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Analysis of the Application of Electric Power Storage Systems at Thermal Power Plants

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ABSTRACT

The desire to improve the production of electricity according to various criteria, whether technological or environmental factors, leads to the development of technologies and their subsequent application in industry. Today a new trend is electricity storage systems. In particular, such technologies can become an integral part of production – as an option for their use in thermal power plants. In Russia, energy storage systems are in the initial stage of development, while energy storage systems are already being actively implemented and operated in foreign countries, and their application is relevant both in industry and in the domestic consumption sector. This article discusses the use of such technologies at thermal power plants in order to increase the energy efficiency of production and reduce costs for their own needs.

Keywords: *Power storage systems, Thermal power plants, Storage, Uninterruptible power supply, Combined cycle gas installations, Power system, Power supply, Generation, Consumption, Electricity, Own needs.*

1. INTRODUCTION

Russia is significantly lagging behind in the formation of a national industry of electricity storage systems (ESS) and the development of a market for their use in various sectors of the economy. In America, it is planned to introduce 1,325 (MW) of storage capacity by 2020–2021. The National Grid company (Great Britain) has purchased 201 (MW) of energy storage systems for frequency control, and the systems themselves have been represented on the country's power market for several years. China considers energy storage to be one of the eight key areas of energy development, 46 (GW) of capacity is planned to be introduced by 2021–2022. In the USA and China large-scale production of storage devices is intensively developing, focused on saturation of the domestic market and also on mass export deliveries [1–3].

According to estimates, based on data from Navigant Research the global market for energy storage systems will amount to $80 billion by 2025. The main reason for the growth is the large-scale development of renewable energy sources (stationary use to smooth out uneven generation) and electric vehicles (batteries for electric vehicles), directly or indirectly using storage devices. The driver is technological progress in a number of solutions in the field of energy storage, capable of reducing the cost of systems to a level acceptable to the market in the short and medium term [4–6].

The development of technologies for energy storage systems will increase the reliability of the power system, make it more flexible, smooth out consumption peaks, expand distributed generation zones, introduce a larger volume of renewable energy into generation, create the possibility of a local transition to DC systems and reduce the need for strict simultaneity of electricity generation and consumption processes [7–9].

But in addition to wide application, it is possible to use these technologies for certain purposes and tasks to improve the energy efficiency of equipment or enterprise.

2. DEVELOPMENT OF ENERGY STORAGE SYSTEMS

The main drivers of the development of the market and the practice of using ESS in the world were – in order of importance – five main factors:

1. Cheapening and mass distribution of generation based on renewable energy, the effective large-scale application of which is impossible without ESS.

2. Development and beginning of mass distribution of private electric transport.

3. Mass industrial development of lithium-ion batteries, acting as a kind of building blocks of the most common ESS today, and a sharp reduction in their cost.

4. Development and reduction of the cost of power electronics capable of efficiently converting current from DC to AC and vice versa, as well as the development of communication systems that allow coordinating and managing a significant number of objects in the power system.

5. An increase in the demand for peak generating and grid capacities (including due to an increase in the share of more uneven household consumption in the total balance of electricity consumption), leading to an increase in the cost of power for consumers and to a decrease in the efficiency of power systems.

The forecast of the world market of electricity storage systems and the structure of their intended use are presented in Figures 1 and 2.

Functions of electric power storage devices:

- align load schedules in the network and dampen power fluctuations, increasing the stability of the system;
- to stabilize the operation of decentralized sources of electric energy, including RES;
- expand the available capacity (to cover peak loads, uninterrupted power supply in transient modes of the power system), both in the basic mode of power supply and when operating from backup power sources;
- provide backup power supply to the main consumers in case of power supply restrictions, shutdowns, accidents;
- provide reactive power compensation, frequency regulation in the power system and active filtering of higher harmonics, within the framework of the concept of using external filter compensation devices.

The main types of electric power storage systems are presented in Table 1. PSPs account for 98,5% of the total storage capacity in the world, electrochemical storage and compressed air storage are in second and third place, respectively.

In Russia today there are more than fifteen enterprises producing electrochemical storage devices and super capacitors. Basically all of them fulfill orders of the military-industrial complex, so most often they are not produced in a ready-made form, but components for them. The only plant producing lithium-ion batteries in Russia is «Liotech». The production volumes of «Liotech» exceed 1 (GW*h) and are even excessive in conditions of low demand in the domestic market. In addition, over the past two years, new production facilities have been launched in Russia in various areas of ESS: in the field of lithium-ion batteries – LLC «Enerzet» (NMC technology), in the field of hydrogen energy and fuel cells – LLC «InEnergy».

In Russia the operation of the ESS is largely carried out at three large PSPPs: Zagorskaya PSPP-1 (1,2 GW), Kubanskaya PSPP (15,9 GW) and Zelenchukskaya HPP-PSPP (320 GW). There are also projects under implementation. [10–11].

Table 1. Classification of electric power storage systems

Electric power storage systems				
Mechanical / Pneumatic	*Thermal*	*Chemical*	*Electrochemical*	*Electric*
Hydraulic storage systems (HSS)	Thermochemical batteries	Energy accumulator with hydrogen cycle		Hydraulic storage systems (HSS)
Underground compressed air storage	Energy storage by heating the substance	Conversion of hydrogen to methane	Ni-Cd	Underground compressed air storage
Liquid air storage system	Energy storage using materials with reversible phases	-	NaS	-
Inertial drives	-	-	LeadAcid	-

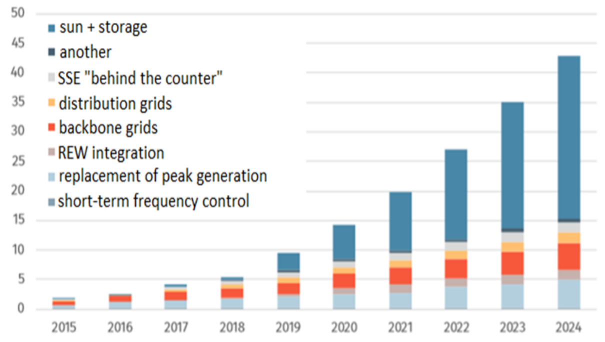

Figure 1 Forecast of growth of the world market of electric power storage systems (GW).

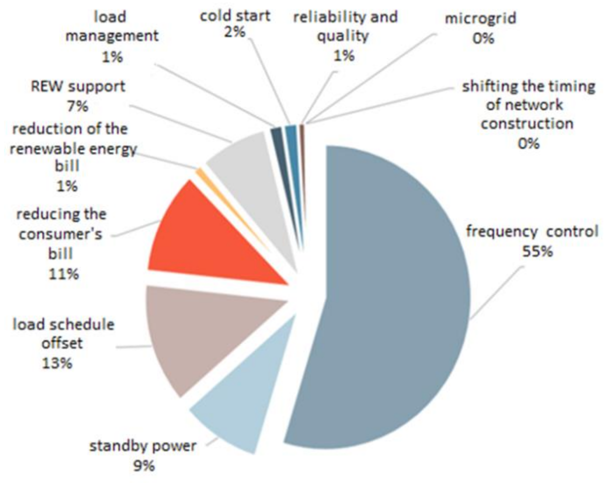

Figure 2 The structure of the targeted use of energy storage systems.

3. OWN GENERATION NEEDS

In the conditions of work on the electricity market, producers in the face of thermal power plants fall under the fact that all the energy they produce is put on the market. But at the same time, any generation has an indicator of energy costs for its own needs, the amount of which producers are obliged to buy from the market at the market price, even if the cost of energy produced will be less. Based on this, the question was raised about the possibility of using an energy storage device for storage and subsequent use both for their own needs and for resale to the electricity market.

For the analysis, a 220 (MW) combined-cycle power unit was selected, which consists of two PG6111FA gas turbine units (GTU) manufactured by "GE Energy" with a nominal capacity of 78 (MW), designed on the basis of a serial MS6001FA gas turbine, two steam recovery boilers manufactured by JSC "EMAlliance", two steam turbine units KT-33/36-7,5/0,12 the production of JSC "Kaluga Turbine Plant" with one regulated selection.

The equipment of own needs includes:

Booster compressor stations;

Feeding electric pumps;

Pumps of condensate path, cooling circuit of GTU, process water, condensate recirculation, condensate of network water heater;

Mains water pumps;

Drainage pumps

Circulating water pumps;

Drainage pumps;

Power supply of various installations, etc.

Depending on the operating mode of the station, the value of the power of its own needs varies – this value is affected by both the schedule of the load of electricity, the surrounding external conditions, the equipment being repaired or scheduled maintenance, and other factors. Usually, the value of own needs is 5–10 percent of the capacity of the generated equipment. Figure 3 shows the change in the capacity of the own needs of the 220 (MW) CCGT during the year. The data were obtained on the basis of the calculated model of equipment operation and annual reports [12–17].

The minimum value of the capacity of own needs falls on the summer period; this is due to the peony repair and technical work.

To select the correct equipment, it will also be necessary to calculate the minimum, maximum and average value of the auxiliary power. This will eliminate drive downtime and ensure proper system operation.

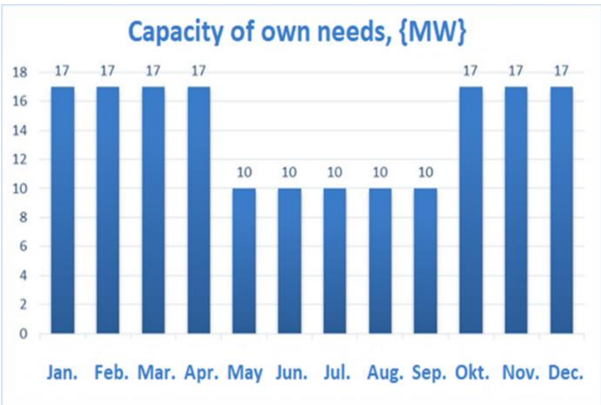

Figure 3 Power consumption for own needs of the combined-cycle gas unit 220 (MW) during the year.

4. ANALYSIS OF THE USE OF ENERGY STORAGE DEVICES

The main components determining the cost of an energy storage system are:

- inverter (power module), which can include a backup module for "hot swapping" in case of failure of one of the modules;

• rechargeable batteries, which include: o battery modules consisting of individual cells, the number of which is determined by the voltage of individual cells (depending on the cell manufacturing technology) depending on the required DC bus voltage; o control system;

• racks, racks or cabinets for battery modules;

• power cables and other auxiliary equipment;

• modular building or container;

• management system, including remote access;

• cooling system;

• room or land plot;

• foundation, fencing;

• the cost of construction and installation works and commissioning;

• the cost of connecting to the network (power output scheme); The most expensive components of the cost are the battery and the inverter. The cost of the battery usually includes the cost of the battery management system (BMS) [18–20].

Cheaper storage devices occurred primarily due to cheaper battery production technologies. Over the past 5 years, the rate of decline in battery prices has been 20 % per year and was largely caused by an increase in demand in road transport, as well as in the energy sector. According to various forecasts, the cost should fall to 130–150 $/ (kW*h). Based on this value, it is possible to estimate the cost of installing the system – for a minimum power (6 (MW)) it will amount to about $ 840,000 or 60 million rubles. The power of one installation can vary in a very large range from 1 (kW) to 3000 (kW) and above – in this case, the question of optimal choice arises, taking into account such parameters as reliability, operation, the need for maintenance and personnel, etc., since energy storage systems are often used as modular installations.

Despite also the difference in prices for different technologies, the rates of falling prices for different types of batteries are about the same. Thus it is predicted that the cost of lithium-titanium batteries will fall from the current 1000–1200 US dollars per (kWh) to 500–600 US dollars per (kWh) by 2022. The costs of newly developed technologies, for example, flow cells based on cheaper (than vanadium) metals, may decrease at a faster pace [21–23].

The power consumption for the operation of the drive is formed from the following factors:

• loss of idle operation of the drive in standby mode;

• losses during the charge-discharge cycle, determined by the efficiency of the drive;

• additional losses arising from the drive connection scheme;

• cooling and ventilation costs;

• the costs of climate technology.

Tables 2 and 3 present the calculation of the use of storage devices for two options – at the price under the program of power supply contracts (on newly commissioned installations) and at the price of competitive power take-off.

For energy storage systems, there are three main potential mechanisms of operation – frequency regulation and competitive power take-off; – shifting the timing of investments in grid construction; and ensuring the reliability and quality of energy supply, and increasing the capacity reserve, reducing the cost of purchasing power.

In this case, the third option is considered but also if necessary others can be used.

Using the drive to reduce its own peak consumption will relatively often conflict with other tasks, while the following factors must be taken into account: – to a lesser extent, this will concern the frequency control market, due to the short-term nature of loading / unloading the drive in this market; – in order to perform other tasks, the owner or operator of the drive will have to develop their own algorithms, using the drive to reduce their own peak on a residual basis if the task is solely an economic effect due to participation in the provision of services to ensure system reliability; – if the task of the ESS owner is to prevent overload within its own power system, then it will have to reduce the amount of storage capacity available for other services.

We have already estimated the cost of the installation for the minimum capacity above, and since the average annual consumption for own needs is used in the calculations, the price for installing the system will be 2,5 times higher – 150 million rubles. But in this case a full-fledged technical and economic calculation is necessary, taking into account all the subtleties at a thermal power plant, including equipment outside the combined-cycle part.

However, paying attention to the initial calculations, we can note the following – when the ESS works 5 hours a day and compensating for the difference in the cost of electricity at different times, the resale income may amount to 30–40 million rubles, which gives a payback period of about 5 years with the full operation of the system. Given the relative novelty of the technology and the knowledge of operation, it is necessary to lay losses and increase the payback period to 6–7 years, which is also a good value for such technologies.

Further technical perfection of technologies and production will further reduce the cost of ESS and its operation, allowing the introduction of drives in different areas of production.

4. CONCLUSION

New technologies and their application are often a challenge and a clash with the unknown. But given the extensive foreign experience and the gradual introduction of energy storage systems in Russia, we can say that in the near future these installations will be installed both in addition to the old equipment and as part of the new capacities being introduced.

Table 2. Calculation of the use of energy storage systems for equipment at a price under power supply contracts

Designation	Dimension	At the price of a PSC (10 years)										The amount
Ccpt (The average price for the region per year is accepted without taking into account the price index)	thousand rubles / (MW)	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	
Capacity of own needs (per year) (Fig. 3)	(MW)	169	169	169	169	169	169	169	169	169	169	
The average capacity of own needs per month	(MW) / per month	14.1	14.1	14.1	14.1	14.1	14.1	14.1	14.1	14.1	14.1	
Cost of auxiliary power per year	thousand rubles	1690 00	1690 00	1690 00	1690 00	1690 00	1690 00	1690 00	1690 00	1690 00	1690 00	
Number of storage hours per day	hours	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	
Electricity supply by the storage device per day	(MW*h)	70.4	70.4	70.4	70.4	70.4	70.4	70.4	70.4	70.4	70.4	
Electricity supply by the storage device per year	(MW*h)	25 702	25 702	25 702	25 702	25 702	25 702	25 702	25 702	25 702	25 702	
The difference in the purchase price Electricity for own consumption	thousand rubles / MW*h	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	
Saving from the purchase of electricity for own needs when the storage devices are operating per year	thousand rubles	7711	7711	7711	7711	7711	7711	7711	7711	7711	7711	92 532
Total additional revenue from the use of energy storage devices per year	thousand rubles	1767 11	1702 61	1702 61	1702 61	1702 61	1702 61	1702 61	1702 61	1702 61	1702 61	2 120 532

Table 3. Calculation of the use of energy storage systems for equipment at a price for competitive power take-off

Designation	Dimension	At the price of CPT (10 years)										The amount
Ccpt (The average price for the region per year is accepted without taking into account the price index)	thousand rubles / (MW)	134.394	167.751	171.123	182.048	193.158	194.900	194.900	194.900	194.900	194.900	
Capacity of own needs (per year) (Fig. 3)	(MW)	169	169	169	169	169	169	169	169	169	169	
The average capacity of own needs per month	(MW) / per month	14.1	14.1	14.1	14.1	14.1	14.1	14.1	14.1	14.1	14.1	
Cost of auxiliary power per year	thousand rubles	22713	28350	28 20	30766	32644	32938	32938	32938	32938	32938	
Number of storage hours per day	hours	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	
Electricity supply by the storage device per day	(MW*h)	70.4	70.4	70.4	70.4	70.4	70.4	70.4	70.4	70.4	70.4	
Electricity supply by the storage device per year	(MW*h)	25 702	25 702	25 702	25 702	25 702	25 702	25 702	25 702	25 702	25 702	
The difference in the purchase price Electricity for own consumption	thousand rubles / MW*h	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	
Saving from the purchase of electricity for own needs when the storage devices are operating per year	thousand rubles	7711	7711	7711	7711	7711	7711	7711	7711	7711	7711	92 532
Total additional revenue from the use of energy storage devices per year	thousand rubles	30424	36 061	36 631	38 477	40 355	40 649	40 649	40 649	40 649	40 649	466 491

Moreover, ESS can be used in various ways, which will expand the scope of their use, or use them in one place in several functions.

Regarding the use of ESS at thermal power plants as compensation for the costs of their own needs, an urgent task is to increase overall energy efficiency and reduce costs. Only the correct selection of equipment is important, since the optimal choice is always a difficult process, but solvable.

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