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Analysis of the process of balanced charging of the battery group with high capacity

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Abstract. The article presents an analysis of the types of high-capacity batteries, their applications and charging processes. The characteristics of stationary batteries are also listed. Comparative characteristics of parameters of modern various chemical accumulators of electric energy of lead-acid, nickel-cadmium, nickel-manganese and lithium-ion batteries are given. The processes occurring in the battery after several cycles of operation are considered as a change in its wear rate. Supplied from a 32 single source, batteries are considered both passive and active charging methods through sequential processes. The disadvantages and advantages of passive and active methods are listed. The influence of the parameters of the state of batteries in a state of voltage imbalance on the number of its cycles, charge level and discharge depth indicators depending on the charging time, on the state of voltage imbalance has been studied.

1 Introduction

In recent years, the collection and use of electric energy in vehicles, renewable energy sources, robotics, autonomous electronic systems, as well as thermal power plants and substations as a source of secondary supply is developing technologically. Currently, the ever-growing market of accumulator batteries, as well as the fact that many scientific studies are being carried out, the development of new types of accumulator batteries (AB) and the implementation of several works in the directions of increasing the efficiency of traditional types are related to ABs. shows how high the demand is [1].

Accumulators are divided into the following large groups based on their chemical composition:

- Lead acid;
- Nickel cadmium;
- Nickel Manganese;
- Lithium Ion

Their comparative characteristics are presented in Table 1 below.

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Table 1. Comparative characteristics of AB.

Parameters	Lead acid	Ni-Cad	Ni-MH	Li-ion
Relative energy density, W·hour/kg	30-50	45-80	60-120	90-120
Internal resistance, Ohm	< 100 AB unit with 12 V	$100 - 200$ AB unit with 12 V	$200 - 300$ AB unit with 12 V	$25 - 2500$ AB unit with 12 V
Number of life cycles	200-300	1000	300-500	1000-2000
Fast charging time	8-16 hours	1 hour	2-4 hours	1 hour
Extreme voltage tolerance	high	medium	low	low
Self-discharge	5%	20%	30%	10%
Nominal voltage	2 V	1.2 V	1.2 V	3.3 V
Shear stress while charging	About 2.4 and 2.25			3.6
Shear stress during discharge	1.75	1.00	1.00	2.8
The peak value of the download token	5 C (0.2 C)	20 C (1 C)	5 C (0.5 C)	>30 C (<10 C)
Charging temperature	-200C to 500C	00C to 450C		
Free-ignition temperature	-200C to 500C	-200C to 650C		-200C to 600C
Service request time	3-6 months (on charge)	30-60 days (charge-free)	60-90 days (charged)	Not required
Security requirements	Heat stable	Heat-stable heat exchangers are usually used		A protective circuit is mandatory
It applies from when	Since the end of 1800	1950	1990	1999

At present, stable batteries are widely used to supply telecommunication systems with continuous electricity. Permanent batteries are widely used in thermal and nuclear power plants, electrical substations, wind and solar energy installations, and automated control systems. They are also used to provide energy to individual buildings and small settlements. Stable ABs have great prospects in the development of high-power devices, especially designed to smooth out load fluctuations in power systems during the day [2, 3]. In developed countries, load power fluctuations amount to several million kilowatts of power. In the ongoing researches, the work on modeling the individual life cycles of each element of the stable AB, improving the operational period by reducing the critical limits, and increasing the level of charge (SOC), reducing the indicators of the depth of discharge (DOD) has not been completed and generally has several disadvantages [4, 5]. Based on this situation, several analyzes were conducted based on the operational requirements of the stationary AB. When charging a large number of stable batteries with high capacity, it is focused on ensuring their long-term operation and optimal performance by checking their operation in accordance with the type, structure, modes of the battery. The article briefly presents the simulation methods in Matlab simulink, the results of charging several high-capacity series-connected stable AB with balanced voltage. These analyzes can be used in thermal power plants with high-power stationary ABs, in the design of assembly units for local energy systems [6, 7].

2 Materials and methods

When a large number of ABs are charged simultaneously from a single source, their voltage drops depend on their electrotechnical parameters, electrochemical properties, and the influence of the environment. The outer casing of the above-mentioned AB protects against external dust, light, pressure and moisture. But it is affected by the temperature of the outside environment [8, 9].

The causes of voltage unbalance are calculated differently and depend on the following technical characteristics of the elements of ABs:

To the electrical capacity of the elements. The capacities of batteries of the same brand in the same batch will also be different. Even for new batteries, their capacity differs from the nominal up to 5%.

Leakage current. The magnitude of the leakage current is not the same for all batteries.

Resistances of accumulator elements.

In addition, there are differences due to the influence of external factors:

Temperature difference in the elements. The temperature inside the battery depends on the ambient temperature and the power dissipation during operation.

Being defective by the factory. Defects in the preparation of electrodes, outputs, as well as electrolytes are included.

Aging process. In each element, the degradation process occurs at a different rate. For this reason, it is not recommended to use new and old batteries together.

There are 2 ways to balance the voltage in the accumulator batteries.

Passive balance. Ballast depends on the dissipation of excess energy in a resistive load. Simple to implement, but not energy efficient, it is critical in battery-intensive devices such as mobile devices [10, 11].

Active balance. Consists of redistribution of energy between batteries. This method is energy efficient, but its implementation requires more laboratory and money.

Table 2. According to the types of permanent accumulators, their electrical characteristics.

features	**Accumulator (battery) type**						
	USV	**Power bloc OPzS**	**OPzV**	**USVdry 12V-bloc**	**OgiV**	**Net power**	**Power bloc OPzV**
Capacity range, A·hour	21÷336	50÷300	200÷300	30÷100	18÷256	100	50÷300
Rated voltage, V	4.6	6.12	2	12	4.6	12	12
Electrolyte type	liquid	liquid	jelly	AGM	AGM	AGM	liquid
Duration of work, year	12	20	20	10-12	10-12	10-12	20
Number of charge-discharge cycles	800	1200	1000	500	800	500	1200
The presence of a plug AquaGen	AquaGen-with plugs	AquaGen-with plugs	VRLA 502722	VRLA 502722	VRLA 502722	VRLA 502722	VRLA 502722
Operating temperature range	-20 to +40	-20 to +40	-20 to +40	-20 to +40	-20 to +40	-20 to +40	-20 to +40

storage time with one charge	3	3	3	3	3	3	3
% per month, self-discharge at 20 C	3	3	2÷3	2÷3	2÷3	2÷3	2÷3
compliance with the standard	IEC 896-1	DIN 40737-3, IES 896-1	DIN 40742, IES 896-2	IES 896-2	DIN 40741, IES 896-2	IEC 896-2	IEC 896-2

3 Results and discussion

Debate. Currently, 16 OPzV 2000 brand lead-acid AGM technology hermetic storage batteries (Fig. 1) are used in the 478 MW workshop of the Navoi thermal power station with steam-gas equipment. ABs are used in two rows of 54 connected in series.

Fig. 1. is a high-capacity 3rd generation AGM battery.

Static batteries are divided into the following types according to their structure:

- surface positive electrode battery - GroE (DIN 40732 and 40738 standard);
- shell positive electrode battery - OpzS (DIN 40736 and 40737 standard);
- spreadable electrode battery OGi (standard DIN 40734 and 40739);
- monoblock battery with spreading electrode - (DIN 43534).

These are batteries36 A·12000 per hourA·hours and the working life is from 10 to 25 yearsmany are actively produced. According to the manufacturing technologies, the first generation batteries were made with liquid electrolyte in open and closed state. The batteries of the second generation are made with sealed helium dark electrodes. The third generation batteries have AGM technology with an absorbed separator electrode (AGM technology Absorbed in Glass Mat). This type of permanent storage batteries are produced in many regions of the world, especially in England by Cholrida Industrial Batteries, in Germany by Varta, Hoppecke, Sonnenschein, in Japan by Panasonic and YUASA, in China by COSLIGHT, in Italy by FIAMM and other companies. High-capacity permanent batteries produced by different companies differ according to their technology and parameters. The main problems in them are to maintain the long-term operational process, to reduce the boundary conditions, to reduce the impact on the external environment, and to maintain the balanced operation of the group batteries [12].

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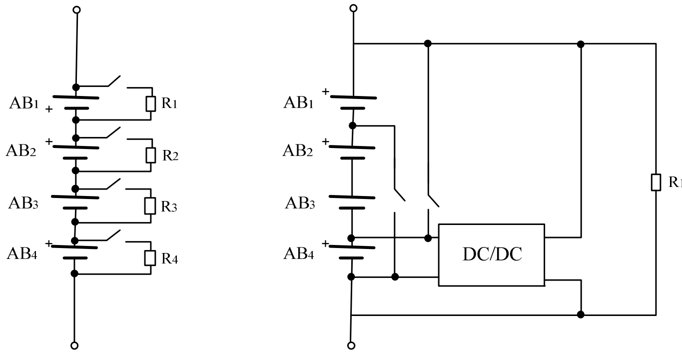

Fig. 2. Ways of balanced charging of accumulator batteries a) passive method (resistor) balanced charging, b) active method (using a DC/DC converter) balanced charging.

It is possible to determine several electrotechnical parameters of the accumulator batteries using the active charging circuit (Fig. 2 b circuit) from the constructed circuits. According to the electrotechnical parameters of the main electrotechnical battery, we determine the following characteristics of its several types.

Based on the scheme given above, using the Matlab/Simulink program, we can see voltages, currents, charging levels, ambient and internal temperatures in battery elements change in time. The difference in voltages in the battery elements of the battery comes to the voltage equilibrium state for a cycle with a change in the electrotechnical parameters in them. The Imitation model for determining electrotechnical parameters in battery elements using the Matlab/Simulink program is presented in Fig. 3.

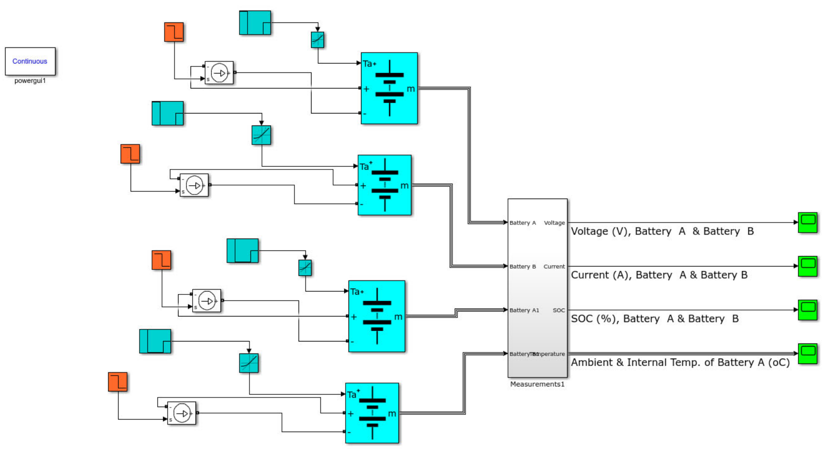

Fig. 3. Akkumulyator batareya elementlarida elektrotexnik parametrlarini aniqlash imitatsion modeli.

Based on the built-in imitation model, below the battery appears an increase in the state of incompatibility with a sharp increase in voltages in the battery elements at the changes in their voltage during charging. The change in voltage values in battery elements is shown in Fig. 4.

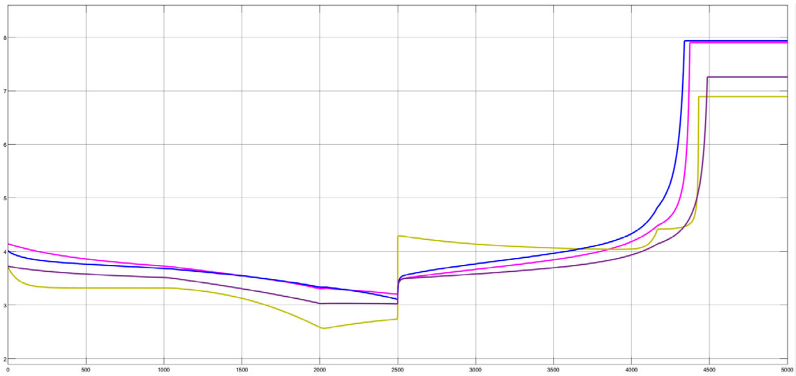

Fig. 4. Change in voltage values in battery elements of the battery.

From the change in voltage at the battery elements at the time of attenuation, its displacement of charge currents in the elements is shown in Fig. 5.

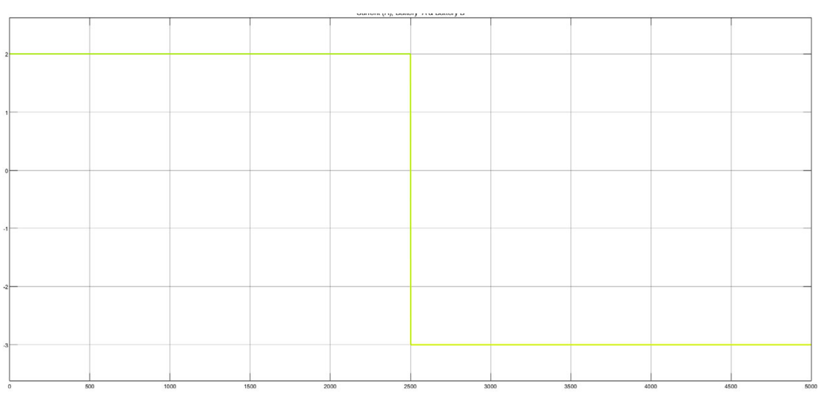

Fig. 5. Change in current strength values in battery elements of the battery.

Despite the fact that the charge currents are uniform in all battery elements, the degree of charge in them occurs differently. As the period of exploitation increases, their capacity increases with each other. This accelerates the degradation process in them. In this, their charging speed also changes. The change in charge indicator in battery elements is shown in Fig. 6.

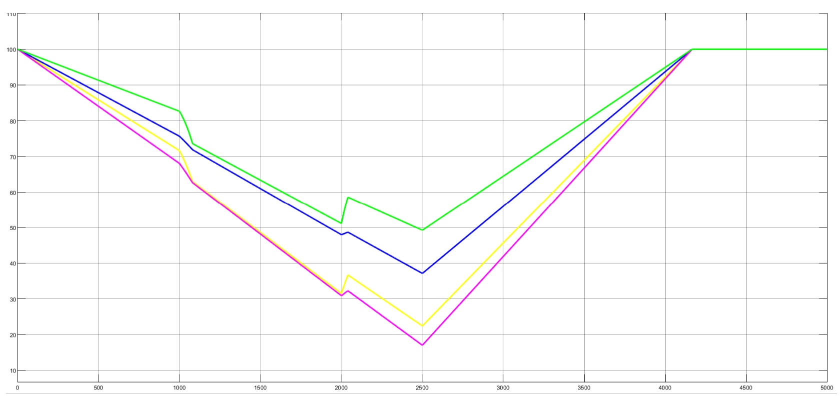

Fig. 6. Change in charge indicator on battery elements of the battery.

After reaching an equilibrium state, differences in internal temperature and external temperatures occur. This is especially noticeable in low-capacity battery elements. Changes in the internal and external temperature in the battery elements are presented in Fig. 7.

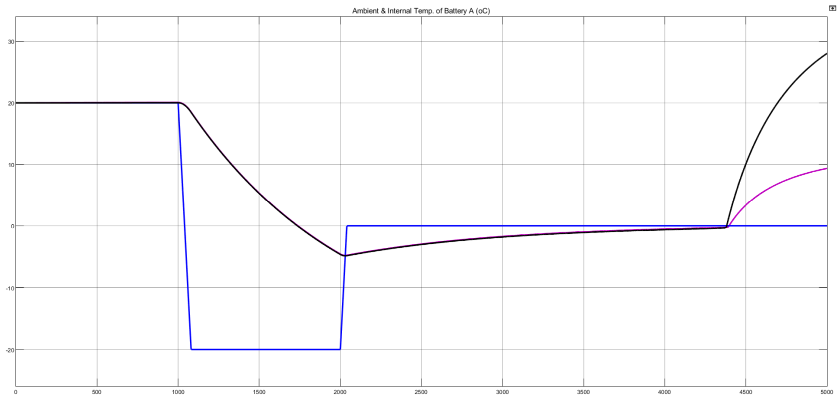

Fig. 7. Changes in internal and external temperature in battery elements of the battery.

In the process of charging the battery battery, a sulfation event occurs inside it, due to which an internal heating is generated. Internal heating continues until it aligns with the ambient temperature.

4 Conclusion

In conclusion, it can be said that today, monitoring batteries, ensuring voltage balance in them is urgent and requires research in many directions. Identifying the factors affecting the voltage imbalance, eliminating them, re-developing the battery control system will serve to improve the private systems of AB.

Passive balancing has lost its essence and has no perspective these days. But by further developing the active method in the future, it will create an opportunity to increase the operating characteristics of ABs and save energy.

The advantages of the active method are as follows:

- saving energy in the battery by balancing;
- equal charge property;
- increase the service life of batteries.

At the same time, there are also disadvantages of the active method, which are as follows:

- the complexity of the structure;
- being expensive compared to the passive method;
- may not be optimal in some cases.

By further improving the active balancing system, the following can be achieved:

- determine the optimal configuration of the system (together with the charging device);
- testing different cases under different working conditions.

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