CAUSES OF THE LIFE SHORTENING OF LEAD-ACID BATTERIES IN PHOTOVOLTAIC (PV) APPLICATIONS

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Introduction

The paper analyzes reasons of short service life of the lead-acid accumulator for photovoltaic (PV) application and shows possibilities of service life magnification.

Experimental

In the course of the operation of PV systems, batteries are permanently exposed to charge/discharge cycles. PV applications feature relatively low discharge rates, deep discharge and infrequent charging, only seldom with full charge. In the course of the daily cycle, the battery is being charged only during the daylight and discharge during the night. Superimposed on the daily cycle is the seasonal cycle, which is associated with periods of the reduced solar irradiation availability. Charging conditions are a very important factor for the "health" of a battery. These conditions are often beyond control, as they depend on the variations in solar radiation.

The life of lead-acid batteries in PV applications is often shorter than what would correspond to experience from other applications – battery life was often found to terminate after half a year of battery operation. This was often brought about by an improper selection of the battery type or by an unsuitable control system of the battery operation management.

Generally:

Batteries suffer at *insufficient charging* by:
- electrolyte stratification
- deep irreversible sulfation

At *overcharging*:
- by dewatering and drying up of the electrolyte
- active mass softening
- corrosion of the csollector of the positive electrode

thermal runaway

There is moreover another source of failures, which cannot be neglected, namely insufficient or poor battery operation management.

The electrolyte stratification occurs mainly in highly flooded cells (<25cm) with open construction, where the process of the vertical redistribution of the electrolyte, depending on its density, so that the electrolyte with the maximum density sets in gradually at the bottom of the vessel [1]. The pronounced stratification carries with it a high content of lead sulfates in the lower part og the bottom part of the negative electrode [4]. This problem can be prevented by the forced electrolyte circulation. The circulation is caused by either a mixing device or by modifying the discharge regime with the intentional development of gas at overcharging.

Maintenance-free VRLA-AGM batteries ate to a limited extent also susceptible to the stratification of electrolyte in the pores of the separator; moreover, the closed nature of this type of the battery does not allow gassing for the removal of this problem. VRLA-GEL batteries do not suffer from stratification, and therefore, from this point of view, suit very well for the specific use for RAPS [2].

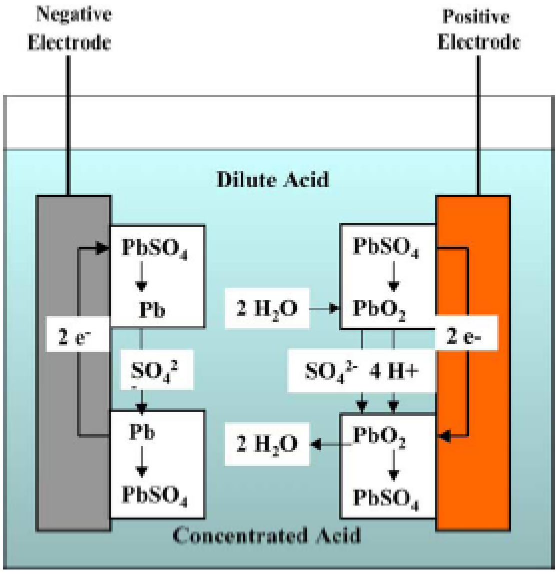

Fig. 1 *Mechanism leading to stratification electrolyte.*

The irreversible sulfation is a phenomenon, where the electrode surface is covered by the insulating layer of lead sulfate. Consequently, the transfer of electrolyte to the still working active mass close to the collector with the subsequent collapse of the battery capacity. The irreversible sulfation comes about in PV applications, when the battery is left in the discharged state for a long time or in case of stratification.

The electrolyte dewatering appears in batteries at overcharging (or at excessive discharge, when electrode reversal occurs). If the electrode voltage exceeds 2.45 V, the pronounced hydrolysis process starts to play a significant role and gassing sets in. Dewatering may also occur at thermal runaway, see below. In flooded cells this problem may by solved by the addition of distilled water, VRLA batteries require a control system, overseeing the batter state.

The cycling is accompanied by periodic volume changes [6], which may result even in the softening of active mass. These changes are due to different volumes of reactants entering charging /discharging reactions and reaction products. These changes are more pronounced at positive electrodes.

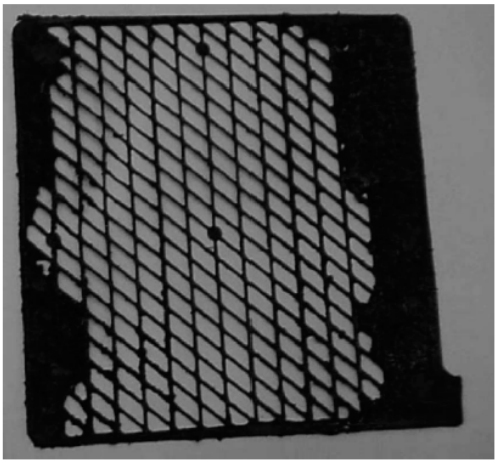

Fig. 2 *Degradation positive active mass, failure consistence*

When the battery is left on open circuit and, in particular, at overcharging a gradual corrosion of the positive electrode collector comes about [7]. This is a parasitic electrochemical reaction, when lead at the collector changes into lead dioxide, i.e. the positive electrode collector is formed through. The collector corrosion can be partially suppressed by alloying the collector with various additives and by strictly keeping the technological discipline in the manufacturing process.

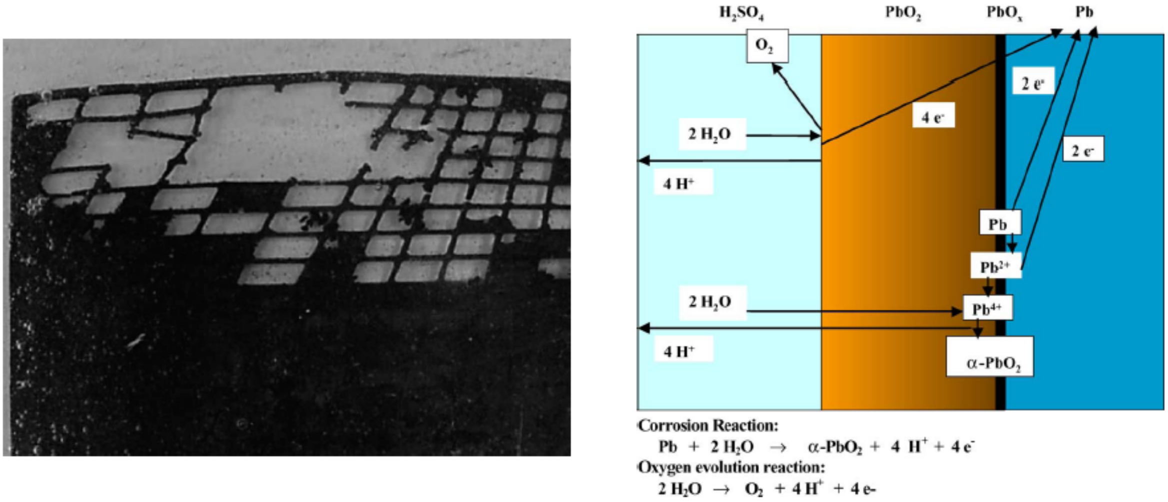

Fig. 3 *Corrosion of the collector of positive electrode in lead-acid accumulator and corrosive mechanism proceed on interface collector/active mass*

AGM batteries are rather sensitive to the temperature of the operation, when at high temperatures thermal runaway may occur; this results in the generation of large amounts of oxygen (which recombines exothermically at the negative electrode), in the drying up of the electrolyte, in the increase of the internal resistance of the cell and in the damage of the tightness of the batter vessel. In an extreme case this may lead to the melting of lead components and to the explosion of the battery [5]. In total, AGM batteries cannot be used under extreme thermal conditions; their operation may be managed by temperature compensation.

Moreover, the cause of the premature battery failure is in many cases apparently the wrong charging strategy. Manufacturers themselves make errors in setting the limits, when the charging is to be terminated. Keeping on with charging with the voltage limit of 2.35V turns out to be a wrong regime, which cannot guarantee that the battery will be charged to its full capacity [8]. A very important role is played by the determination of the state of charge (SOC) of the battery, when the use of a wrong or inexact method entails errors, so that the SOC value then becomes wrong [9]. This may later lead to the SOC error accumulation with the salient shortening of the battery life. When calculating the SOC from the measurement of the charge passed, it is necessary to include in the calculations also the losses, which are brought about by parasitic electrochemical reactions. Therefore, it is essential to carry out now and then the conditioning charging and the recalibration of the SOC value.

The experience gained in the research of hybrid electric vehicles (HEV) leads to the conclusion that the ideal regime is such regime, when the battery stays for the most time in the state of incomplete charge, where its ability to accept electric charge is high and the conditioning charging to the state of the full charge occurs only infrequently. It is quite difficult to keep the VRLA battery close to the state of the full charge without the loss of charging efficiency because of the functioning of the internal oxygen cycle. VRLA batteries work worse that the flooded ones when they are exposed to a permanent long-term charging at constant voltage [4]. Therefore, the general recommendation is that the GEL VRLA batteries work in the partial state of charge (PSOC) regime [3]. This, however, carries with it other problems associated with the sulfation at the long-term battery idling in a much discharged state.

Acknowledgements

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