IOP Conference Series: Materials Science and Engineering

PAPER • OPEN ACCESS

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To cite this article: A D Ziganshin *et al* 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **570** 012105

IOP Conf. Series: Materials Science and Engineering **570** (2019) 012105 doi:10.1088/1757-899X/570/1/012105

Particular properties of operation of stationary lead-acid batteries at power distribution facilities

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Abstract. The article provides an analysis of the features of operation of stationary lead-acid rechargeable batteries at power plants as a source of power for operational DC circuits. The aim of the study was to compare widely used lead-acid battery systems with free electrolyte with dryfit and AGM technologies. The result of the study is to determine the significant advantages of sealed batteries in the implementation of gas evolution and recombination processes. On the basis of the conducted research and the revealed modern trend in the implementation of hardware for automation and telemechanics based on low-maintenance and maintenance-free equipment, conclusions have been made about the feasibility of using sealed lead-acid batteries as sources of operational direct current at power distribution facilities.

Introduction

At present, the highest requirements are placed on the quality and reliability of equipment used at power distribution facilities. To power the operational circuits of the protection, automation and alarm relay, electromagnets for switching off and on switching devices, operational direct current is used predominantly. The current source is mainly the batteries of the lead-acid system manufactured according to the classical technology with liquid electrolyte, which is predetermined by the breadth of the model range, relative simplicity of production and unpretentiousness to operating conditions [1, 2].

The peculiarities of operation of lead-acid batteries with liquid electrolyte should include the need to adjust its level and density and a significant amount of gas evolution during charging, which makes it necessary to install the battery in a separate capital room equipped with forced supply and exhaust ventilation [1-8].

Study of the features of operation of stationary lead-acid batteries

Lead acid battery (LAB) as any other chemical source of current is a system of unstable equilibrium. All processes occurring in it are associated with its slow "destruction", expressed in irreversible loss of capacity.

In order for the processes of "destruction" to proceed with a characteristic speed for this type of batteries and their mode of operation, i.e. in order for the battery life to be predictable, it is necessary

IOP Conf. Series: Materials Science and Engineering **570** (2019) 012105 doi:10.1088/1757-899X/570/1/012105

to ensure the correct operating conditions as well as charge / discharge parameters, which must comply with the modes permitted by the manufacturer [9, 10].

A promising solution to this problem is the use of sealed LAB with their installation in a capital building with natural ventilation. At the same time, the use of modern technologies allows placing LAB in a separate room, as well as in a room with electrical and switching equipment.

Sealed LAB have made a breakthrough in the production technology of lead batteries for industrial use. Thus, in 1957, a battery with a bound electrolyte was developed, the so-called "non-spillable" battery, and the technology itself was named *dryfit* and was patented. The idea of creating a non-spinning battery is based on the principle of thickening the electrolyte to a jelly-like state and sealing the internal volume with an overpressure valve, which is installed in the filling hole to provide one-way communication with the external environment to release a small amount of gas. Later in the 70s of the last century, another electrolyte binding technology was invented by impregnating separators with good capillary properties. This technology is called *AGM* (from Absorbent Glass Mat), and glass fiber sheets are used as separators [10, 11].

The common property of all sealed LAB is that there is no need to dilute the electrolyte during their operation. Overpressure valves are installed during production and do not disassemble during the entire service life of the batteries. Another important quality of the batteries of the sealed design is low gas emission, which significantly softens the requirements for the rate of air exchange at the location of the battery.

However, when building industrial power installations with a high power battery, it is impossible not to take into account the fact of the occurrence of a side reaction of electrolysis of water when charging stationary lead-acid rechargeable batteries.

It is known that when a recharge current flows through a battery, electrolysis of water produces gaseous oxygen (at the positive electrode) and gaseous hydrogen (at the negative electrode). If no special measures are taken, then both gases are released into the surrounding space of the battery in an amount determined by the Faraday electrolysis law, which in terms of 1 Ampere-hour of electricity is 0.037 g or 0.418 l of H_2 (hydrogen) and 0.299 g or 0.209 l of O_2 (oxygen) as a result of decomposition of 0.336 g of H_2O (water). Hydrogen is a potential threat: it is an explosive combustible gas whose mixture with air becomes dangerous by fire, starting with a 4 percent concentration by volume [10, 11].

To remove hydrogen, it is necessary to ensure adequate air exchange of the location of the battery due to natural or forced ventilation. The air exchange rate is determined by the standard GOST R MEK 62485-2-2011 [5].

In a sealed LAB in a bound electrolyte, a mechanism of internal recombination of gases with the formation of water is implemented. The conditions for the reaction are the presence of recombination channels: microcracks in the gel or electrolyte-free pores in the glass fiber separator, through which gaseous oxygen is delivered to the negative electrode, where it enters an electrochemical reaction with hydrogen, accompanied by heat evolution H2 + ½O2 → H2O + heat.

The recombination reaction coefficient in systems with a bound electrolyte is 98–99%, which corresponds to an approximately 100-fold reduction in gas evolution compared with classical structures in which the electrolyte is not bound [10, 12].

In accordance with GOST R MEK 62485-2-2011, the minimum air exchange rate of the location of the battery is calculated by the formula:

$$\mathrm{Q} = 0.05 \cdot \mathrm{n} \cdot I_{gas} \cdot C_{\mathrm{rt}} \cdot 10^{-3},\ [\mathrm{m}^3/\mathrm{h}]$$

where I_{gas} – gassing current for sustained or accelerated charge [mA / Ah],

C_{rt} – capacity of 10-hour discharge of lead-acid elements to a voltage of 1.8 V at a temperature of 20 ° C,

n – number of cells in the battery.

The values of the gas emission current I_{gas} for battery cells depending on the charge mode and the state of the electrolyte are presented in Table 1.

IOP Conf. Series: Materials Science and Engineering **570** (2019) 012105 doi:10.1088/1757-899X/570/1/012105

Table 1.
Values of gas evolution $I_{\text{газ}}$ for LAB with liquid electrolyte (antimony content <3%) and sealed LAB (with overpressure valve) depending on the charge mode

Charge mode	**Gassing current I_{gas}**, мA/A·h	
	LAB with liquid electrolyte	Sealed LAB
Charge support	5	1
Accelerated charge	20	8

The minimum area of the input and output vents for natural ventilation is calculated by the formula:

$$A \geq 28 \cdot Q, \text{ [sm}^2\text{]}.$$

In the immediate vicinity of the battery, it is necessary to observe a safe air gap, where there should be no spark-forming or hot devices. The required size of the exclusion zone, measured by the straight distance from the battery valves, depends on the type and capacity and is calculated by the formula:

$$d = 28.8\sqrt[3]{I_{gas}} \cdot \sqrt[3]{C_{\text{rt}}}, \text{ [mm]}.$$

For a monoblock battery, the gas output is determined by the number of elements connected in series in a single housing, connected by a single ventilation system or through a tube. When calculating the safety distance, the value C_{rt} is determined by multiplying the capacity of the monoblock by the number of elements in it.

Based on the above formulas, it can be established that for LAB with internal recombination of gas with a capacity of up to 1000 A·h the size of a safe air gap in any charge mode does not exceed 1 meter. Thus, the creation of an exclusion zone of 1 meter in natural ventilation will guarantee the safe operation of sealed LAB, which allows them to be installed in a common room with electrical and switching equipment [9, 10].

Conclusion

In the industry of automation and telemechanics at the objects of electricity distribution, to a greater or lesser extent, batteries are produced in all three of the above-listed technologies. In this case, the vast majority of batteries used as a source of operating direct current, have a classic design with free electrolyte. The current trend in the development of technical equipment for automation and remote control involves a gradual transition to low-maintenance and maintenance-free equipment [10-12, etc.]. To achieve this goal, it is advisable to use current sources, based on sealed lead-acid batteries, which will reduce operating costs while maintaining the required level of reliability.

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