Analysis of Abnormal Low-voltage Line Loss in the Transformer Area Caused by Distributed Photovoltaic Access

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Abstract. This paper analyzes the problem of abnormal low-voltage line loss in the transformer area caused by distributed photovoltaic access. First, it summarizes the solutions of distributed photovoltaic access to the transformer area through low-voltage, studies the calculation method of the current low-voltage line loss in the transformer area and then analyzes the reasons of the abnormal line loss caused by distributed photovoltaic access in both technology and management, finally, the countermeasures are given in the conclusion.

1. Introduction
In recent years, as distributed photovoltaic have been connected to low-voltage distribution networks, some power supply stations report abnormalities in low-voltage line losses after distributed photovoltaic access. The main manifestation is that the low-voltage line loss in the transformer area is higher than before, which is not conducive to the economic operation of low-voltage distribution networks.

2. The Solutions of distributed photovoltaic access to the transformer area through low voltage

2.1. The solution of distributed photovoltaic access to a public transformer through a low-voltage dedicated line
This solution uses one circuit to connect distributed photovoltaic to the 380V bus of a 10kV public transformer[1]. It is mainly suitable for distributed photovoltaic with centralized access, centralized metering, and all generated electricity is sent to the public grid, as shown in figure 1. The public connection point is the 380V bus of public transformers. The total installed capacity is generally 20 to 200kw. The metering point is set at the photovoltaic grid-connected access box which is installed at the junction point of the photovoltaic inverter or the low-voltage outlet of the public transformer. The actual installation position can be adjusted according to the site conditions.
2.2. The solution of distributed photovoltaic access through low-voltage public grid

This solution uses one circuit to connect distributed photovoltaic to 380V public lines, which is mainly suitable for distributed photovoltaic with 220V (380V) access and all generated electricity is sent to the public grid, as shown in figure 2. The total installed capacity does not exceed 8kWp, and it is connected to the grid through 220V. When the total installed photovoltaic capacity is 8-20kWp, it is connected to the grid through 380V. The installation location of the energy meter can be determined according to the actual situation, and the installation location is reserved in the photovoltaic grid-connected access box.

3. The calculation method of low-voltage line loss percentage in the transformer area

The low-voltage line loss percentage of the transformer area before the distributed photovoltaic access = (the low-voltage side power consumption of the transformer area before the distributed photovoltaic access - the sum of the power consumption of low-voltage users in the transformer area) / (the low-voltage side power consumption of the transformer area before the distributed photovoltaic access) [2];

The low-voltage line loss percentage of the transformer area after the distributed photovoltaic access = (the low-voltage side power consumption of the transformer area after the distributed photovoltaic access + the electricity sent by distributed photovoltaic to public grid - the electricity reversed by the transformer area - the sum of the power consumption of low-voltage users in the transformer area) / (the low-voltage side power consumption of the transformer area after the distributed photovoltaic access + the electricity sent by distributed photovoltaic to public grid - the electricity reversed by the transformer area);

Remarks: The measuring point of the public transformer is set on the low voltage side.

4. Analysis of abnormal low-voltage line loss in the transformer area

4.1. Technical aspects

The first, when the distributed photovoltaic line loss metering point is set on the photovoltaic side of the low-voltage grid connection line (the line loss metering point is inconsistent with the connection point of the public grid):

In addition to the low-voltage users in the transformer area or the reverse transmission through the transformer area, a part of the distributed photovoltaic power generation is also consumed by the
grid-connected low-voltage line[3], therefore, the electricity sent by distributed photovoltaic to public grid = distributed photovoltaic power generation - the line loss of photovoltaic grid-connected line. When distributed photovoltaic is connected through low-voltage dedicated line or low-voltage public power grid to the transformer area, if the distributed photovoltaic line loss metering point is set on the photovoltaic side of the low-voltage grid-connected line instead of the connection point of the public grid, at this time, the electricity sent by distributed photovoltaic to public grid is incalculable, can only be replaced with photovoltaic power generation. So when using the formula to calculate, it is equivalent to adding a photovoltaic grid-connected low-voltage line loss to the numerator and denominator, the value of the true fraction will become larger, so it can be concluded that the calculated low-voltage line loss in the transformer area after distributed photovoltaic access will increase. Taking a transformer area with a rated capacity of 200KVA, a monthly supply of 288,000kwh, and a line loss of 4% as an example, when a distributed photovoltaic with a capacity of 100kwp and a maximum monthly power generation utilization hour of 120h is connected to the transformer area through a low-voltage dedicated line, see the table 1 and figure 3 for the low-voltage line loss in the transformer area.

Table 1. Calculation of low-voltage line loss in the transformer area after distributed photovoltaic access with different grid-connected line length

| Length of photovoltaic grid-connected lines (km) | 0 | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 |
|-------------------------------------------------|---|-----|-----|-----|-----|-----|
| Monthly power consumption of photovoltaic grid-connected lines (kwh) | 0 | 669 | 1338 | 2008 | 2677 | 3347 |
| Photovoltaic monthly power generation (kwh) | 12000 | 12000 | 12000 | 12000 | 12000 | 12000 |
| The low-voltage side monthly power consumption of the transformer area (kwh) | 28800 | 17469 | 18138 | 18808 | 19477 | 20147 |
| The low-voltage line loss in the transformer area before photovoltaic access (kwh) | 1150 | | | | | |
| The low-voltage line loss in the transformer area after photovoltaic access (kwh) | 1819 | 2488 | 3158 | 3827 | 4497 | |
Figure 3. Change of low-voltage line loss in the transformer area after distributed photovoltaic access with different grid-connected line length

It can be seen from the above table and graphics that the low-voltage line loss of the transformer area will increase after the distributed photovoltaic access, and the longer the grid-connected line, the more the line loss will increase. As shown in the calculation example, when the length of the grid-connected line is 500 meters, the line loss in the transformer area will increase to 13.99%, which is 2.5 times higher than the line loss before the photovoltaic access. It can be seen that the distributed photovoltaic access to the transformer area has a great impact on the low-voltage line loss.

When distributed photovoltaic is connected to low-voltage public grid, in addition to increasing the loss of grid-connected lines, it will also cause the line loss of 220V low-voltage public lines to change[4], that is: when the low-voltage public lines are originally heavily loaded, if the low-voltage public line reaches the economic load rate after the photovoltaic access, the line loss will decrease. If the low-voltage public line is lightly loaded after the photovoltaic access, the line loss may be unchanged; when the low-voltage public line is originally at the economic load rate, if the low-voltage public line is lightly loaded after the photovoltaic access, the line loss will increase.

The second, when the distributed photovoltaic power generation metering point is set on the grid side of the low-voltage grid connection line (the line loss metering point is consistent with the connection point of the public grid): This situation is only possible when the distributed photovoltaic adopts T-connected 220V low-voltage public lines for grid connection, it will affect the load rate of the 220V low-voltage public lines, thus causing the line loss of the 220V low-voltage public lines to change.

In addition, after the distributed photovoltaic access, it will also affect the transformer load factor and the three-phase load imbalance of the transformer, resulting in changes in transformer losses, which in turn will affect the line loss of the medium-voltage distribution network.

4.2. Management aspects

The low-voltage line loss percentage of the transformer area after the distributed photovoltaic access = (the low-voltage side power consumption of the transformer area after the distributed photovoltaic access + the electricity sent by distributed photovoltaic to public grid - the electricity reversed by the transformer area - the sum of the power consumption of low-voltage users in the transformer area) / (the low-voltage side power consumption of the transformer area after the distributed photovoltaic access + the electricity sent by distributed photovoltaic to public grid - the electricity reversed by the transformer area), if the file is not created and the calculation formula of the low-voltage line loss is not modified in time after the distributed photovoltaic access, it will lead to chaos in the calculation of
line loss in the electricity information collection system[5], and the following two typical problems may occur:

- The transformer area with high low-voltage line loss becomes a transformer area with low low-voltage line loss. After the distributed photovoltaic is connected, although the power consumption of low-voltage users in the transformer area has not changed, the low-voltage side power consumption of the transformer area after the distributed photovoltaic access has been reduced, resulting in the illusion that the low-voltage line loss in the transformer area has been greatly reduced;

- The phenomenon of "zero line loss" and "negative line loss" in the transformer area. After the distributed photovoltaic access, the power consumption of low-voltage users in the transformer area has not changed. The monthly power generation of photovoltaic is equal to or greater than the monthly power consumption of low-voltage users, resulting in a cumulative monthly power consumption of 0 in the low-voltage side of the transformer area, and even negative, causing the illusion of "zero line loss" or "negative line loss" in the transformer area after the distributed photovoltaic access.

5. Conclusion

- For distributed photovoltaic where the line loss metering point is set on the photovoltaic side of the low-voltage grid-connected line (the photovoltaic line loss point is inconsistent with the connection point of the public grid), the location of the photovoltaic grid-connected access box can be transformed, and the photovoltaic line loss metering point can be set at the connection point of the public grid;

- When the distributed photovoltaic power generation measurement point cannot be changed due to site conditions, the photovoltaic access point can be adjusted according to the development of the distribution network, and the length of the photovoltaic low-voltage grid-connected line can be shortened as much as possible, thereby reducing the impact on the low-voltage line loss;

- The power supply station should sort out all the transformer area connected to the distributed photovoltaic, establish files in time and modify the calculation formula of the low-voltage line loss in the transformer area.

References

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