PLANNING AND OPTIMIZATION STRATEGIES OF MV DISTRIBUTION NETWORK IN SHANGHAI

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ABSTRACT

Current situation, main connection modes and their applicable conditions of MV distribution network in Shanghai, China are introduced first. Considering the practical conditions of Shanghai, MV distribution network are classified into three types: overhead line network, cable network and overhead line-cable mixed network.

Planning and optimization strategies of each type are analyzed based on supply ability, reliability level and economical efficiency. For overhead line network, the installed capacity and the properties of the customers determined the number of the sections and links of a certain overhead line. Optimization must be adopted in accord with the network reconstruction. For cable network, switching station and ring network are the two main modes. Connection modes, type and number of the stations should be analyzed carefully upon the actual situation of a district. For mixed network, appropriate balance should be considered first, according to three key factors: the regional characteristics, the developing stage of a district and the corresponding planning scheme.

Practice in optimization of MV distribution network is introduced in the end of the paper. One example is about the optimization and reconstruction strategy of the distribution network in a mature district, the other is based on the reformation of overhead lines in a developing zone. These two kinds of projects are now very popular in Shanghai, especially in central town.

INTRODUCTION

Compared with HV network, MV distribution network is much more complicated and various in connection modes in typical districts of cities, especially in Shanghai and other big cities of China. It also experienced several periods along with the establishment and development of the cities. For a long time, there are no definite standards for planning and optimization of MV distribution. Planning control is also not carried out strictly. Such situation causes the casualness and variety of the connection modes in MV distribution network.

On the other hand, expanding of MV distribution network is now obviously subject to the site constraints of distribution stations in cities. So it is significant to adopt proper optimization strategy to improve power supply ability under site constraints of distribution stations.

PLANNING STRATEGIES OF MV DISTRIBUTION NETWORK

DIRECT SUPPLY FROM SUBSTATION

This connection mode is usually used for large consumers, whose installed capacity is more than 4000kVA, but less than 6300kVA.[1] Single incoming supply, two incoming supplies (both are often used, backup for each other), two incoming supplies (one is often used and the other is backup) are three often adopted forms in this mode.

SUPPLY FROM SWITCHING STATION

This mode is suitable for the regions with high load density to fully utilize the power supply capability of a certain substation. Limitations of the feeder intervals in a certain substation can also be relieved using this mode.

Direct supply from switching station

This mode is applicable to the power users with installed capacity from 1250kVA to 4000kVA, usually used in industrial parks and business districts, where large power users are concentrated intensively. [2] (See Figure 1, S represents sourcing substation, K represents switching station, u represents users)

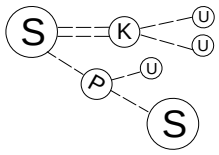

Figure1. Direct from switching station

Single ring network from switching station

This mode is suitable for small and medium power users, such as residential users, usually including three forms: (a) supply from circle network station (or ring main unit), which is sourced from switching station (See figure 2.a, K represents switching station, P represents circle network station or ring main unit). (b) supply from box-type transformer substation, which is sourced from switching station (See figure 2.b, wx represents box-type transformer substation). (c) supply from box-type transformer substation connected to circle network station, sourced from switching station (See figure 2.c). The installed capacity of a single ring is limited to 4000kVA. This mode can meet "N-1" rule. [3]

Double ring network from switching station

This mode is often used in important areas, where power users needing high supply reliability are concentrated, such as central business districts, high grade residential areas. The power sources of each circle network station are from two different switching station (or different buses of a certain switching station). This mode can usually meet "N-2" rule.

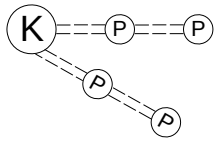

Figure 2.a From single ring network

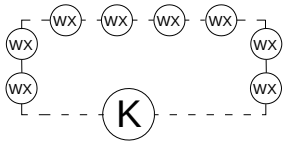

Figure 2.b From wx

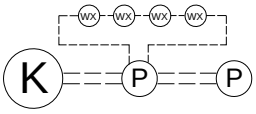

Figure2.c From wx connected to single ring network

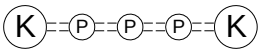

Figure3. From double ring network

Short overhead line from switching station

This mode is often used in relatively unimportant areas for saving investment. Short overhead lines are connected to a certain switching station. The installed capacity of each overhead line is limited to 2000kVA, considering the constraint conditions of relay protection. Each overhead line should be linked to another with load switchgear for power supply reliability. (See figure 4)

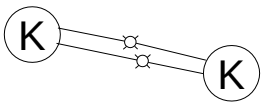

Figure4. From short overhead line

SUPPLY FROM RING NETWORK

This connection mode is often used in areas for small and medium power users, with high economical efficiency and flexible operating mode. It is commonly utilized in the distribution network in Shanghai, especially in nearby suburbs. Users can be connected to single ring network (See figure 5.a) or double ring network (See figure 5.b), which are sourced from two different substations or different buses of a certain substation.

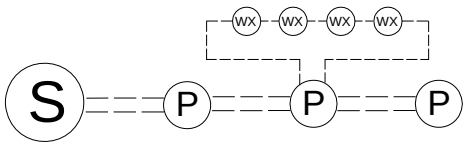

Figure 5.a Supply from single ring network

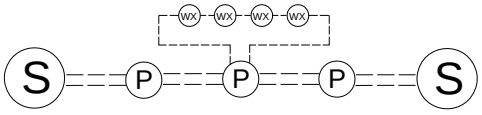

Figure 5.b Supply from double ring network

SUPPLY FROM OVERHEAD LINE

This connection mode is also one of the main modes in Shanghai, especially in suburbs. The features of this mode include: convenience for finding out faults, short failure recovery time, more external disturbances and bad environmental effects. It is often used for unimportant small and medium power users, with the installed capacity between 0 and 1000kVA (for ungrounded neutral system or arc suppression grounded neutral system, the upper limit capacity can be raised to 1250kVA) [1]. This connection mode is consisted of two types.

Radial connection with single power supply

It is suitable for remote areas and unimportant users, with poor power supply reliability. The distribution line is not linked to others. The supply line can be separated into several sections for narrowing blackout scopes when faults occur. Figure 6 is a typical example.

Open ring network with muti-power supplies.

This mode is applied in the areas with high load density and high power supply reliability. There are two or more than two power supplies for a certain line and can meet N-1 rule. When power faults occur, power supply of the faultless section can be recovered after switching operation. This mode includes three types according to the number of the sections and links of the supply lines.

(a) One section-one link

Figure 7.a is a typical example. The load rate of Line A cannot exceed 50% for another 50% of the supply capability should be retained for spare capacity.

(b) Two sections-two links

In this type, the load rate of each supply line can reach 67%. Power load of each section can be shifted to other lines flexibly.

(c) Three sections-three links

In this type, the load rate of each supply line can reach 75%. But the switching operation of dispatching department is more complicated compared with other modes.

We can also use multi-section-multi-link mode, but it is not recommended for complication of dispatching operations.

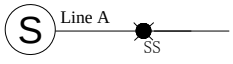

Figure6. Radial connection

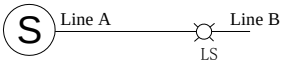

Figure 7.a One section-one link

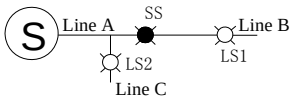

Figure 7.b Two sections-two links

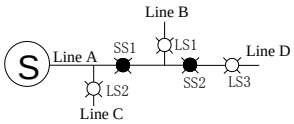

Figure 7.c Three sections-three links

(SS—Section switch, LS—Load switch)

RECOMMENDED SUPPLY MODES OF TYPICAL AREAS

The reliability, economical efficiency and other performances of a certain MV distribution network are determined by the connection modes. For a certain area, which supply mode should be adopted is often concerned in the distribution network construction. Several important points should be considered thoroughly: (a) how to select a suitable and reasonable supply mode considering different emphasis. (b) transition supply mode in different developing stage of a certain area. (c) optimization and reformation of the MV distribution network in mature area. Typical strategies of different areas in cities are showed in table 1.

Table 1.Typical supply strategies of different areas

Type of areas	Recommended power supply mode
Residential areas	Common residential areas can adopt single ring network supply mode, for example, S-K-P(WX) or S-P-P-P. High grade residential areas can adopt double ring network supply mode, for example, K-P-P-P-K or S-P-P-P-S. For some mature areas, supply modes can be reformed on the basis of the existed network, combing the reformation of the local distribution network. (See the following example)
Business districts, Public areas	Large scale and centralized business districts or can centralized public areas be supplied direct from S or adopt S-K mode.(backup supply sources should be considered) Common business districts or dispersed areas can adopt S-K, S-P-P-P or S-P-P-P-S mode, upon the supply reliability.
industrial parks, development zones	Large users can be supplied direct from S or adopt S-K mode, upon the installed capacity. Small and medium users can adopt S-K or S-P-P-P mode. Users supplied with LV can adopt S-K(with transformer), S-P(with transformer), S-K-wx or S-P-wx mode.
Remote areas	Overhead lines are usually adopted for economical efficiency. Which type will be selected is upon the actual characteristics and the developing stage of the certain area.

(S, K, P, wx represents substation, switching station, ring network, box-type transformer respectively.)

A general diagram of the overall supplying modes for overhead line network and cable network is shown in figure8.

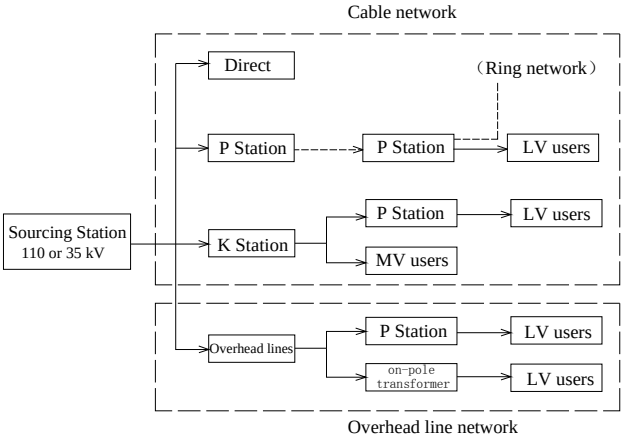

Figure8. General diagram of different supply modes

PRACTICE IN OPTIMIZATION OF MV DISTRIBUTION NETWORK

EXAMPLE1: OPTIMIZATION OF EXISTED DISTRIBUTION NETWORK

In figure 9, S1 represents a substation with the voltage 35 kV, P1 and P2 represent circle network station. P3 represents a terminal distribution station. S1, P1, P2 and P3 were constructed years ago, and S1-P1-P2 consist a single ring network. With the development of local economy, power load also grows quickly. In 2008, S2 (representing a substation with the voltage 110 kV) was constructed to meet the need of the power requirement. In the reformation of the local distribution network, P3 was reformed to a circle network station, and S1-P1-P2-P3-S2 consist a double ring network. This mode can meet “N-2” rules and the supply reliability was also upgraded to a new level.

In the preliminary developing stage of a certain area, single ring network is always adopted as the connection mode for lack of power sources. With the development of the supporting facilities nearby, power load grows quickly. New substations should be constructed. Combining the construction of the new substations, the local distribution network can also be considered to be optimized by adjusting the existed connection modes. This strategy is suitable for the above situation.

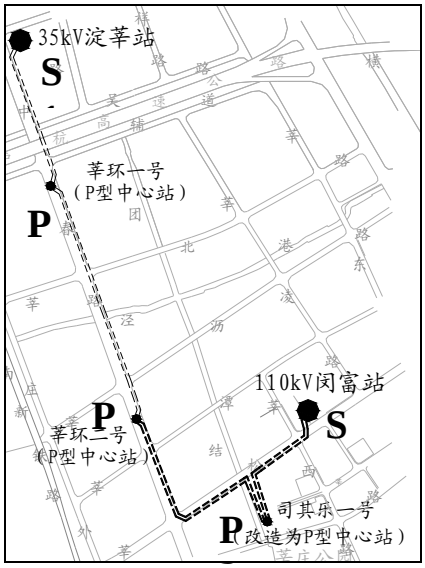

Figure9. Optimization of existed distribution network

EXAMPLE2: REFORMATION OF OVERHEAD LINES

Figure 10 shows a main line in a certain district in Shanghai. Along with the road, all kinds of power users such as residents, businesses, scared factories, administration branches and others are dispersed. Overhead lines are adopted in the first stage for economical reasons.

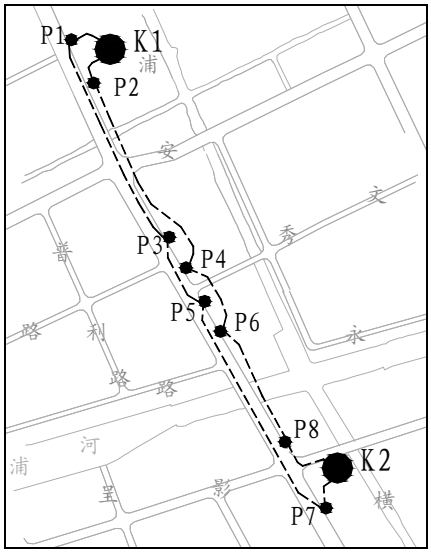

Figure10. Reformation of overhead lines

With the development of the city, new businesses appeared faster and faster. The existed overhead line supply mode cannot meet the requirement of power supply and city sights. In the process of the reformation, S-K-P-S mode was adopted. In figure 7, K1 and K2 are switching stations. P1~P8 are ring main units. K1-P1-P3-P5-P7-K2 and K1-P2-P4-P6-P7-K2 consists a single ring network respectively. In the selection of the sites of ring main units, P1 and P2, P3 and P4, P5 and P6, P7 and P8 are set nearby for convenience of power users to getting 2 or more different feeders.

In some unimportant or secondary branch roads, short overhead lines are retained to save investment. The short overhead lines are connected to the buses of K1 and K2, and the nearby overhead lines are linked with on-pole load switchgears. (refer to figure4)

CONCLUSIONS AND PROSPECTS

Reliability, economical efficiency and reasonability of MV distribution network are closely related with connection modes. Some often used connection modes of MV distribution network in introduced in this paper, and their applicable conditions are analyzed in detail. Because development degree of each area in a city is different, characteristics and different stages of each area should be considered carefully. Adaptation to local conditions should be researched thoroughly.

Planning of MV distribution network is an important problem, and is paid more and more attention by power supply companies. But transition planning is also very important in the construction of MV distribution network. In a way, it is much more important, because boundary and practical conditions should be considered due to the different developing stages. In the progress of network construction, optimization and reformation on the basis of the existed network must be emphasized to meet the development of the city. Proper strategies should be adopted for saving additional investment without reduction of reliability. The examples in the paper show two practical engineering applications in the reformation of MV distribution network. However, planning and optimization of MV distribution network is a complicated work, boundary conditions, especially practical conditions of a certain area should be considered throughout. The importance of a certain area, the requirement of different customers, the limit conditions of total investment and the long-range plan are four main factors for consideration in the optimization of MV distribution network.

REFERENCES

[1] Shanghai Electrical Power Company, 2004, *Several regulations on Shanghai Electric Power Grid*, Shanghai, China.

[2] ZHANG Dali, 2007, “Connection modes of MV distribution network and settings of K-style substations”, *Power System Technology*, Vol.31, 83-86.

[3] YAO Lina, ZHANG Jun, 2006, “Analysis of typical connection modes of urban middle voltage distribution network”, *Electric Power Automation Equipment*, Vol.26, 26-29