Power Loss Reduction Practices in the Supply Area of a Typical Substation in Huangshan City in China

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Abstract. The negative impact of distribution power losses is often passed down as costs to customers. Besides, the percentage of distribution losses is one of the important indicators to evaluate the performance of a distribution company. Therefore, minimizing distribution power losses shall be one of the key objectives of a distribution company. In this paper, a typical case of power loss reduction and the project’s effect in the supply area of a typical substation in Huangshan city in china are given to demonstrate the common practices that China uses to reduce technical distribution power loss.

1. Introduction

1.1. Project Introduction

The line loss rate is a very important economic indicator of the power supply sector. The percentage of power lost in the network to the total power supply is called the line loss rate. Anhui Province initiated power loss reduction project all over the province in 2010. The project covered 16 prefecture-level cities and 63 million customers. It includes both non-technical losses reduction practices and technical losses reduction practices. In this paper, we focus on the measures taken in the supply area of a typical 35kV substation, Guilin Substation, in Anhui Province. It is a typical case as it includes the commonest practices China uses to reduce power loss in distribution grid.

2. Situation of Supply Area of Guilin Substation before Project

2.1. Substation

Guilin Substation had two main transformers, with capacity of 4000kVA and 6300kVA respectively. The type of customers was mainly residential. Transformers were not equipped with voltage regulation functions. There was a reactive power compensator with a capacity of 600kVar. The average power factor of the MV busbar of the substation was 0.886.

2.2. Monitoring Devices

The following monitoring devices and a DMS system have been installed before power loss reduction project.
98 voltage monitors were installed at substation’s 10kV busbars, 10kV feeders, distribution transformers and LV feeders. They communicated with DMS via wireless network.

RTU was installed in substation and sent substation status data to DMS system.

Smart meters were installed in the MV outlets, distribution transformers, and users of the substation. All meter data were sent to the AMI system through optical fiber and wireless network.

2.3. MV Feeders
There are 6 MV feeders powered by Guilin Substation. The length, no. of transformer, power factor and power loss are between 10-12km. Voltage curves of MV feeders are recorded in DMS. The lowest voltage was only 9.1 kV. The highest power loss is 11%.

2.4. Distribution Transformer and Customer
Typical voltage curve of LV side of distribution transformers are shown in figure below. We can see an obvious voltage drop during peak time.

![The voltage curve of LV side of a distribution transformer](image)

**Figure 1.** The voltage curve of LV side of a distribution transformer

2.5. Non-technical Power Loss
Non-technical losses are usually caused by the following 4 reasons.

- System data do not match with the actual situation, for example incorrect feeder-transformer relationship, incorrect transformer-customer relationship, etc.
- Errors happen during meter reading. The commonest error is that data at different freezing time are read and this leads to error in power loss calculation.
- Errors in meter management, such as malfunction meters, meters with problematic wiring, incorrect meter files, etc.
- Electricity theft via various methods [2]

Based on the analysis of system data and field investigation, we found that non-technical loss in the Guilin Ss is mainly caused by the 4 reasons above. Measures should be taken to prevent the errors and electricity theft actions.

3. Problem Analysis
Generally speaking, there are 2 types of methods to reduce power loss. The first type is by investing grid, such as building new substations, changing old devices etc. The second type is by optimizing grid operation status, such as reasonably opening/closing switches, changing grid operation modes, etc. [3] Measures such as investing in substations, shorten distribution feeders are shown effective in reducing loss reduction from the management and technical aspects. [4]

3.1. Substation
- Main transformer had no voltage regulation capability.
Reactive power compensation capacity is insufficient.

3.2. MV Feeder
- With an average power supply radius of 15km, the power supply radius was too long.
- The cross section of the wire was small, and the cross section of the main feeder was less than 120mm².
- The load rate exceeded 70%, but distribution grid didn’t meet N-1 structure and uncapable of load transfer.
- No reactive power compensation was available on MV feeders.

3.3. Distribution Transformer and Downstream
- With an average power supply radius of 1.11km, the power supply radius was too long.
- Lots of transformers are S7 and S9 type (high power consumption).
- The proportion of heavy-loaded and overloaded distribution transformers was 21%.
- Reactive power compensation, less than 10% of the distribution transformer capacity, was insufficient.

3.4. Non-technical Loss Causes
We further examine the 4 types of causes and summarize the commonest errors.
- Mistakes during topological information input
- The alteration to the consumer-transformer relationship is not updated in time
- For transformer meters and customer meters, data at different freezing time are read
- Incorrect meter reading and data input
- Some meters are omitted during manual reading
- Incorrect meter installation, such as incorrect wiring connection
- Meter operational failure
- Various methods of electricity theft

4. Technical Loss Reduction Measures

4.1. Grid Structure Retrofit
We constructed a new 35kV Sanyang Substation to increase the power supply source and reduce the power supply radius. MV feeder are sectioned with sectionallizers. A ring main structure is formed between 2 substations. The distribution grid after retrofit is shown on the map.

![Figure 2. Grid structure after retrofit](image)
4.2. Improving Voltage Regulating Capability and Power Quality

4.2.1. To improve the voltage regulating capability of substations
We replaced the two 35kV main transformers SL7-4000kVA and 6300kVA of Guilin SS with two on-load voltage-regulating type, SZ11-8000 kVA /±4×2.5 and replaced CT and protection devices correspondingly.

4.2.2. To improve the voltage regulating ability of MV lines
We installed intelligent line voltage regulator at the 2/3 the length of the distribution feeders.

4.2.3. Applying VVC function
VVC module of DMS system was applied to monitor the operation status of distribution grid in real time and perform dynamic voltage and reactive power optimization control.

4.3. Enhancing Power Factor with Reactive Power Compensator

4.3.1. Substation: Replacing reactive power compensator at substations
Based on the analysis of the loss levels of distribution transformers, it is shown that using more efficient transformers can further reduce losses to a large extent. For substation, the original reactive power compensation device was changed to an intelligent compensator set with grouping switch functions. The actual reactive power compensated can be regulated as needed. The average power factor of substation after is 0.99.

4.3.2. Feeders: Adding reactive power compensator on feeders
We add compensators at the 2/3 length of the feeder nearer to the customer side for 4 feeders with low power factors.

4.3.3. Transformers: Adding reactive power compensator at transformers
Take transformers on feeder 917 for instance.
Feeder 917 was 10.1 km in length, with 55 distribution transformers. According to the historical data of DMS, the user’s feedback and field investigation, we found that 15 distribution transformers were overloaded and without reactive compensation equipment.
According to Regulation of Distribution Grid Design of SGCC, transformers with capacity of more than 100kVA need to be configured with reactive compensation equipment and the compensation capacity should be 20-40% of the transformer capacity. Therefore, 15 reactive compensators were installed with a total capacity of 810kVar.
4.4. Add New Distribution Transformers
The original capacity of a transformer was 200kVA, with a load rate of 60% and 220 households of users. Power supply radius was 1,020 meters. The voltage at the end of feeders was only 182V.

In this case, we added a 200kVA distribution transformer and reduced supply radius to 600m and improve voltage quality.

Figure 3. Reactive power compensator installed at transformers

Figure 4. Grid before project

Figure 5. Grid after project
4.5. Change into New Energy-efficient Distribution Transformers
Take feeder 918 for instance, the annual energy supply of feeder 918 (length: 12km) was 8.07 million kwh and power loss was 11.2%. There were 17 distribution transformers on this feeder, 9 of which were S7 type (2 of 30kVA, 5 of 50kVA, 2 of 80kVA) and 8 of which were S9 type (100kVA).

We changed all S7 and S9 transformers into S13. Power loss was reduced to 6.6% after the replacement.

5. References
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