The effectiveness of implementation grid energy storage in power supply systems

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Abstract. The most important indicator of the reliability of the power system is the quality of the supplied electricity. The quality of power supply depends on many parameters, the maintenance of which at a given level (voltage, frequency deviation) is carried out using various devices. One of these devices is grid energy storages, allowing you to even out schedules of daily, weekly, seasonal and annual electrical loads. Energy storage devices can also act as an uninterrupted power supply for substations and electrical grids, provide increased dynamic and static stability, and increase the transmission line throughput. However, the use of energy storage to eliminate irregularities in the schedule of generating capacities is not a traditional way. When using energy storage devices, the most important task is to determine their total capacity and energy intensity, as well as the location of the storage devices in the energy system and the economic feasibility of these measures. The criterion for the placement of storage devices is to reduce energy losses when using grid energy storages. In the course of the research, graphic and analytical dependencies of the distribution grid loads were obtained before and after the placement of grid energy storages, depending on the average daily active load.

1. Introduction

The quality of electricity is one of the most important indicators affecting the reliability of both power systems and their equipment. Electricity quality is the degree to which electricity parameters meet the required values. A negative impact on quality is exerted by: voltage deviation, frequency deviation, coefficient of the non-sinusoidal voltage curve, coefficients of the negative and zero sequence voltage. A decrease in the quality of electricity supplied to consumers entails a decrease in the reliability of power supply, disruption of the operation of electrical appliances, control systems that use computer technology. To resolve these problems, it is necessary to introduce new devices into power plants that can ensure the normal functioning of the grid. All power systems depend on the mode of electricity consumption, which is constantly changing with time.

The most important indicator of the power system mode is voltage. It is voltage that affects the quality of electricity, the reliability of power supply, the modes of operation of the power system, the efficiency of work.

At the present time, the main problems of electric power systems include: increasing the unevenness of load schedules, increasing the steepness of these schedules, turning local accidents into system ones due to the complexity of the internal structure of power systems. At the same time, the variable part of the load schedules is not always possible to cover with the help of power plant units in the conditions of constant load of generators, which increases the need to use grid energy storages to...
meet the needs of the electricity consumer. A few years ago, energy storage devices were used to accumulate a small amount of energy, however, with the increase in the number of consumers and the expansion of the use of grid energy storage, these devices began to be used on a larger scale. Also, the use of grid energy storage allows you to increase the system effect in distributed generation grid. For compaction of load schedules, maneuverability of equipment and the possibility of placement on any part of the system, any node are required [1-2]. In addition to the main function - balancing load schedules, additional functions of grid energy storages include: redistribution of power transmitted through power lines, redistribution of dynamic power, static stability of the operating modes of the system, maintaining voltage at selected points of the power system, as well as regulating power exchange flows between power systems [3-5]. Voltage dips in the grid are one of the main problems that can be eliminated when using grid energy storage. Under the voltage dip is meant a temporary decrease in the voltage value at the point of the power system, which lead to malfunctions of the equipment of the shops, automation and control.

Overvoltage also negatively affects the functioning of the grid. Surge refers to a temporary surge in voltage followed by a return to the normal voltage value. Voltage surges cause flickering of lighting, damage to devices, contacts, insulating layers.

Deviations of the fundamental frequency from the nominal frequency due to an excess or lack of generating capacities also have a negative effect on the grid. With frequency deviations, the performance of the electric motors deteriorates. Low frequencies reduce the operation of electric motors, high frequencies overheat and wear out electric motors, reducing their life.

All the described problems that arise during the operation of the grid can be eliminated not only by traditional methods, but also by using grid energy storage.

Energy storage devices have several operating modes, such as:

- charge mode - the period when the energy storage is charged with energy of the power plant during the failure of the schedule;
- discharge mode - the period when the energy storage delivers the accumulated energy to the grid;
- emergency mode - the mode of liquidation of accidents arising in connection with sudden changes in load.

The functionality of the grid energy storages is determined by the maximum power, the total energy consumption, the operating time of the storages, the time of reverse power and time constant.

For the optimal placement of energy storages, it is necessary to determine the total and unit capacity, energy consumption of energy storages, their number and places of their localization.

The operation of energy storages in the nodes of the power system changes the flow of power, and, as a result, power loss.

Determining the location of grid energy storages directly depends on the operating modes: in the charge mode, a failure is maximally filled in the load graph section with the minimum power, the discharge mode reduces the peak load. The load graph is leveled, as in the whole system, and in individual nodes - energy storage locations. The load schedules of power systems are very uneven due to the increase in electricity consumption by household, transport and agricultural enterprises.

Thus, despite the presence of voltage regulators, with the help of which consumers themselves can change the grid parameters to improve the quality of electricity, this method of covering peak loads has a negative impact on the consumers themselves. The use of grid energy storage helps cover peak and intermediate loads that could be disconnected to avoid peak consumption. In turn, grid energy storage can accumulate electricity and deliver it to the grid when peak loads occur, compensating for the load and providing high-quality power supply.

In addition, in the modern energy sector, the digitalization process is actively underway, which involves the introduction of new devices into a smart grid, including grid energy storage. Digitalization is a priority area of development in the energy sector for the next decades, so the use of grid energy storage is based not only on their technical advantages, but also on the requirements for upgrading grids.
The use of grid energy storage will reduce fuel consumption, significantly reduce the costs of energy companies, and increase the reliability of power supply.

2. Analytical methods for determining the electrical loads of a power system

The unevenness in the operation of electrical equipment is due to the need to ensure continuous generation of electricity and maintain a balance between the generated capacities and electricity consumption, taking into account all losses.

The load of the power system depends on connecting and disconnecting consumers at a certain point in time.

The main processes that occur during the day in any power system include:
- switching on and off, changing the loads of individual consumers of electricity;
- enable and disable individual power lines;
- voltage regulation;
- regulation of the starting and self-starting modes of electric motors.

In this work, the effectiveness of implementation grid energy storage in power supply systems the use of grid energy storages in power supply systems will be considered on the example of an industrial workshop that has specific loads and modes.

A power system mode is a set of processes occurring within a power system that determine its state at a given moment in time or at a certain time interval.

The mode of the power supply system is determined by such parameters as:
- power and voltage in nodes;
- shift angles of voltage and current vectors;
- coefficient of performance.

These parameters are closely related. The parameters of the power system are determined experimentally and calculated.

The average daily schedule of active and reactive loads is characterized by: maximum active / reactive load per day, maximum active load in the busiest shift, active / reactive energy consumption per day, active / reactive energy consumption for the busiest shift [6-8]. Using the characteristic values of the active load characteristic of the daily schedule, as well as knowing the total rated power of power consumers, such a key indicator is determined as [9]:

- average active load per day, kW:

\[ P_{\text{day}} = \frac{W_{\text{day}}}{24}, \]

\[ W_{\text{day}} \] – active energy consumption per day, kW / h.

The study was conducted on the example of the power supply system of an industrial workshop located in St. Petersburg.

The results of the calculation of daily loads can be given in tabular form (table 1).

3. Graphical methods for determining the electrical loads of a power system

The daily schedule clearly shows the change in grid loads for each hour during the day [10-15]. Based on the calculated loads for each hour, we will build a daily schedule before and after the placement of the grid energy storage (Figure 1, 2).

The graph shows that the greatest load falls on the period from 8 to 23 hours, the smallest workload is observed from 0 to 7 hours. Peak loads are observed from 9 hours to 11, while the load increases by 130 kW.
Table 1. Average active load per day.

| P_{day}, kW / h | hour | P_{day}, kW / h | hour |
|-----------------|------|-----------------|------|
| 50              | 0    | 110             | 12   |
| 55              | 1    | 130             | 13   |
| 50              | 2    | 125             | 14   |
| 70              | 3    | 95              | 15   |
| 50              | 4    | 90              | 16   |
| 40              | 5    | 110             | 17   |
| 50              | 6    | 115             | 18   |
| 50              | 7    | 80              | 19   |
| 180             | 8    | 60              | 20   |
| 175             | 9    | 55              | 21   |
| 230             | 10   | 70              | 22   |
| 240             | 11   | 75              | 23   |

Figure 1. The daily schedule before placing the grid energy storage.

Figure 2. The daily schedule after placing the grid energy storage.
4. Analysis of the results of studies

Due to the uneven consumption of electricity during the day, it is necessary to cover peak loads on the grid due to the fact that these loads worsen the quality of the voltage and adversely affect the operation of the equipment. The main method of dealing with emerging loads is to disconnect loads at the request of users, taking into account the capabilities of the supply grid, however, this is not always possible without reducing the quality of power supply [16-20]. In this paper, we considered an industrial workshop, where the average daily load varies depending on the load of the equipment currently operating. The operating time of the equipment is determined by specific technological processes. In addition to the load of installed power equipment, there is a load of lighting.

On the graphs, with a load in the range from 125 to 180 kW, energy is accumulated for subsequent compensation of the arising load. Then, in the area from 180 kW and above, there is a sharp jump to the peak load, where the transfer of accumulated power to the grid begins, compensating for this load. After smoothing the jump, energy storage begins again.

5. Conclusion

Thus, we can conclude that the location of the grid energy storage allows you to smooth out the irregularities of the daily load schedule of the power system by redundant additional power and its supply to the grid in the event of a sharp jump in load to stabilize the voltage level in the power system by 25%.

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