Application of Low Voltage Treatment Device Based on Electrochemical Energy Storage

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Abstract. With the rapid development of social economy, the power supply capacity of the existing power grid has been far from the increasing load demand, especially the summer (winter) peak period. The problems such as heavy overload of power grid equipment and low voltage of line are extremely prominent and seriously affects the safe and stable operation of the power grid. This problem is more serious in the rural power grid. In order to increase the progress, shorten the construction cost of upgrading and transformation of the traditional power grid, a technical scheme is proposed in this paper by using electrochemical energy storage technology to solve the overload and low voltage problems of local power grid equipment, and obvious results have been achieved through pilot project.

1. Introduction

The low voltage problem of the rural power grid is the one of the problems that perplex the power grid companies[1]. On the one hand, during the construction,the capacity of the users of the rural distribution network has changed greatly from that at present, and the transformer capacity and wire diameter are relatively small. Therefore, the foundation of the rural distribution network is relatively weak. On the other hand, the power load of rural power grid is scattered, the load density is low, and there are many changing factors such as the relocation of users and the increase of power demand, which make the power supply capacity of many power grids are always"late"for the application demands. At present, the transformation of rural power network is a systematic project, which needs to be promoted step by step according to the plan. Therefore, the problem that the transformation and demand can not keep pace often occurs[2].

2. Research Status

In order to solve this problem, literature [3] proposes to optimize reactive power compensation for medium voltage distribution network to solve the low voltage problem, but it cannot solve the low voltage problem at the end of low-voltage distribution network. Literature [4] governs low voltage through compensation based on fast switching series capacitor, but it is not applicable to low-voltage power grid with large resistance. Literature [5] proposed the voltage control method of series transformer, but there are problems in economy and loss. Document [6] proposed to configure distributed power supply at the end of rural power grid to improve the voltage, which has certain applicability, but has a large investment. Literature [7-8] has designed the reactive power compensation by optimizing the capacitor configuration, which can reduce the reactive power shortage of the line, and has a certain effect on the low voltage problem caused by reactive power, but can not solve the voltage drop caused by line resistance. Literature [9] The scheme of optimizing grid load distribution and improving voltage. Document [10] proposed the method of changing network structure and adding line voltage regulator to improve line terminal voltage. Document [11] proposed to adopt the method of on load voltage regulation, and connect a transformer in series in the line to improve the terminal voltage of the line. Literature [12] proposed a comprehensive regulation method for rural power grid low-voltage governance based on series voltage compensation control method, combined with a comprehensive compensator based on SVG+shunt capacitor, to achieve three-phase load imbalance governance and reactive power compensation. To sum up, the main means to solve the low voltage of the power grid at present are: configuring reactive power compensator, increasing and optimizing the distribution transformer layout, and expanding the transmission line diameter. These methods improve the voltage quality of distribution network to a certain extent, but they are not practical and economical for rural power distribution network with low load density.

3. Necessity and advantages

The energy storage devices which are based on the battery have excellent performance of fast control response, flexible control, active and reactive four quadrant decoupling control. The electrochemical energy storage system can be charged when the power consumption is low, discharged when the power consumption is high which means to achieve peak load cutting and valley

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filling by adopting reasonable scheduling and control strategies.

3.1 Excellent Performance and Fast Control Response

Based on the battery energy storage device's excellent performance of fast control response, flexible control, active and reactive four quadrant decoupling control, the electrochemical energy storage system can be charged when the power consumption is low, discharged when the power consumption is high, and part of the active power is consumed locally to achieve peak load cutting and valley filling by adopting reasonable scheduling and control strategies; At the same time, the converter of energy storage which is called PCS can be used as a dynamic reactive power compensation device to adjust the power factor of the line into a reasonable range by outputting and absorbing reactive power. Therefore, the electrochemical energy storage technology is not only feasible, but also has great potential in improving the power quality of the power grid.

3.2 Short construction period and low cost.

The traditional treatment measures about the power grid equipment overload and low voltage include installing compensation devices on the line or load side, re erecting lines and rebuilding power supply points nearby, which have problems such as high investment cost, long construction period, and great construction difficulty.

In addition, for the power supply line or power supplying district which have the obvious seasonal and load peak valley characters, the upgrading and transformation of traditional transformers, transmission and distribution lines and other equipment will lead to problems such as leisure and low utilization rate during the low load valley period, which is less economical.

If the energy storage system is used to settle this problem, the advantage is obvious. First it is easy to install. Second , the equipment production and construction period is short which is only 2 months., Third, the cost is reduced by 60% compared with the traditional transformation method. It has another important advantage: if the characteristics of load power consumption change, the energy storage equipment can be reused by adjusting the installation position.

3.3 Diversified application scenarios

The energy storage equipment is especially suitable for some special application scenarios, such as: it is very difficult to increase the substation layout or outgoing line spacing which is limited by environmental conditions; Scenarios of insufficient transformation capacity, small line diameter and transformer capacity expansion in the central urban area. In addition, the areas which have good lighting conditions (especially in mountainous areas), the light storage integrated system can effectively reduce the one-time investment of the project while solving the low voltage problem at the end of the line.

Therefore, this paper proposes a novel method to control low voltage by using electro-chemical energy storage devices. It can replace new lines and reduce the problems of long approval process and large investment. Moreover, the installation and removal of energy storage equipment are simple, and it can flexibly cope with the problems such as user relocation.

4. Technical principles

4.1 Technical principles

Figure 1 is the schematic diagram of the energy storage device connected to the low-voltage side of the distribution transformer.

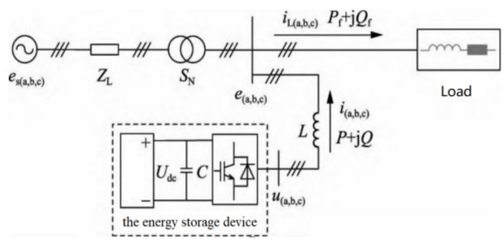

Figure 1. The schematic diagram of the energy storage device.

Figure 2 is the equivalent circuit diagram, where U_N is the rated voltage on the grid side; R+jX is the sum of equivalent impedance values of line and transformer; U is the voltage loss of the line; The load is P_f+jQ_f; The output power of the energy storage device is equivalent to the load with a power of -(P+jQ).

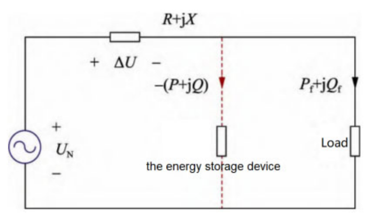

Figure 2. The equivalent circuit diagram of the energy storage device.

The line voltage loss after the energy storage device is put into operation is

$$\Delta U_2 = [(P_f - P)R + (Q_f - Q)X]/U_N \tag{1}$$

When P < Pf、Q < Qf, it is easy to see that the line voltage loss is decreased with the increase of active and reactive power output by the energy storage device.

4.2 Low Voltage Technical Solution for Energy Storage Equipment

For energy storage equipment to solve low-voltage problems, it is necessary to consider not only the needs of users, but also the facilities and configuration of the power grid. Therefore, its technical solution should have at least two levels: substation transformer level and terminal user level. The station level mainly considers whether there is low voltage at the outlet and whether there is heavy overload; In addition, if the station area where the energy storage equipment will be installed at the terminal user level, its capacity needs to be verified again and set according to the network situation.

5. Functions of Energy Storage Equipment

The Energy Storage Equipment should have the following functions:
(1). Quick start, eliminate low voltage and compensate for insufficient power;
(2). It has the function of safe and fast disconnection, and reverse power transmission is forbidden;
(3). It has data transmission capability, and can set parameters remotely to achieve remote control functions;
(4). It is easy to install and suitable for the conditions such as the terminal of the rural power grid. There is no limit to the form of support and floor type, but the devices should be safety guarantee for equipment to avoid electric shock and leakage hazards;
(5). It shall be able to adapt to high temperature, low temperature, high humidity and other external environments, and ensure the power supply quality of equipment, with maintenance free function.
(6). It is mainly aimed at the terminal user. The capacity is about 7-15kW. It is recommended to configure it as 10kW.

6. Point Selection Requirements of Energy Storage Equipment

6.1 Installation Point

For energy storage equipment of the terminal user level, it should be used as close to the user as possible to reduce the impact of compensation effect that caused by line transmission. The equipment shall be installed according to the site conditions according to the actual situation.

6.2 Load Characteristic

There are many reasons that can cause the low voltage problem. For the problem of transmission wire is too long, it is necessary to consider line reconstruction to reduce line loss to improve the voltage value at the end of the line, which is not suitable for the application of energy storage technology. For the energy storage technology, the most suitable condition is that the load suddenly increases in a period of time, and the power supply capacity of the line is not sufficient the scenario. It is because only on such lines there could have enough time to charge and discharge the energy storage equipment. At the same time, it is also the scene where the user load changes greatly and can replace the line transformation best.

7. Application Effect of Energy Storage Equipment

7.1 Basic Information

There is no low voltage and heavy overload at the outlet of the substation area. The main electrical equipment is cooking appliances which power is about 9kW. After the appliance is put into use, there is obvious period low voltage problem (generally 7:00~9:00). Except this user, other users at the end of the substation area have no low voltage problem. The compensation power of the energy storage device is 3kW, and the compensation capacity is 3.6kWh.

7.2 Control Strategy of Energy Storage Device

7.2.1 Energy storage charging strategy

set the threshold of starting charging voltage and stopping charging voltage of the energy storage device as 225V and 220V respectively, that is, when the voltage at the monitoring point is greater than 225V, the energy storage device starts charging; When the voltage at the monitoring point is lower than 220V or the charging is completed, the energy storage device stops charging.

7.2.2 Energy storage and discharge strategy

set the threshold voltage for starting discharge and stopping discharge of the energy storage device as 205V and 210V respectively, that is, when the voltage at the monitoring point is lower than 205V, the energy storage device starts discharging and compensates the terminal load; When the voltage at the monitoring point reaches 210V or the discharge is completed, the energy storage device stops discharging.

7.3 Control Results

The day compensation curve is is shown in the figure 3. The voltage after compensation is the above curve and the scale is on the left while the compensated power is below curve and the scale is on the right. overload at the outlet of the substation area.

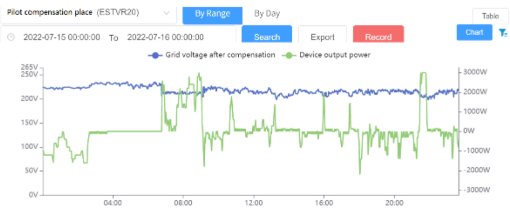

Figure 3. The control result diagram of the energy storage device.

It is obvious that the energy storage device starts immediately when the overload occurs and it is about 7 o’clock in the morning. The voltage is compensated to the

205Volt. When the overload is end, the device starts charging according to the setting rules.

8. Pilot conclusion

(1) Distributed battery energy storage device can be used to solve the problem of short-time low voltage caused by load increase.
(2) The compensation capacity of the energy storage device is limited to the battery capacity. It is important to calculate and meet the user's low voltage governance demand.
(3) Using the electrochemical energy storage equipment to solve the low voltage problem, in essence, it is not controlled the voltage directly, but operates as a power generator. After solving the problem of insufficient power, the voltage returns to normal. Therefore, it can also solve other grid problems through different control methods except solving the problem of insufficient power, such as APF mode, solving the three imbalance problems, harmonic problems. However, coordination and priority should be considered when implementing multiple control strategies.

Acknowledgments

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