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Active balanced charging of multi-element electrical energy collective devices

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ABSTRACT: The article examines passive and active balanced methods of charging and discharging of high-power, multi-element series-connected, uniform-voltage lead-acid helium stationary storage batteries. The model of active charging and discharging of accumulator batteries was checked in Matlab Simulink. Advantages and disadvantages of passive and active charging of accumulator batteries are analyzed. The change of the electrotechnical parameters of the accumulator batteries after the operational period was analyzed. Active and passive charging processes are compared and optimization aspects of their charging modes are studied. This article shows the simulation results of Matlab simulink program on increasing the service life of multi-element electric energy harvesting devices by providing them with a balanced voltage issues of achieving efficiency and resource saving through serial connection of electric energy collective devices are reflected.

KEY WORDS: electric energy collective device, series connection, charging, voltage balance, charging level, depth of discharge indicator, group charging.

I.INTRODUCTION

Large-capacity lead-acid batteries are still used as many modern energy storage sources. In the power supply system, accumulator batteries are widely used in transport, aviation and space equipment, water equipment, and stationary objects. First of all, it is used to continuously supply critical consumers, as well as their technological processes and management systems of entire production complexes with electricity. The energy storage system is developing in the market economy. The main issue will be to control the main parameters of the batteries and increase the energy efficiency. Today, many modern facilities or autonomous facilities experience a large amount of material losses due to power outages through accidents, breakdowns, and other critical situations. In addition to solving these problems, the introduction of complex electrotechnical devices requires the development, storage, transformation and transmission of electrical energy [1].

Group storage batteries are used in series and parallel connection. In this case, they are charged and discharged from one side. Charging and discharging based on multi-element storage batteries is a very complex system. The increase in the number of elements complicates its control and management system, as well as the lack of the ability to monitor the electrical parameters of each element during their charging and discharging, thereby reducing the service life of accumulator batteries. The main reason for this is that the full charge voltage of batteries with the same voltage changes over time, and in this case, the different discharge currents lead to a decrease in the charge level of the batteries and an increase in the depth of discharge indicator[2,3].

Nowadays, the use of energy is growing very rapidly. Currently, there are large base substations with a capacity of up to 2 MW. In this case, the number of batteries in the complex exceeds 1000 [4]. Operational experience shows that the technical characteristics of batteries differ from each other, which negatively affects the overall efficiency (reduced capacity, reduced long-term performance, etc.). That is why it is important to connect the diagnostics, balancing and control system of batteries [5].

Control system, balancing and diagnostic systems are now a necessary part of the systems available in cycle rechargeable batteries. The main directions of such development are aimed at reducing the mass measurement indicators of storage battery systems, developing more efficient storage battery management algorithms, reducing energy consumption and preventing battery overheating. One of the problems with using a battery pack is the lack of voltage balancing across the batteries [6].

Disturbance of the voltage balance is an excess of voltage differences between the contacts of the accumulator batteries under the influence of various factors. The article considers the balancing of large-capacity accumulator batteries. Figure 1 shows the charging and discharging process of 6 gel technology OpzV 16-2000 battery power supplies with a nominal voltage of 2 V in series, balanced and unbalanced conditions. The service life of OpzV 16-2000 brand batteries is up to 20 years. According to the parameters of the batteries of this brand, a scheme is built in Matlab simulink, and the voltage and current values are controlled using measuring devices of the voltage changes of each of their elements during charging and discharging.

II. SIGNIFICANCE OF THE SYSTEM

Currently and in the next decades, lead-acid helium stationary high-capacity batteries will not lose their place in power stations, substations, and alternative energy generating stations. There is an opportunity to increase their service life with balanced charging, as well as to increase the efficiency of electricity for consumers. The study of literature survey is presented in section III, Methodology is explained in section IV, section V covers the experimental results of the study, and section VI discusses the future study and Conclusion.

III. LITERATURE SURVEY

Many scientists have to work with balanced charging and balancing of accumulators. After studying their work, several conclusions were drawn. We will consider some of them.

Serdechniy Denis Vladimirovich considered in his works the improvement of the balancing process of multi-element lithium-ion batteries for the objects of autonomous electric transport in order to improve the operational characteristics. In doing so, he developed and implemented a method of balancing them passively.

Y.B. In his works, Kamenev also considered improving the operational characteristics of hermetic lead-acid batteries of large capacity. He has done a lot of work on improving the conductivity of the positive electrodes and balancing the evaporation to increase the service life of the accumulators.

S.S. Volkov also worked on the modeling of the process of changing the electrical properties of lead-acid batteries, and in his work, through mathematical models, by changing the Shepherd's equation, he theoretically discussed the issues of slowing down the degradation process in batteries. things were carried out.

IV. METHODOLOGY

This method is energy efficient, but its implementation requires more labor and money.
The reasons for the imbalance are calculated differently and depend on the following technical characteristics of the battery cells:
- To the electrical capacity of the elements. Batteries of the same brand in the same batch will also have different capacities. Even for new batteries, their capacity differs by up to 5% from the nominal value.
- Leaking current. The amount of leakage current is not the same for all batteries.
- Resistance 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.
- A factory defect. Defects in preparation of electrodes, outputs, and electrolyte defects are included.
- The aging process. In each element, the degradation process occurs at different speeds. For this reason, it is not recommended to use new and old batteries together.

Dataset Description

A) Figure 1 shows the fully charged voltages of batteries with a nominal voltage of 2 V each when connected in series.

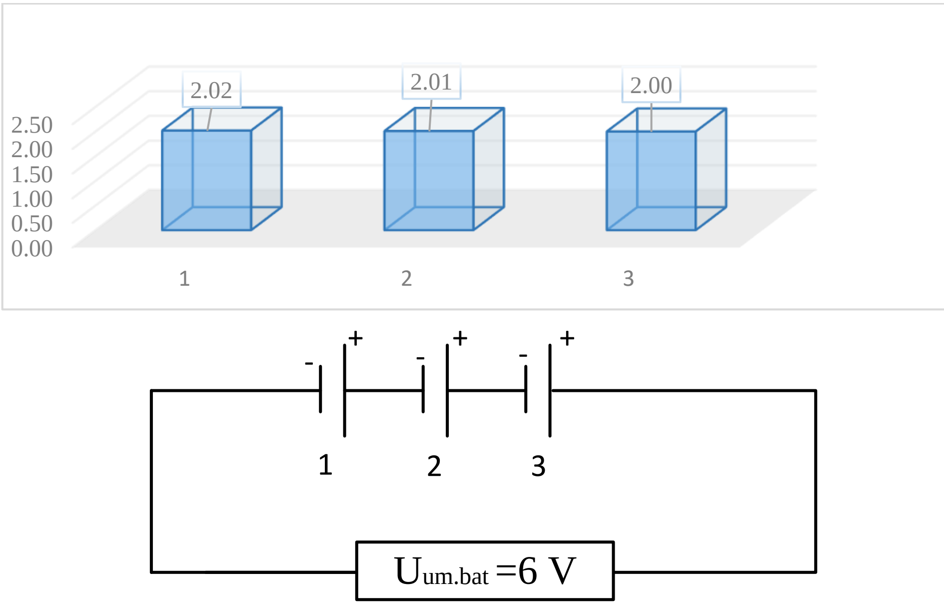

Figure 1. Voltage values of battery cells connected in series when fully charged when new

B) The voltage in common batteries is 2·3=6 V. After several years of operation, the voltages in the batteries will change. That is, after a long period of operation, it creates non-uniform voltages with a total voltage of 12 V in the batteries. In this case, the first battery has a high voltage of 2.52 V (the maximum voltage for the OpzV 16-2000 battery is 2.4 V). This causes damage to the internal structure of the battery. The voltage on the fifth battery is 1.59 V (the minimum voltage for the OpzV 16-2000 battery is 1.6 V). This causes a degradation process in the battery, that is, it leads to a decrease in resource and capacity. In the rest of the batteries, the voltage falls within the working voltage range. But even in them, the voltage difference is higher than 0.1 V, and this also leads to unconscious states of the resources of the elements.

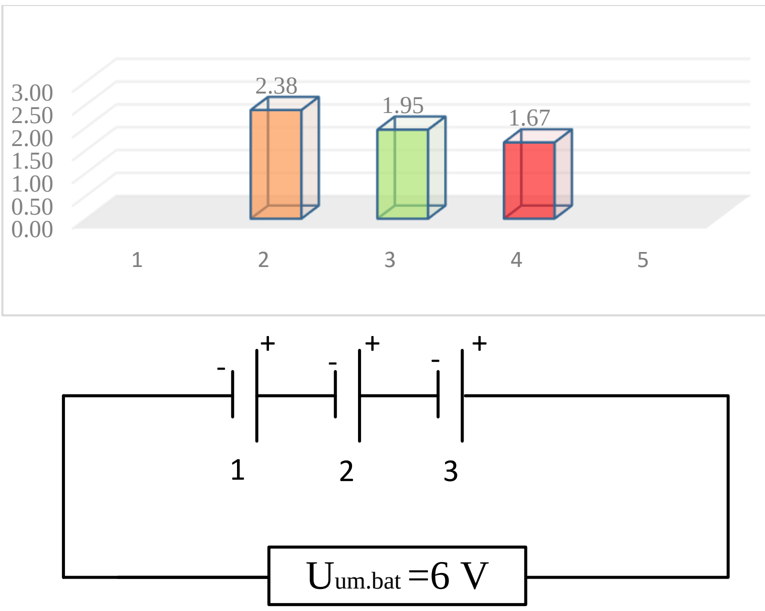

Figure 2. Voltage values of series-connected battery cells at full charge after 5 years of service life

Analyzing the experience, we can conclude that it is desirable to implement battery modeling using switching circuits from standard electrotechnical packages for simulation to ensure accuracy and versatility. Based on the principles of

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physical sufficiency, it is preferable to create a switching model without using a voltage source, but only the capacity and other components that limit the minimum and maximum voltage in it, as well as the overvoltage during charging and other characteristics of the battery in the circuit are simulated. Based on the constructed scheme, we get the following results [8,9].

In Fig. 3, we obtained the results in the Matlab Simulink program by connecting a battery with homogeneous parameters in series. The change of its voltage, current and level of discharge over time was studied.

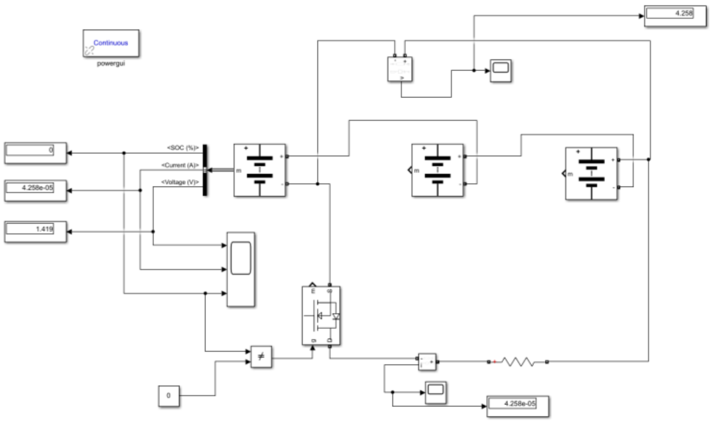

Figure 3. Simulation of the discharge process of series-connected accumulator batteries.

V. EXPERIMENTAL RESULTS

Based on the obtained results, it can be said that the charging current has a non-linear character in conditions of imbalance. In this case, disconnecting and connecting the batteries will have a negative effect on its working condition. The change in charge level decreases linearly. Charge and discharge voltages cannot be drastically different from each other. In this case, the charging rate of the battery is up to 80% of the capacity, but after that, the battery starts to run out of material. While the power in the source load is changing uniformly, the power in the consumer and the battery is passing through jumps in the initial state of time. In this case, the power dissipation depends on the transition time of the imbalance process.

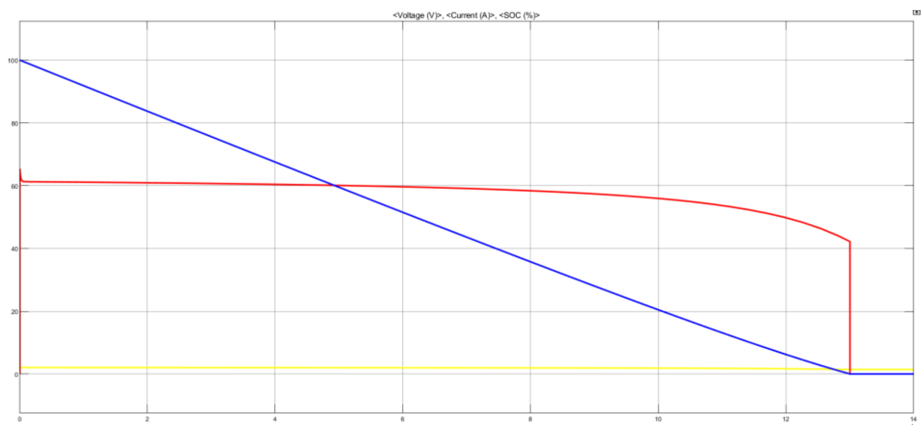

Figure 4. Simulation level of charge gap, voltage and current changes

VI. CONCLUSION AND FUTURE WORK

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

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Passive balancing has lost its essence these days and has no future. But by further developing the active method in the future, the accumulator will create an opportunity to increase the operational characteristics of the batteries and save energy.
The advantages of the active method are as follows:
- saving energy in the battery by balancing;
- feature of equal amount of charging;
- 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;
- it is expensive compared to the passive method;
- not being optimal in some cases.

By further improving the active balancing system, the following can be achieved:
- determination of the optimal structure of the system (together with the charging device);
- Testing different cases under different working conditions.

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