**Analysis of factors affecting the reliability of battery batteries of power plants**

Khasan Murodov1, Maftuna Bozarova1,a), Asliddin Norqulov1, Sultonbek Abduraxmonov2

1Navoi State University of Mining and Technologies, Navoiy, Uzbekistan

2 Andijan State Technical Institute, Andijan, Uzbekistan

a) Corresponding author: [maftunabozarova@yandex.ru](mailto:maftunabozarova@yandex.ru)

**Abstract.** This paper has examined closely the key reasons involved in influencing the reliability of accumulator batteries applied to power plants. It was revealed that the technical state of the accumulators, operating conditions, service status, and external physical and technical impact are the key factors of the continuous functioning of energy supply systems. The paper investigated the process of degradation of batteries, chemical, thermal, charging-discharge, location-vibration vibrational and electromagnetic effects and the use of a monitoring system.

**INTRODUCTION**

The consistent and uninterrupted functioning of power plants is strategic in the modern energy systems. The situations of accidents, which may happen at the large-capacity power generation facilities, are a significant threat to not only the stagnation of the production process, but also to the supply of energy of the whole area. That is why the technical situation and stability of auxiliary systems, especially battery batteries, which provide a stable operation of stations, occupy a significant position. The simplest such element that acts to provide an autonomous power source during the case of an accident is battery batteries, which ensures the same continues to run automation, tele mechanics, relay protection and control chains. They ensure that there is a long-term energy security as the critical systems will receive the required amount of energy even during short-term loss of power supply during the functioning of the station. Thus, the successful work of batteries influences directly not only the technical efficiency, but also the constant functioning of the whole energy system [1-6].

Among the significant scientific and technical activities is the thorough investigation of the factors which influence their work to make the batteries implemented in the energy system more reliable, extend the time of their work and the expenses of their maintenance less. The scientific-based research on most issues including the analysis of the quality of the materials to be used and the behavior of the battery under different loading conditions, temperature variation and stability of the electrochemical processes have been relied upon to offer a high level of reliability to the energy objects [7,8].

**EXPERIMENTAL RESEARCH**

The credibility of battery batteries is predetermined by a number of technical factors which are tracked during the process of their work. The primary outcome of such experimental studies is to determine, analyze and measure factors that diminish the long - term battery life or decrease their capacity. During the research, various models of batteries were experimented under laboratory conditions on charge discharge cycles, temperature, current loads and dynamic changes of internal resistance. [9-11].

The charge and discharge regime is one of the factors that make the greatest effect on the reliability of batteries. It has been experimentally demonstrated that a discharge beyond the norm causes the internal resistance of the battery to increase rapidly, in rapid methods of charging, the stability of the electrochemical processes is disturbed, the extent of sulfation of the plates is greater, and in situations where the depth of discharge is greater than 80, the number of cycles reduces exponentially [12].

Thus, the experiment findings authenticated that the provision of the best charge discharge modes is of fundamental significance in the reliability of batteries.

It is assumed that one of such factors is temperature that has a significant impact on the long-term life of batteries. In the course of the research, batteries were put into temperature conditions of +5o C, + 20o C and + 40o C. The effect of this was that at low temperature, the conductivity of the electrolyte dropped by 20-30% and in high temperature, the evaporation rate of the electrolyte rose and the speed of internal corrosion processes grew, the optimum temperature regime was preserved in the range of +18... 25C. best indicators of reliability were recorded with the batteries [13].

The other significant variable that influences reliability is internal resistance among battery elements. It has been tested that oxidation of contacts leads to rise in internal resistance, dynamics of resistance change during the charge discharge cycles is a significant diagnostic parameter of determining the extent of contact battery wear and that when contacts are attached to bad quality, voltage loss is higher and the overall battery capacity is reduced by 5-10% [14].

The currents of loading the batteries were varied during the experiment. Then we draw to the conclusion that a loading current which surpasses the nominal loading current improves the heating and deformation processes of the battery plates and a long operation at low loading current in the batteries increases the sulfation processes and the indicator of reliability in the battery that is being operated under constant loading has become more stable than the variable loading state [15].

The efficiency of the battery directly depends on the physicochemical parameters of the electrolyte. The densities of 1.20 g/cm3, 1.25 g/cm3 and 1.30 g/cm3 were experimented. Results:

– excessive low density causes drastic reduction in capacity;

– a high density, however, is very large, and increases the rotting of the plates;

– The highest results were obtained with the Optimal density in the range of 1.27-1.29 g/cm3.

These parameters can be controlled in an optimal manner that guarantees stable operation of batteries in the long-term, as well as a large decrease in the cost of operating them.

The external factors and external influences The reliability of batteries directly depends not only on the internal electrical characteristics of the batteries, but also on the parameters of the external environment. The primary external conditions, which considerably influence battery efficiency, are temperature, mechanical fluctuations, humidity and dust. This part examines the scientific analysis of the technical and physicochemical impact of these aspects.

The best operating temperature of the batteries is between 20-25&C when it becomes deviated the derailment of the electrotechnical parameters occurs. Research indicates that as the temperature rises to 10 o C, the speed of chemical reaction will dwell by two times, and this decreases the service life by one and a half to twofold.

High temperatures have the following consequences:

– denser, as a result of evaporation of the electrolytes;

– amplified processes of corrosion in plates;

– faster reaction in the separation of gases, resulting in the buildup of H 2 and O 2;

– power losses due to additional internal resistance.

Effects of low temperature:

– ion conductivity of electrolyte decreases (to -10 o C 35-40");

– decrease in capacity to 20-40% ;

– the acute worsening of the capacity of receiving a charge. The following expression can be used to find the temperature dependence of the battery capacity:

(1)

here: CT - T temperature capacity, C25 - 25°C capacity in, *k* - temperature compensation coefficient (for lead-acid battery batteries 0.006–0.01).

The vibration level is high in the power plants particularly in the section of diesel-generators. Constant mechanical vibrations have severe effects of destroying mechanical strength of the accumulators. Effects of vibration These effects are fragmentation and fracture of lead plates, loose aggregate contacts with high resistance, microcracks in the hull, separation of the electrolyte by vibration into the floors. Vibration-contact resistance bond is located in the following fashion:

(2)

here: R*v* — resistance under vibration, R0 — resistance in normal condition, ω — vibration frequency, A — vibration amplitude.

Dust accumulation and high humidity levels in the rooms where the batteries are located have a serious impact on their performance. As a result of dust, oxidation of contact areas, a decrease in current permeability, error of diagnostic results (due to sensor contamination) occur.

Oxidation of contacts is represented by the following formula:

(3)

here: R*ox* - resistance in the oxidized state, R*clean* - pure contact resistance, k*ox* - oxidation rate coefficient.

In the case of negative consequences of moisture, however, corrosion on metal parts accelerates, condensation of electrolyte vapors occurs, the risk of short circuit increases as a result of a decrease in insulating resistance. Maintaining an Optimal temperature, reducing vibration, keeping service rooms clean and dry will ensure stable operation of the battery system and reduce operating costs by at least 20-30% [16].

**SIGNIFICANCE OF THE SYSTEM**

Batteries used in power plants serve to provide uninterruptible power in case of an accident, to guarantee stable operation of automation and relay protection systems. The battery type is usually selected depending on the power requirement of the station, operating mode, safety level and operating conditions. The following describes the technical characteristics, advantages and limitations of the most widely used battery types in the industry on a scientific basis.

**Lead-acid batteries-lead-acid batteries (SKBS) are among the most commonly used batteries in power plants. Their electrochemical basis is reversible reactions between lead dioxide (PbO₂), metal lead (Pb) and sulfuric acid (H₂SO₄).**

**Due to the high reliability, the stability of electrochemical processes and the simplicity of the construction make them suitable for severe operating conditions, and the lead-acid technology has been developed for many years, with a low cost of production. It is characterized by the ability to give high current and is able to transmit large currents in a short time during an accident. But the electrolyte level, density, degree of sulfation of the plates require constant control. Low energy density due to its large weight makes them sometimes uncomfortable in modern systems [17].**



**FIGURE 1.** Accumulator FIAMM SD 23

**Lead-acid batteries are often used in relay protection, emergency lighting and control systems.**

**AGM and GEL-type VRLA accumulators-VRLA (Valve Regulated Lead-Acid) accumulators are valve — controlled lead-acid systems, divided into AGM (Absorbent Glass Mat) and GEL (gel-state electrolyte) types. These batteries are distinguished by the fact that the electrolyte does not spill, the gas separation is minimal, and maintenance is practically not required.**

Distinguished by the fact that it does not require maintenance, the electrolyte is stored in a closed system, and the maintenance costs are minimal. As a result of recombination processes, the separated gases react again, increasing safety. Resistance to deep charge-discharge cycles is considered stable. But high temperatures dramatically reduce the service life of GEL and AGM batteries. Failure to give the correct charge voltage causes the gel crystals to erode.

VRLA type batteries are more commonly used in automated control systems, telecommunication equipment, and stations requiring high security.



**FIGURE 2.** Leoch 12 OPzV 1200 valve-regulated gel electrolyte battery

**Lithium-ion accumulators in recent years, lithium-ion (Li-ion) accumulators have become widely used in energy systems due to their energy density, efficiency and long service life. Their electrochemical basis is the high frequency diffusion of lithium ions between the anode and cathode.**

The energy density of lithium-ion accumulators is very high, which means that although small in mass and size, it can store large power. The cycle number is long-lasting due to its 3-5 times greater than that of lead-acid batteries. In charge/discharge, the efficiency is high 95-98%. But raw materials and production technology are considered expensive. Each battery block is required to be controlled via a BMS (Battery Management System). Due to its sensitivity to high temperatures, there is a risk of thermal out of control at temperatures above 60°C. Li-ion accumulators began to be used in large GES/GRES, in fast ATS systems, in the energy storage module (ESS).

The types of batteries used in power plants differ depending on their technical reliability and economic indicators. While lead-acid batteries are cheap and reliable, VRLA systems minimize maintenance costs. Lithium-ion batteries, on the other hand, have the advantages of high energy density and long-term operation, but the control system is complex and the price is high. Therefore, the battery type is selected based on the loading nature of the power plant, safety requirements and operating conditions [18].

**LITERATURE SURVEY**

The scientific literature on the physicochemical, electrochemical and electrotechnical processes of battery batteries provides an in-depth analysis of factors determining their reliability, wear processes and effectiveness. According to the researchers, the quality of operation of batteries is mainly determined by charge–discharge processes, temperature, internal resistance, degradation of materials and interaction with the external environment.

Classical studies on lead-acid batteries (scientists such as Plante, Faure, Pavlov) explain the effect of the electrochemical sulfation process, the structure of electrodes and the electrolyte density on Energetic indicators. Modern sources, on the other hand, detail changes in the crystal structure of lead plates, active mass decay, and the effect of hydrogenation processes on reliability. The irreversible phase of sulfation in particular is cited as the main factor limiting the total battery resource.

Scientific work devoted to VRLA (AGM and GEL) accumulators interprets the electrolyte as being in an immobile state, gas recombination mechanisms, and the function of valve control systems as the main technological solution that prolongs battery life. Studies show that one of the advantages of VRLA technology is the reduction of water loss to a minimum due to the return of gases to the back reaction and a decrease in the need for maintenance. However, it has been noted that under the influence of high temperatures, a violation of the gel structure or a change in the capillary balance between AGM tumor fibers leads to rapid wear on this type of battery.

The scientific literature on lithium-ion accumulators focuses specifically on the issues of high energy density, ion migration rate, sei (Solid Electrolyte Interphase) layer formation, and thermal stability. Studies show that the stability of inter-electrode ion transport in Li-ion batteries and the qualitative formation of the SEI layer are the main factors that determine the battery resource. There are also a number of scientific works on the risk of lithium dendrites growing at high temperatures, which makes the application of BMS (Battery Management System) in energy systems mandatory, as the phenomenon increases the likelihood of thermal explosion [10].

In the literature on applications in energy systems, a great emphasis is placed on the role of batteries in accident situations. Monitoring of charge levels (State of Charge — SoC) and health status (State of Health — Soh), automatic temperature control, dynamic distribution of loads, and “early warning” systems are recommended as the most effective methods that increase systems reliability. Most sources provide mathematical models of battery management algorithms, time-varying internal resistance, and simulations of wear Kinetics.

In general, most of the literature shows that the long — term reliability of batteries depends on many factors, the most important of which are the temperature regime, optimal charge–discharge processes, electrolyte parameters, mechanical safety, automation of the diagnostic process and the use of modern control systems [19].

**EXPERIMENTAL RESULTS**

**Increasing battery reliability the continuous and safe operation of battery batteries in power plants is a decisive factor for the stability of the entire energy system. In order to increase their reliability during Operation, it is recommended to follow the following scientific and technical proposals.**

**Ensuring the Optimal temperature regime-the working temperature range for the effective operation of batteries is 20-25°C. This deviation from the range leads to a decrease in capacity, an increase in internal resistance and an acceleration of the rate of wear as a result of slowing or increasing electrochemical processes. Therefore, it is necessary to modernize heat exchange systems, create a stable microclimate in battery rooms and strengthen the cooling system in high-temperature rooms.**

**The use of automatic charging systems – incorrect charge modes are responsible for the reduction of the service life of batteries to 40%. To prevent this, microprocessor-controlled automatic charging devices, voltage and current dynamic control inverters, and temperature compensation charging algorithms should be used. Such systems prevent overcharging, deep discharge and sulfation.**

**To keep the technical condition of the batteries stable as a result of regular battery diagnostics, it is recommended to perform monthly diagnostic steps such as measuring internal resistance, checking the equality of voltages, assessing electrolyte density (for SKB types), as well as determining heat points in the thermal chamber and controlling the condition of contact compounds:**

**As a result of the introduction of” Early Warning "equipment, however, the implementation of" early warning " (early warning) algorithms to detect initial battery failures in power plant control systems greatly increases efficiency. Such algorithms provide real-time warning based on parameters such as sharp changes in internal resistance and a decrease in charge absorption capacity, temperature out of range, and extremely low voltage states.**

**In the step-by-step transition to modern battery technologies, however, compared to conventional lead-acid batteries, VRLA (AGM/GEL) and lithium-ion batteries have the following advantages, with longer service life (3000+ cycles per Li-ion), less maintenance needs, higher energy density, minimal gas separation. For this reason, it is recommended to step by step to modern technologies in energy facilities.**

**Strengthening anti-vibration protection measures is necessary that is, protecting batteries from mechanical vibrations significantly reduces their wear and mechanical damage. To do this, it is necessary to install vibration-absorbing elastic diapers, shock-absorbing platforms, sensors monitoring the level of vibration.**

**It is necessary to organize an effective ventilation system in battery rooms. Ventilation prevents the accumulation of gas separation (H₂ and O₂) as a result of installation, provides heat exchange, reduces the concentration of electrolyte vapors, sharply reduces the risk of explosion and fire. Ventilation is a mandatory requirement because VRLA batteries also have a minimum level of gas separation [20-49].**

**According to the result of regular control of electrolyte density, the electrolyte density in lead-acid batteries directly determines the battery charge level, chemical process activity and capacity. The Optimal density should be maintained in the range of 1.27-1.29 g / cm3. A decrease in density leads to a decrease in capacity, and an increase leads to the decay of plates. Regular measurement using hydrometers is therefore necessary [14,15].**

The proposed measures will significantly extend the service life of battery batteries, reduce the likelihood of accident cases and serve to increase the overall reliability of power plants. When an integrated approach is applied, the stability of the energy supply system can increase by 25-40%.

**CONCLUSION AND FUTURE WORK**

Studies and experimental observations have shown that the reliability and service life of batteries directly depends on a number of technical and external factors. Key results include:

1. The importance of the quality of Service and temperature regime – analyzes show that the reliability of the battery at a level of more than 50% depends on the quality of their operation, charge–discharge mode and temperature control. The Optimal temperature range (20-25°C) and stable charge mode allow the batteries to extend their service life and stability of efficiency. An increase or decrease in temperature disrupts electrochemical processes, increases internal resistance and reduces capacitance.

2. The effect of improper charging – as determined by experimental observations, the non-optimal charging mode reduces the battery's total service life by 30-60%. This is mainly due to deep discharges, overcharges and fast charging methods. Therefore, the use of automatic charging systems and the application of temperature-adjusted charging algorithms significantly prolong the service life.

3. The importance of Monitoring and diagnostic systems – real-time monitoring systems installed in power plants reduce the likelihood of accident cases by 2-3 times. Such systems provide constant control over internal resistance, electrolyte density, voltage and temperature changes, provide early warning, and reduce the need for reactive repair.

4. Cost-effectiveness of lithium-ion batteries-long-term calculations show that lithium-ion batteries are more economical than conventional lead-acid batteries in terms of operating costs due to their long service life and high energy efficiency, despite their initial high cost. Their long-term performance, energy density, and large number of service cycles increase the stability of the energy system.

Research shows that the quality of Service, optimal temperature regime, the presence of automated charging and monitoring systems are the most important factors in increasing battery reliability. Also, the transition to modern lithium-ion technology provides long-term economic efficiency and significantly reduces the occurrence of accident situations.

**CONCLUSIONS**

**The reliability of battery batteries in power plants is a decisive factor for the stability and safety of the entire energy system. The results of studies show that the performance of the battery depends on several basic parameters, that is, the temperature regime maintaining the optimal range ensures the stability of electrochemical processes, and the battery slows down the rate of wear, incorrect or deep discharge in the charge–discharge order significantly reduces the service life. Automatic and temperature-adjusted charging algorithms reduce this risk. In chemical stability, electrolyte density, sulfation rate, and degradation of electrode materials are the main factors determining battery efficiency. And as a result of external influences and mechanical stability, vibration, moisture, dust and mechanical shocks increase the wear rate of batteries, so it is necessary to protect them. Monitoring and diagnostic systems constantly allow real-time control to warn from the beginning and significantly reduce the occurrence of accident situations.**

**Through the Integrated Control and optimization of these factors, the service life of batteries is significantly extended, operating costs are reduced, and the overall reliability of power plants is increased. At the same time, the transition to modern technologies — the use of VRLA and lithium-ion batteries — provides long-term economic efficiency and further strengthens the security of the system.**

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