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Dmytro Zakharchenko, PhD student
Serhii Stepenko, PhD in Technical Sciences, Associate Professor
Tymofii Yakushkin, PhD student
Chernihiv Polytechnic National University, dimazakhar@gmail.com

BATTERY STATE OF CHARGE ESTIMATION AS A COMPONENT OF COMPLEX QUALITY ASSURANCE OF THE AUTONOMOUS ELECTRIC POWER SYSTEM

The efficient operation of an energy storage device is based on continuous monitoring of the state of its main parameters [1]. An urgent task is to determine the structure of the energy storage control system and develop an algorithm for its charge, which will determine the optimal ratio of the storage time and the time spent on the charging and balancing process. The development of electric power systems has recently been characterized by an intensive growth in the use of energy storage devices such as batteries or capacitors [2]. This is largely facilitated by progress in such areas as renewable energy sources, network technologies for data processing and management based on smart grid technologies. A rechargeable battery based on lithium-ion batteries has an optimal ratio of weight and size characteristics and stored energy and, as a result, can be used not only in stationary, but also in mobile systems for various purposes [3].

The safe and efficient operation of batteries is based on continuous monitoring of the main parameters of the battery, as well as monitoring of the charge/discharge history and the actual capacity. When forming a multi-element series-connected battery, the problem of voltage spread and charge levels of individual battery cells arise. When at least one of the cells reaches the critical voltage during discharge, it is necessary to disconnect the drive from the load, since further discharge will lead to a violation of the operating requirements. In this case, the capacity of the battery will be determined by the capacity of the weakest cell.

State of Charge (SOC) management: SOC can be referred to as a parameter that characterizes the amount of energy that is stored in the energy storage at a certain point in time. In order for the accumulation of electricity to be as efficient as possible, the storage management system must maintain the SOC in the required range, which is predetermined. This range makes it possible to balance the availability of energy and increase the durability of the drive.

Currently, there are several ways to measure SOC of an energy storage device, in our case a lithium-ion battery or its depth of discharge (DOD) [4]. Some methods are quite difficult to implement and require complex and technologically advanced equipment. We will look at two of the most popular and at the same time simple ways to assess SOC of a battery, namely: 1) Voltage or open circuit (OCV) method and 2) Coulomb counting method.

SOC estimation by OCV. All types of batteries have one thing in common: their voltage always changes as their charge level changes, namely the highest voltage will be when the battery is fully charged and the lowest when the battery is discharged. This dependence of the charge level on the battery output voltage depends on the type of battery and the technologies used in it. Fig. 1 shows the voltage versus charge level for a lead acid and lithium-ion battery. On these dependencies, you can see that the first type of battery has a fairly linear relationship, which makes it easy and accurate to assess the level of its charge after measuring its voltage [5].

A lithium-ion battery has a different dependency; it maintains a stable voltage for a fairly large range of charge levels. In the operating range, the output voltage of such a battery changes slightly. This type of battery has the simplest dependence curve on the graph, which makes it difficult to assess SOC when simply measuring the output voltage, namely, it makes it inaccurate. Fig. 1 shows that for a charge level of 40% and 80%, the voltage difference is 6V for a lead-acid battery and only 0.5V for a lithium-ion battery. At the moment, calibrated priors are used to determine the charge level of a lithium-ion battery by voltage, which allows accurate measurement of voltage and, in combination with modulation of the load curve, allows you to calculate the SOC value with an accuracy of 10%. The disadvantage of such devices is the need to disconnect the load from the battery and put it to rest for the measurement.

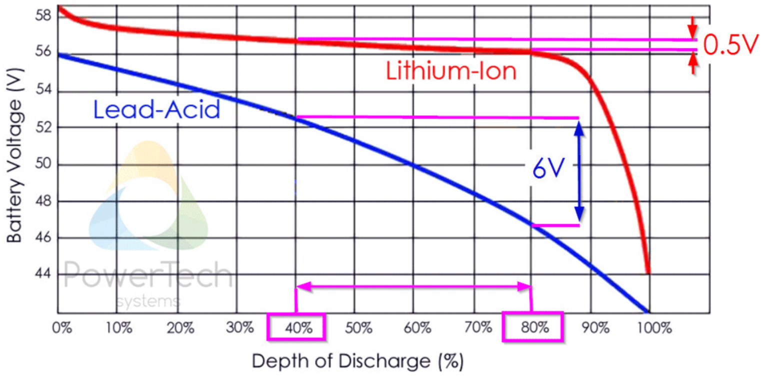

Fig. 1 – Voltage ratio to the level of charge for a lead acid and lithium-ion battery.

SOC estimation using the Coulomb counting method. To determine the level of charge of the battery, the method of current, which is produced simultaneously with the use of the battery, is quite accurate. This integration makes it possible to determine the number of charges that have entered or have been removed from the battery during its use. This technique makes it possible to accurately determine the SOC value of the battery [6]. Unlike the open circuit voltage method, this method allows SOC measurements to be taken while the battery is in use. To do this, it is not required to turn off the workload and put the battery into a dormant state. When using this method, the current measurement is performed by a precision resistor, certain errors may occur, which are associated with the sampling rate. To minimize and correct these errors, it is necessary to calibrate the coulomb counter at each load cycle. This method allows measuring SOC of a lithium-ion battery with an accuracy of up to 1%, which makes it possible to accurately know the level of remaining energy in the battery [7]. Unlike the OCV method, this one allows the determination of SOC regardless of the fluctuating power of the battery, which can cause a drop in output voltage, and the accuracy is maintained regardless of whether the battery is used.

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