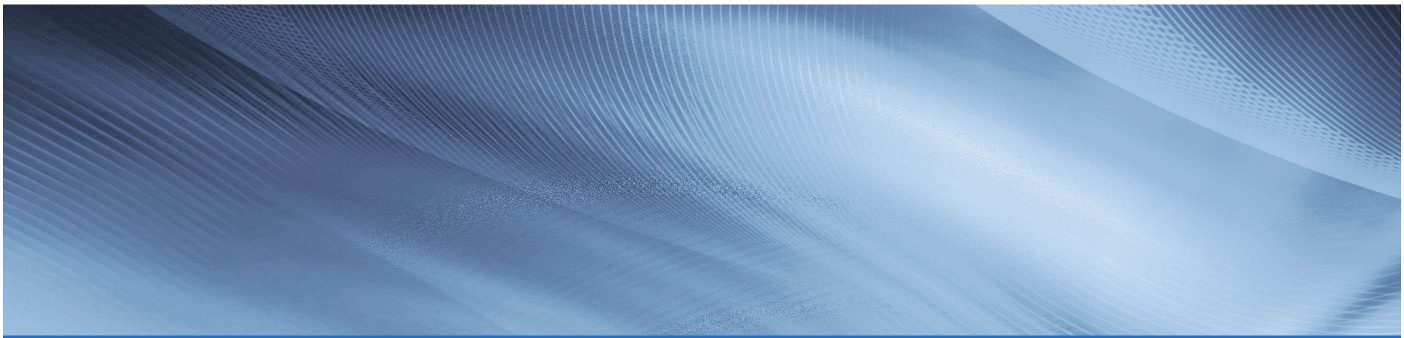
Lead-Acid Battery

European Association for Storage of Energy



Electrochemical Energy Storage

1. Technical description

A. Physical principles

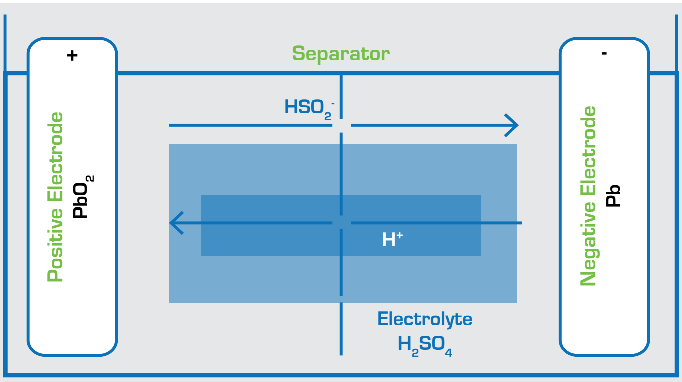
A lead-acid battery system is an energy storage system based on electrochemical charge/discharge reactions that occur between a positive electrode that contains lead dioxide (PbO_2) and a negative electrode that contains spongy lead (Pb). Both electrodes are immerged in an aqueous sulphuric acid electrolyte which participates in the charge/discharge reactions.

B. Important Components

The main components are the following:

- 2V cell composed of an assembling of electrodes, electrolytes and separators
- 4/6/12/.. V mono-blocks composed of serial assembling of cells
- Battery systems composed of a large assembling of cells or modules
- Power Conversion System (PCS)

Illustration: Charging principle of a Lead-Acid Battery



The products of charge (left) and discharge (right):

$$PbO_2 + Pb + 2H_2SO_4 \longleftrightarrow 2PbSO_4 + 2H_2O$$

C. Key performance data

Power range	Some Mw
Energy range	Up to 10 MWh
Discharge time	Min to more than 20 hours
Cycle life	500 - 3,000 cycles
Life duration	5 – 15 years
Reaction time	Some millisec
Efficiency	75 - 85 %
Energy (power) density	25 - 35 Wh/kg
CAPEX: energy	100 – 200 €/kWh
CAPEX: power	100 – 500 €/kW

D. Design variants (non exhaustive)

The following design variants are available:

Valve regulated (maintenance-free with starved electrolyte) or flooded (vented)

Positive electrodes with tubular or flat grid plate design

Negative electrodes with lead or copper grid

Spiral (round) or prismatic cells and mono-blocks

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2. State of the art

There are two main design subtypes:

- Flooded (Vented Lead-Acid (VLA)) batteries requiring maintenance
- Valve Regulated Lead-Acid (VRLA) batteries, either absorbent glass mat (AGM) or gel designs.

Within these two subtypes, positive electrodes feature tubular, planté or flat grid plate designs, and negative electrodes feature either lead or copper grids. Cells can be organised in a spiral (round) configuration, or as prismatic cells and mono-blocks.
The cells are produced in formats from 1 Ah up to 16000 Ah. They can be connected in large battery arrangements without a sophisticated management system, and are differentiated by a low cost per kWh to install and low cost per kWh electricity throughput.
Industry has extensive experience in many industrial applications including small, medium and large Battery Energy Storage Systems (BESS).

3. Future developments

Despite being in use for a hundred years, there still remains extensive potential for advanced lead-acid battery technology. Specific power is being improved with advanced additives to the active materials and lower resistance designs. Further cost reductions are being realised through automation and process improvement. The cycle life will be increased through design enhancements such as newly improved corrosion-resistant alloy materials and intelligent battery management (including new charging strategies).

Furthermore, new “Advanced Lead-Acid” concepts are being developed:

- Addition of some “super capacitor-like” features that improve the power capability
- Development of high-energy carbon electrodes to increase the energy density (lead-carbon batteries)
- Use of advanced electrolytes to address the performance related to acid stratification

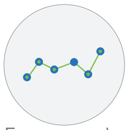
Complete turnkey systems including battery management with a power rate up to the MW size are being developed. Moreover, lead-acid batteries could be integrated into hybrid systems in combination with other high power storage technologies to maximise benefits and minimise costs.

4. Relevance in Europe

An established manufacturing base for lead-acid batteries already exists in Europe, accounting for over 20000 direct jobs. The batteries’ inherent advantage of efficient performance at low investment cost is expected to encourage their widespread adoption across Europe in grid-connected and off-grid applications.
Lead-acid batteries have a collection and recycling rate higher than any other consumer product sold on the European market.
Lead-Acid batteries are used today in several projects worldwide. The European installations are M5BAT (Modular Multi-Megawatt Multi-Technology Medium-Voltage Battery Storage) in Aachen (Germany) for energy time shifting application, capacity power supply and grid services, and the “Energy Buffer Unit in Alt Daber” (Brandenburg) project focused on frequency regulation.

5. Applications

Lead-acid technology is used in nearly all applications except small portable and mobile systems. The large variety of applications includes:



- stationary stand-by & UPS
- motive power applications (e.g. in forklifts)
- starter batteries (e.g. starting, lighting, ignition (SLI)) requiring high power at low temperatures.

For example, wet cell stand-by (stationary) batteries designed for deep discharge are commonly used in large backup power supplies for telephone and computer centres, grid-connected energy storage, and off-grid household or residential electric power systems.

6. Sources of information

- EASE Members
- EUROBAT
- ISEA RWTH Aachen