U_s I_s\angle\theta_s+\alpha_s}{2} + \frac{U_s I_e\angle\theta_e+\alpha_s}{2} - \frac{U_e I_s\angle\theta_s+\alpha_e}{2} - \frac{U_e I_e\angle\theta_e+\alpha_e}{2}\right) \end{aligned} \tag{11}$$

Further,

$$\begin{cases} \Delta p = \beta\sqrt{3}\left(\frac{U_s I_s}{2}\cos(\theta_s+\alpha_s) + \frac{U_s I_e}{2}\cos(\theta_e+\alpha_s) - \frac{U_e I_s}{2}\cos(\theta_s+\alpha_e) - \frac{U_e I_e}{2}\cos(\theta_e+\alpha_e)\right) \\ \Delta q = \beta\sqrt{3}\left(\frac{U_s I_s}{2}\sin(\theta_s+\alpha_s) + \frac{U_s I_e}{2}\sin(\theta_e+\alpha_s) - \frac{U_e I_s}{2}\sin(\theta_s+\alpha_e) - \frac{U_e I_e}{2}\sin(\theta_e+\alpha_e)\right) \end{cases} \tag{12}$$

β is empirical coefficient, it is related to the sector branch line quantity and distribution transformer capacity. When the sector has more branch line, and the capacity of distribution transformer jointed each branch is approximately equal, then $\beta \approx 1$. In the approximate calculation, can take $\beta = k$, k is the shape factor, these content in the literature [1], [3] have described in detail, no longer gives unnecessary details about it.

Above of all expounds application of loop current method and current-voltage method in a sector for the computation of variable line losses. Variable line losses add no-load losses may obtain the total line losses of the sector. In the actual computation process, the current and voltage calculated which can uses mean current and mean voltage in a day or the current and voltage on schedule. Although it increases computational complexity by doing so, improves the computation precision, the feed line losses is the sum of each sector's line losses.

4. CASE ANALYSIS

In the sector which as shows in Fig.1, the line head end which RTU measured its voltage is $10.5/0^0$ kV, current is $185/28^0$ A; the line terminal end which RTU measured its voltage is $10.25/-15^0$ kV, current is $105/13^0$ A. Node 1 which TTU measured its voltage is $10.4/-8^0$ kV, branch current is $35/20^0$ A. Node 2 which TTU measured its voltage is $10.35/-10^0$ kV, branch current is $58/61^0$ A.

According to loop current method to calculate, the variable theory line losses of on this sector is 428.96+j584.41kVarh, and active power of the sector head end is 2970.61kWh. It can be seen, this sector's load is heavy, voltage drops more, so line losses are much heavy.

Utilize current-voltage method to carry on the calculation when $\beta = 1$, the variable theory line losses of on this sector is 415.40+j368.52kVarh. Compare with loop current method, the active loss just have a little difference but the reactive loss is rather different because of imbalance of load distribution on this sector.

5. CONCLUSION

This paper proposes loop current method and current-voltage method to calculate theory line losses. Loop current method calculates precisely and the computation of current-voltage method is rough, both of them take the sector as the unit to calculate theory line losses.

The double methods made full use of measured data, depended not upon equipment parameters, and ignored the network complex topology, the calculation of them is simple and convenient, are unearthly method to calculate theory line losses for distribution network.

References

[1] Huang Deren, Li Quanzhong, Zhaoshilong. Power supply handbook. Hydropower press. 1996.

[2] Gao Songjiu. SCAD and GIS for line losses calculate. 2001, 18(3): 50~51

[3]Fang Fuqi. Distribution power automation. China power press.2000

[4]zhu Huaguo. Distribution line losses calculate based on RTU. Power engineering technology. 2001, 25(5): 38~40

[5]Yan Changqun, Zhang Yan.A new method about Distribution line losses calculate. The proceedings of Distribution power automation, 1998: 24~28