

ELECTRICAL ENERGY STORAGE

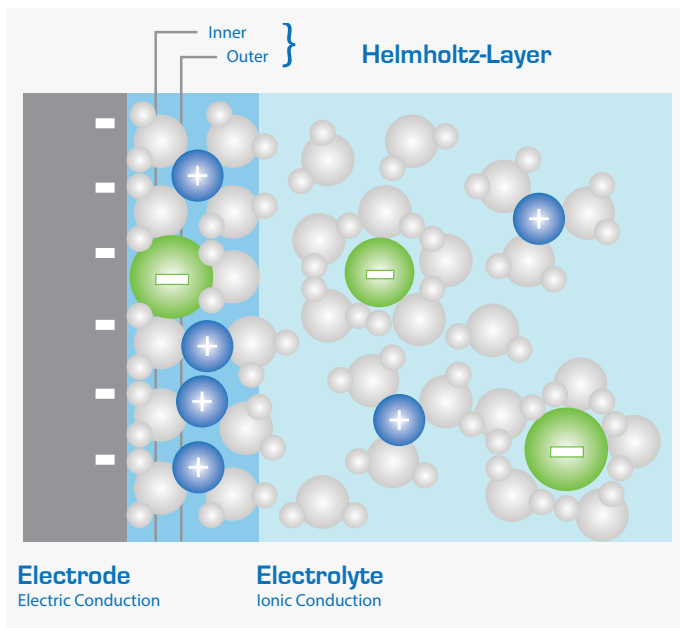
1. Technical description

A. Physical principles

An Electrochemical Double Layer Capacitor (EDLC) System is an energy storage system based on electrostatic effects that occur between two carbon electrodes with high specific surface areas per volume, e.g. activated carbons. The electrodes are immersed in an electrolyte, and a separator between the electrodes is used.

By charging the capacitor, cations are accumulated at the boundary between the solid negative electrode and the electrolyte on one side and anions at the boundary between the solid positive electrode and the electrolyte on other side, forming the so called Helmholtz-layers. In contrast to batteries, only electrostatic effects are used for the storage of the electrical energy. The differential voltage between the electrodes is limited by the dissociation voltage of the electrolyte, which is about 0.9 V for aqueous ones and about 2.7 V for organic solvent based ones. In terms of operating temperature, EDLCs are able to work between -40°C and 70°C.

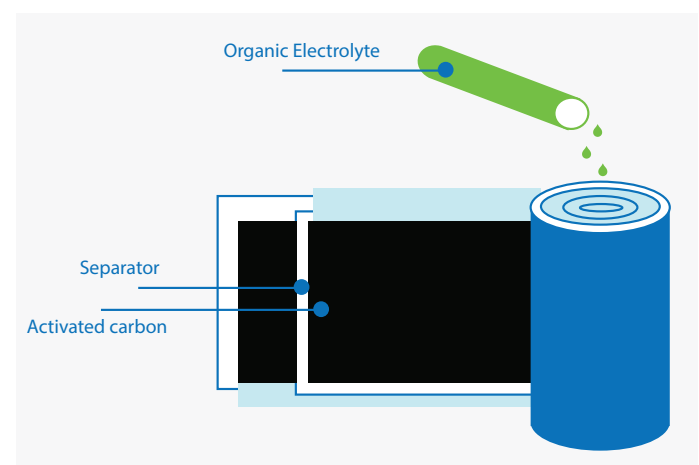
Illustration: Charging principal of EDLC



C. Key performance data

Power range	Up to some MW
Energy range	Some kWh
Discharge time	Some sec - some min
Cycle life	1,000,000
Life duration	10 years at RT
Reaction time	5 millise
Efficiency	90 %
Energy (power) density	4 to 7 Wh/kg [5 to 8 kW/kg]
CAPEX: energy	10,000 to 20,000/kWh
CAPEX: power	100 to 500 €/kW

Illustration: Basic EDLC Design



B. Important components

The main components are the following:

- Two carbon electrodes
- One electrolyte
- One separator
- One EDLC system



D. Design variants (non exhaustive)

The following design variants are possible:

- Different types of cells: by winding or stacking the electrodes capacitors with different shapes, cylindrical or prismatic are produced.
- Different types of electrolyte: Aqueous electrolytes as well as non aqueous electrolytes, e.g. quaternary ammonium salts in acetonitrile.
- Different system design: capacitors are connected in parallel and/or in series of modules to achieve required operational voltages, energy and power content.

2. State of the art

Since the mid-80s, small EDLC were used as reliable backup power mainly in consumer electronics. During the late 90s, large cells were developed to be used in industrial electronics. Since then, millions of large EDLC have been produced and are in operation under very harsh environmental conditions (e.g. in the pitch control of large wind turbines).

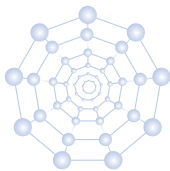


Recently, EDLCs have been used in start/stop systems for cars. This energy storage system is able to recuperate electrical energy during braking and can provide the power boost for a smooth start of the engine for more than 500,000 charge and discharge cycles.

Driven by the increasing demand for large cell materials, production processes were improved in order to meet price targets of less than 0.01 €/Farad.

In the beginning, Japanese companies were dominating the market; however, due to the demand for a storage device with a repetitive high power output in industrial electronics (like for example diesel-electric buses and blade control of wind generators), large cell production facilities were established in other Asian countries (South Korea and China), European countries (Germany and France) and in the USA.

3. Future developments



Today, the electrodes are made of activated carbons based on synthetic or wood precursors. By developing highly porous electrodes (such as graphene-like carbons or carbon nano tubes), a further increase of the specific capacitance will be achieved. In addition, the specific energy will be increased by electrolytes which will enable higher operational voltages.

Sir Andre Konstantin Geim and Sir Konstantin Novoselov were awarded the 2010 Nobel Prize in Physics for their work on graphene.

4. Relevance in Europe

The technology can be used to store surplus energy from the grid at low electricity prices at the European Energy Exchange (EEX) in order to sell the stored energy at high spot market prices of electricity. Storage systems like this also have a grid stabilising effect and avoid shutdown of renewable power plants at times when more renewable electricity is produced than needed. Moreover, the plant produces dispatchable electricity according to the market requirements, thus balancing the intermittent volatile feed-in of renewable energy sources. Finally, the generator provides alternating current with capacitive phase shift in order to compensate ohmic losses in the grid.



5. Applications

Due to the relatively high specific energy combined with low internal resistance and the capability to withstand up to one million charge and discharge cycles without significant wear out, EDLCs are used in a large variety of applications.



Uninterruptible Power Supply (UPS) systems to back-up short power failures and cover peak power demands



Safety electronics as a maintenance free power back up



Renewable energy for smoothing voltage sags and power boost

6. Sources of information

- EASE Members
- A Review of Energy Storage Technologies for Renewable Integration
- Progress in electrical energy storage system: A Critical Review
- Energy Storage Technology Review