Batteries Division

ZVEI information leaflet No. 19

August 2019

Duration of service life – Considerations on stationary lead-acid batteries in standby parallel operation

1. General

Stationary batteries take on countless functions in everyday life in the field of electricity supply, ensuring security for people, production processes and data storage. Stationary batteries – like all electrochemical energy storage media – are subject to ageing. This manifests itself in a reduction of capacity and increase in the internal DC resistance as the interior conductive cross-section of the battery for instance, is reduced (corrosion). If the functions of the stationary battery can no longer be sufficiently guaranteed as per the specifications/definitions, then the end of service life has been reached. For long-term, reliable functionality, knowledge of the service life is important. The definitions of various service life terms for batteries are explained in ZVEI information leaflet No. 23.

The service life of stationary batteries is mainly determined by:

- the design
- the quality of materials used
- the quality of manufacture
- the operational conditions
- maintenance

While the first factors can be influenced by the battery manufacturer, the operational conditions and maintenance are determined by the user.

Critical operational factors that can influence and markedly reduce the service life include, for example:

- **Increased operational temperature**
  The recommended operational temperature for lead-acid batteries is 10 °C to 30 °C. The technical data applies to a nominal temperature of 20 °C. The ideal operational temperature is 20 °C ± 5 K. Higher temperatures can shorten the service life (see figure 1), lower temperatures reduce the available capacity.

- **Temperature gradients within a battery**
  The temperature difference between the cells with the highest and lowest temperatures should not exceed 3 K.

- **Float charge voltage and its adjustment to temperature and discharge regime**
  Insufficient float charge voltages lead to a rapid loss of capacity, rendered irreversible by sulphatisation; excess float charge voltages lead to increased corrosion, water decomposition and gassing in the battery.

- **Alternating current load**
  Alternating currents of frequency > 30 Hz essentially lead to an increase in the battery temperature, thus causing increased water decomposition and accelerated corrosion. Alternating currents of frequency < 30 Hz lead principally to insufficient charging and cyclical loading.

- **Mode of operation (buffer or standby parallel operation)**
  In buffer operation, a cyclical load always arises; cycles increase the ageing of the battery in comparison to standby parallel operation.

- **Number of discharge/charge cycles**
  Frequent discharges/charges (cyclical load) lead to accelerated ageing.

- **Depth of discharge**
  Deep discharge leads to accelerated ageing.

Results of accelerated service life tests in laboratories can be transferred into expected service lives only under certain conditions. The guide values given are thus based on the results of accelerated service life tests and practical experience under comparable conditions.

The extractable capacity of stationary batteries changes over the service life (figure 2). Usually, the service life is over when it fails to meet 80 % of the projected capacity.

Batteries also age independently of the mode of operation. Ageing processes also lead to a reduction of the conductive cross-sections inside the battery. Once ageing has progressed to a certain extent, the reduced cross-sections are incapable of conducting the current designed for the loading condition over the defined period of time. When discharging at high currents, the heat produced is out of proportion, leading to thermal overload on the reduced cross-sections. This can, in extreme cases, lead to an unexpected failure of the battery.

The common statements on service life relate to the nominal current over a 10-hour discharge (long-term discharge). The criterion for the end of service life (80 % of the projected bridging time) is reached significantly faster (figure 3) in structures with much higher currents (discharge < 1 h). The extent of the loss of capacity due to age when discharging at high currents strongly depends on the battery type (internal construction, type of electrodes and design of the battery). The consequence is that the battery must be oversized in design. The ageing factor to be applied in this case should be determined in consultation with the battery manufacturer.

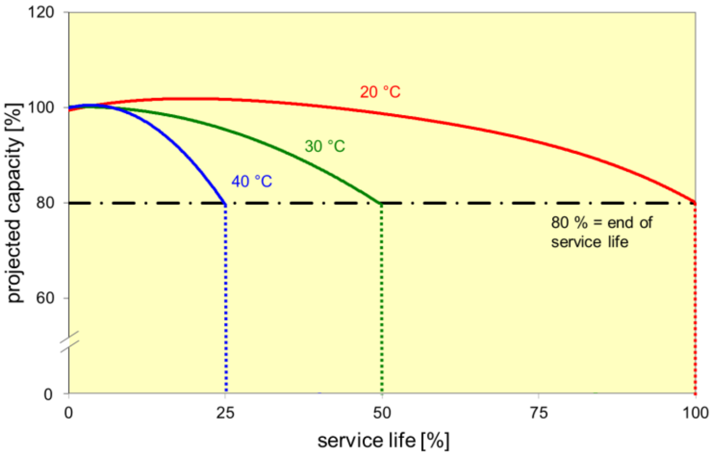

Figure 1: Schematic representation of the relationship between duration of usability in batteries and the ambient temperature

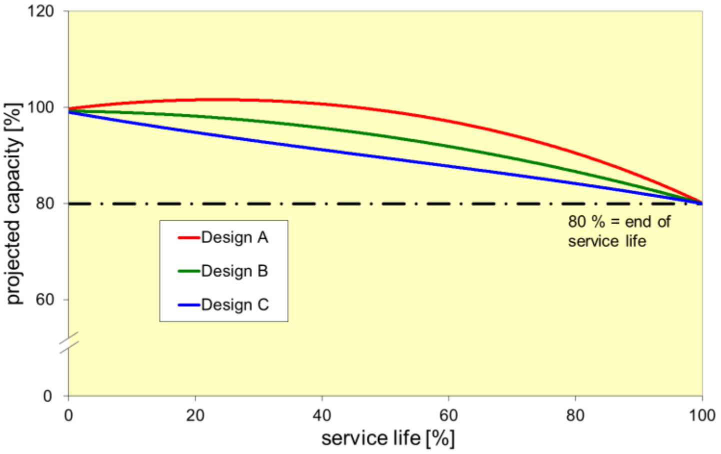

Figure 2: Typical trends in battery capacity across the service life

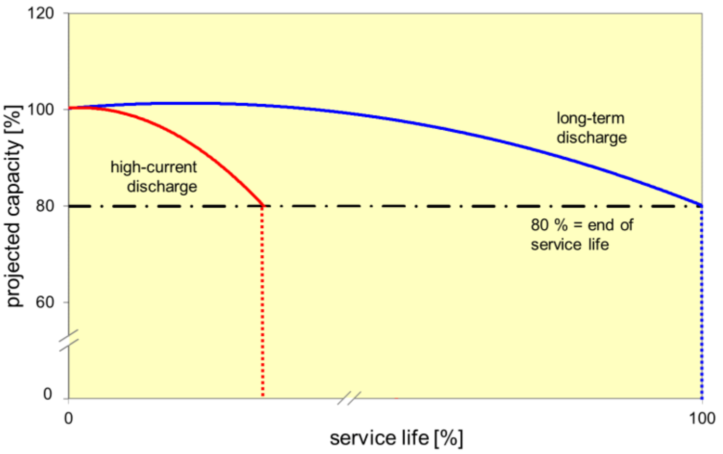

Figure 3: Typical progresses of projected bridging times for high-current discharges or long-term discharges over the service life of the battery

2. Empirical values for the service life of standard batteries

The service lives of the various types of batteries are specified in each case by manufacturers, with specific relation to application and environment. In the following, empirical values for some standard batteries' service lives from long-term discharge are given:

OPzS cells	DIN 40736	15 years
OPzS block batteries	DIN 40737	13 years
GroE cells	DIN 40738	18 years
OGi block batteries	DIN 40739	12 years
OGi cells	DIN 40734	14 years
OGiV block batteries	DIN 40741, T1	12 years
OPzV cells	DIN 40742	14 years
OPzV block batteries	DIN 40744	13 years

Optimum conditions for use

– **Mode of operation**	standby parallel operation
– **Discharges**	max. once per month
– **Discharge current**	nominal current
– **Discharge depth**	max. 80 % C_{10}
– **Float charge voltage**	depends on battery design, as stated by the manufacturer
– **Operating temperature**	20 °C ± 2 K
– **Superimposed alternating current I_{eff}**	max. 2 A per 100 Ah C_{10} in closed batteries and 1 A per 100 Ah C_{10} in sealed batteries
– **Compliance with the technical usage and operating instructions in each case**	

3. Principle course of failures

The course of failures in structural elements is usually represented by the so-called “bathtub curve” (figure 4). The progression of the curve is also characteristic for batteries and is divided into three types of failure.

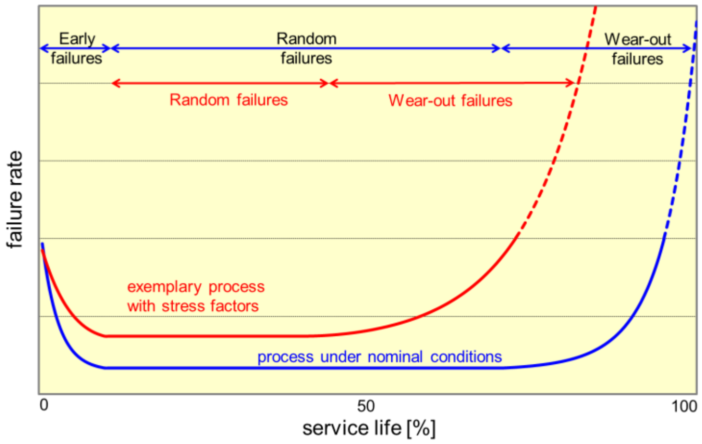

Figure 4: Process of failure in batteries (“bathtub curve”)

- **Early failures**
  The rate of failure in this section is essentially determined by errors in the manufacturing of the product and its installation / commissioning

- **Accidental failures**
  The failure rate in this section is essentially determined by the operational conditions and stress factors connected with them (see chapter 4).

- **Wear-related failures**
  In this section, the first wear-related failures occur, i.e. a part of the whole unit (battery) reaches the end of its service life. The start and rate of wear-related failures are strongly dependent on care and maintenance and are thus out of the sphere of influence of the battery manufacturer, unless there is a corresponding service contract in place. The reliability of the overall system (overall battery power, spread of individual components) is reduced exponentially towards the end of this phase. The battery should be exchanged before the failure rate reaches its final increase.

Alongside the stress factors listed in chapter 1, compliance with the float charge voltage and quality of maintenance defined in the manufacturer’s instructions have a great influence on the process of failures and the absolute value of the failure rate.

4. Operational safety of the battery system

In general, the functionality of the battery must be regularly checked using a capacity test in order to guarantee the operational safety of the system. Care must be taken that the capacity test is carried out with the maximum current for which the battery is designed in its highest loading condition. Regular checks of the battery can markedly reduce the risk of unexpected failures. It is thus recommended to carry out professional capacity tests at regular intervals, at least once a year. Experience shows that such a test is not necessary in the first 3 years of the service life.
Additional regular impedance measurements (e.g. once a year) on the cells/block batteries can provide important information on potential deviations from the expected service life. For this, after installation of the battery a reference measurement must be taken, in which the battery will have been operated with float charge voltage for at least 2-3 days. Further measurements must then be recorded under constant conditions (full charging status is recommended). The trend line to be determined from the regular measurements serves to recognise significant changes in internal resistance. This provides information to support further capacity or load tests.

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