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Redox Flow Batteries: practical DC Integration for large-scale energy storage

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Raúl Ramón
rramon@epicpower.es

elincom

Danny Langbroek
d.langbroek@elincom.nl

PE&ES event 2026

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Elincom Electronics B.V.

- Since 1975 specialist distributor of components for industrial electronics and industrial automation
- Over 800 B-to-B customers in the Benelux
- Focus at technical design-in

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Epic Power Converters S.L.

Bidirectional DC/DC Converters for

Lift / Cranes

Intra-logistics

Energy storage

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Biggest battery in the world - Now it’s a flow battery!

1.2 GW

Battery performance

The maximum power output of the storage facility corresponds to the output of the Leibstadt nuclear power plant.

2.1 GWh+

Battery capacity

This corresponds to supplying 1 million households for 5 hours or 210'000 households for 24 hours.

75 %

Water content

The electrolyte consists largely of water - safe, environmentally friendly and resource-efficient.

100 %

Non-flammable, non-explosive

Maximum safety thanks to non-flammable and non-explosive technology

[Redox Flow Battery Storage | FlexBase]

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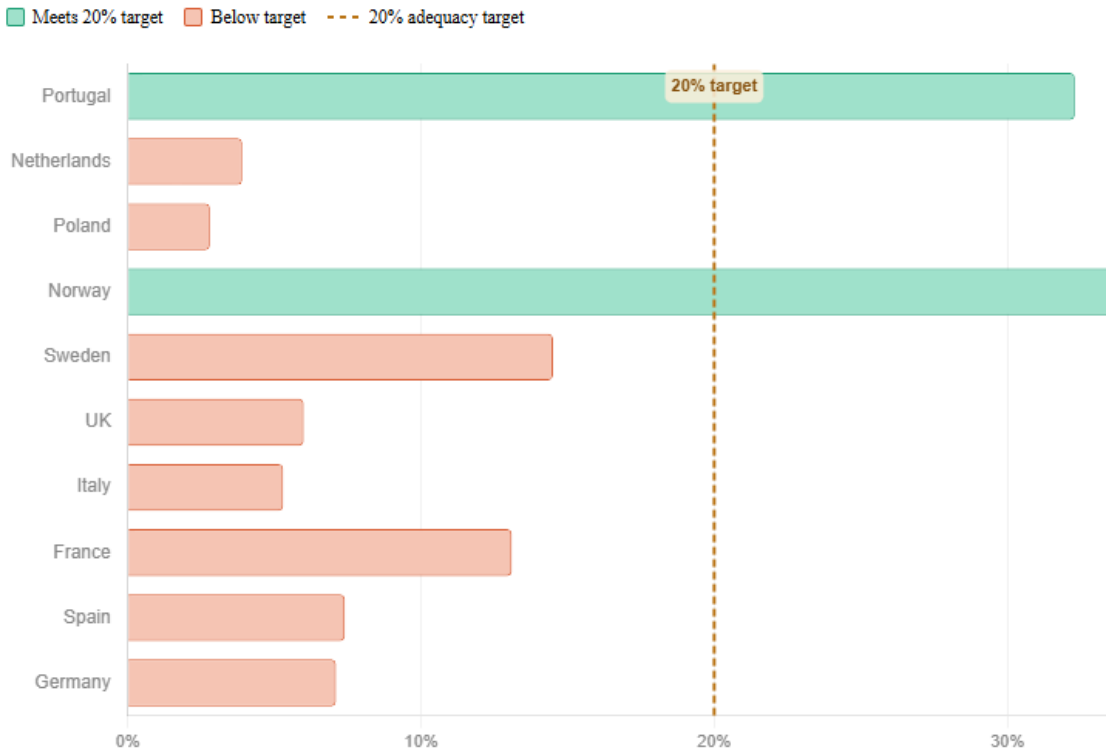
Increasing renewables require energy storage



Top 10 ranked by total installed renewable capacity (end-2023). Sources: IRENA 2024, EASE European Energy Storage Outlook 2024, ENTSO-E.

Storage vs renewable capacity < 15 %

↓

Curtailment and unmet demand

Storage vs renewable capacity > 25 %

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Returns diminish

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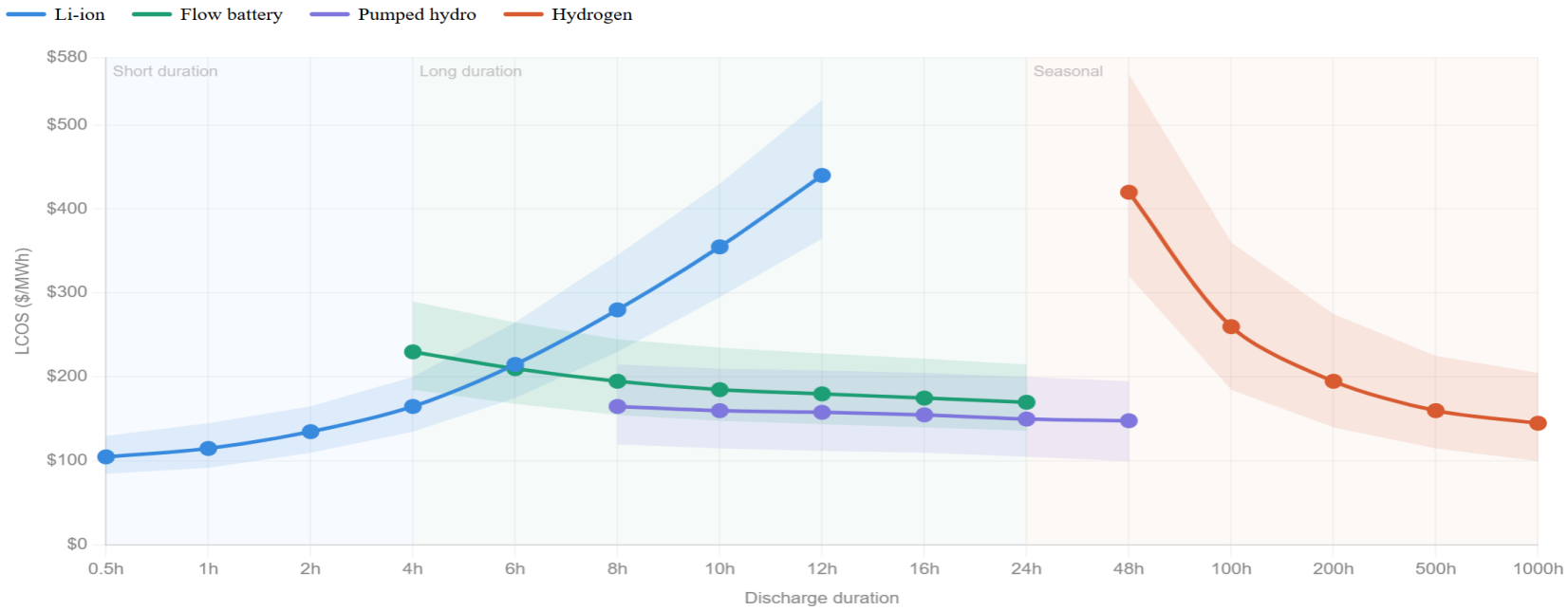
Short duration vs long duration energy storage



Midpoint values from NREL/PNNL 2024, Lazard LCOS v8.0, INL/DOE 2024, BloombergNEF 2023. Shaded areas = published low–high ranges. Charging cost $50/MWh

Why is long duration important?

- Dunkelflaute events
- Daily or seasonal curtailment
- Need for gas peakers

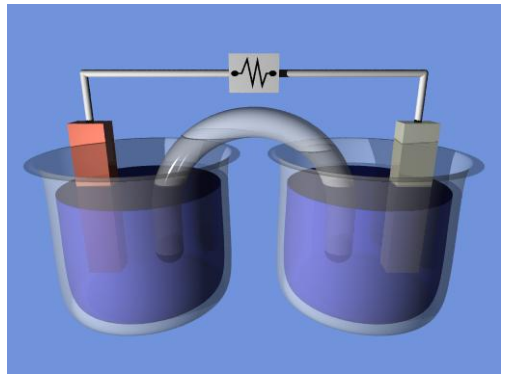
Redox Flow Batteries (RFB) since 1879

By John Doyle – first time flow batteries were patented

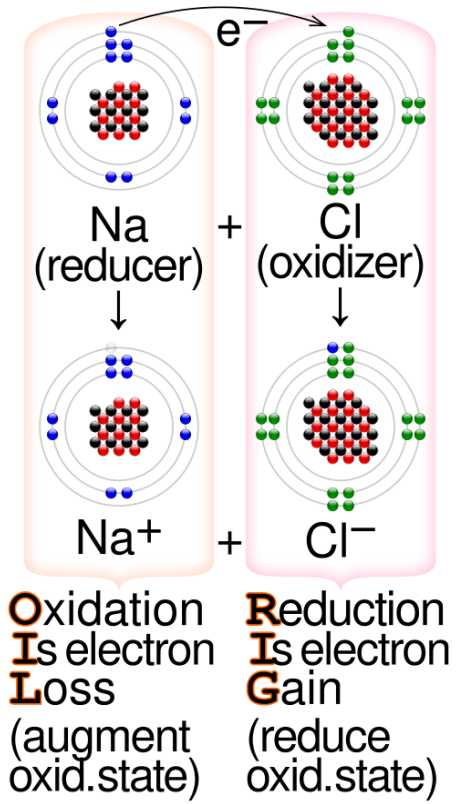
Redox: Reduction – Oxidation → Chemical reaction where one atom loses (oxidation) one electron while another atom gain it (reduction). This electron movement can create different oxidation states in an element.

Flow: These batteries work with two chemical components dissolved in liquid that are pumped on separate sides of a membrane. Ion transfer is permitted inside the cells where both electrolytes meet (but not touch).

Batteries: As they can store energy in the difference of potential between the two states of electrolytes



Simplification of two tanks connected with an ion exchanger path



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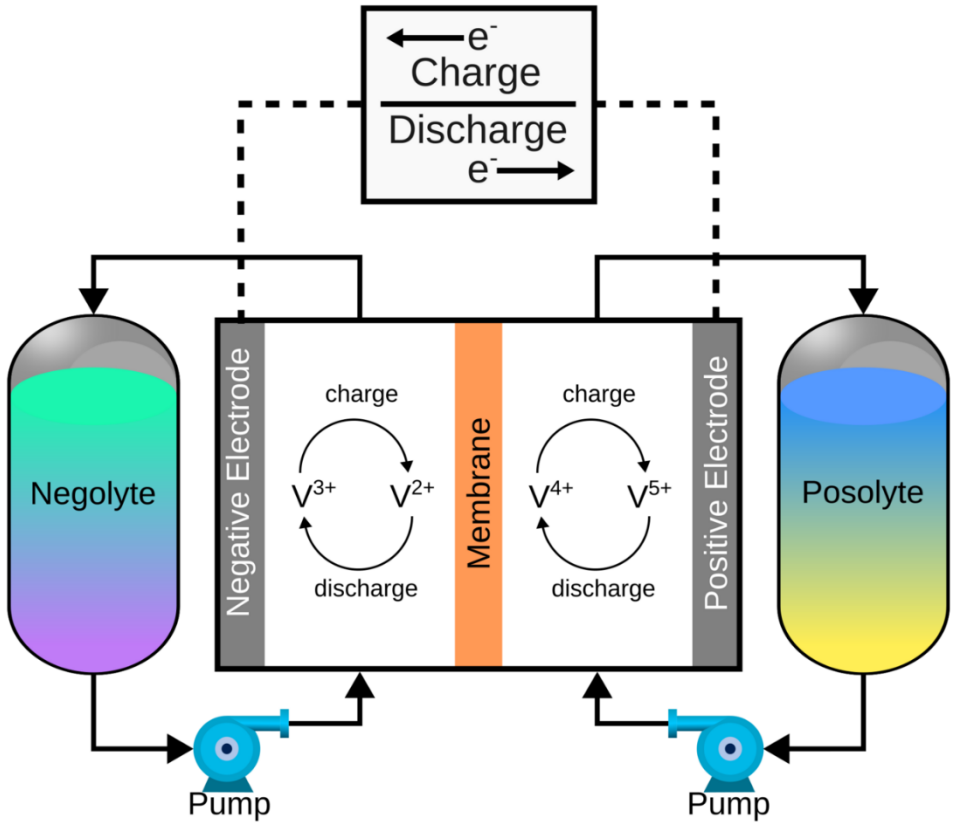
Redox Flow Battery types and comparison

Type of RFB	Typical Energy Density (Wh/L)	Levelized Cost of Storage (LCOS) ($/MWh discharged)	Round-trip Efficiency (%)
Vanadium Redox Flow (VRFB)	20–35	150–300	70–85
Iron–Chromium (Fe/Cr)	10–25	100–250	65–75
Iron–Iron (all-iron flow)	20–40	80–200	65–80
Zinc–Bromine (Zn-Br)	60–85	120–250	65–75
Polysulfide–Bromine (PSB)	15–30	100–220	65–80
Organic redox flow	10–50 (highly variable)	80–250 (projected)	60–80
Hydrogen–Bromine (H_2/Br_2)	10–20	150–400	70–90

Most common Flow battery type in the market

Most promising technology in terms of LCOS

Subsystem in RFB and cost distribution



Subsystem of RFB installation (Vanadium)	Cost Share (%)
Electrolyte	>40%
Battery Stack	≈25–35%
— Membrane (Nafion or equivalent)	≈8–12%
— Electrodes (graphite felt)	≈5–8%
— Bipolar plates / flow frames	≈6–10%
— Current collectors, gaskets, hardware	≈3–5%
Balance of Plant	≈25–35%
— Power electronics (PCS, inverter, controls)	≈10–15%
— Sensors, piping, valves, auxiliaries	≈5–10%
— System integration & housing	≈5–10%

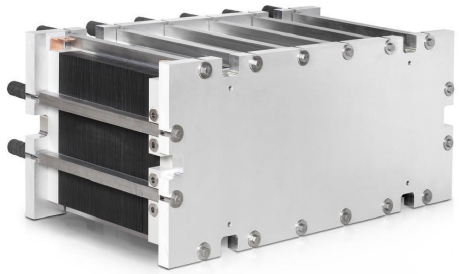
Stack – the power core

- Battery stacks are built out of several electrochemical cells built in series. Each cell can have voltages between 1 and 1.65 V when working with vanadium electrolyte.

- The most standard cell layout is 40-50 cells in series with current capabilities between 100 and 300 Amps

- More stacks in series or higher current reduce the efficiency.

Reaching MW power installations



Most common power level per stack range from 5 to 15 kW.

Many stacks & strings of stacks are required

Serialization of stacks
- Reduction of efficiency
- Reduction of availability
- Low cost

Stacks at low voltage
- Increased efficiency
- Increased availability
- Higher cost as + current

Multi MW inverter

750-950 Vdc for 400 Vac
1000 – 1500 Vdc for 690 Vac

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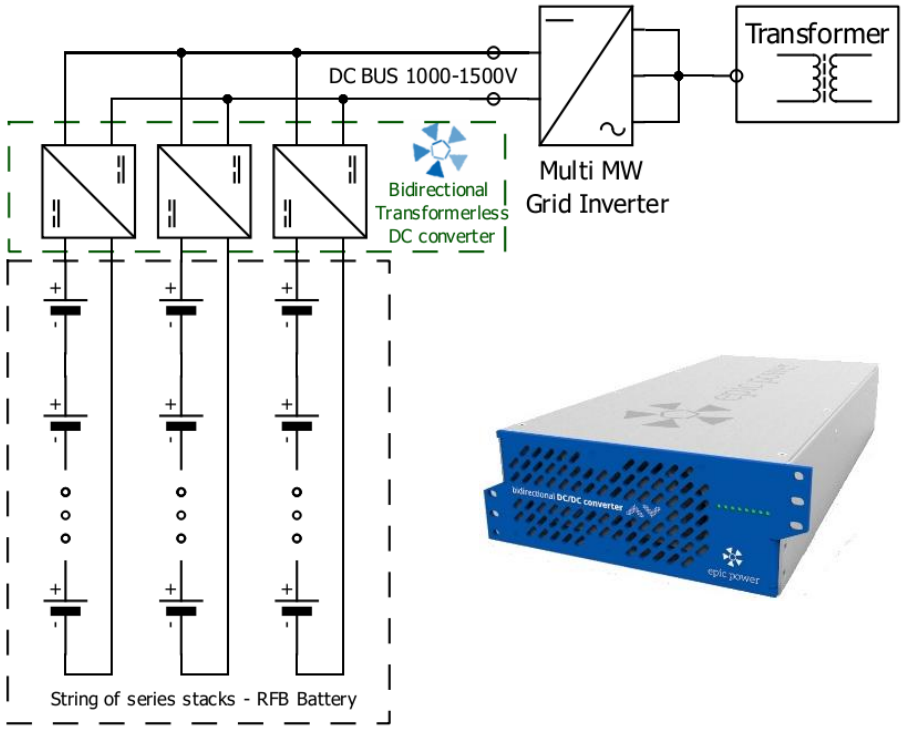
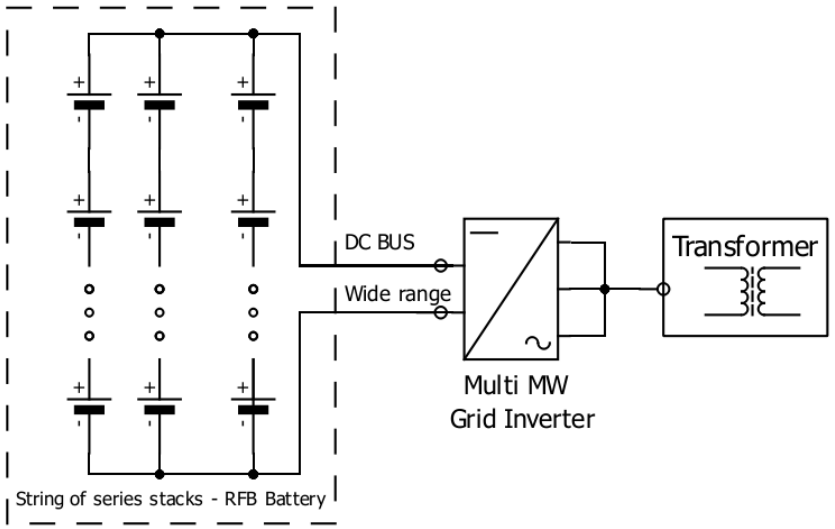
For MW level installations

Serialization of stacks
- Efficiency compromised
- Reduction of availability
- Lower cost – direct connection

Option 1 – String separation + optimization



Option 2 – String parallelization



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For MW level installations

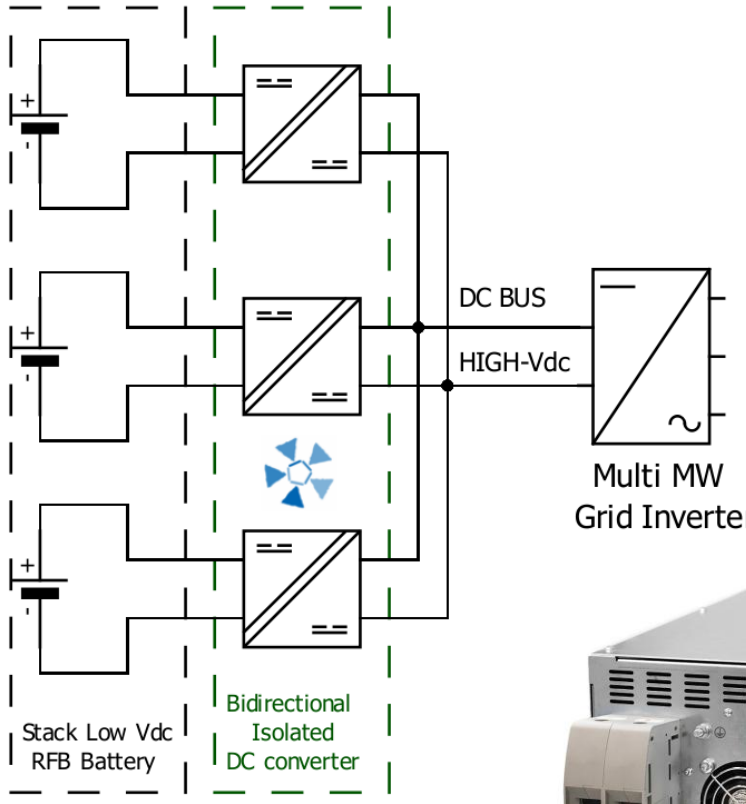
Stacks at low voltage

- Increased efficiency
- Increased availability
- Higher cost as + current required

Isolated converters working with low voltage RFB stacks ensure:

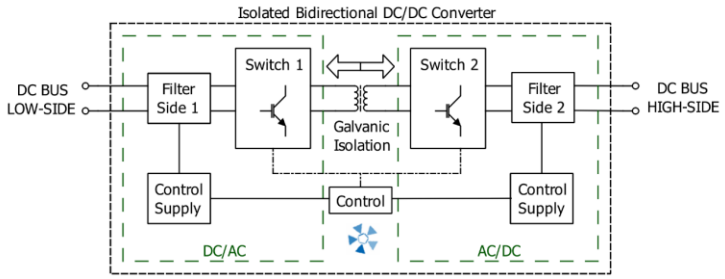
- Higher efficiencies per stack
- Galvanic separation between stacks
- String failure proof system

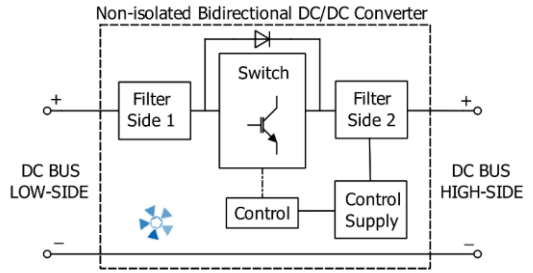
Option 3 – Isolated DC converter with LV stack



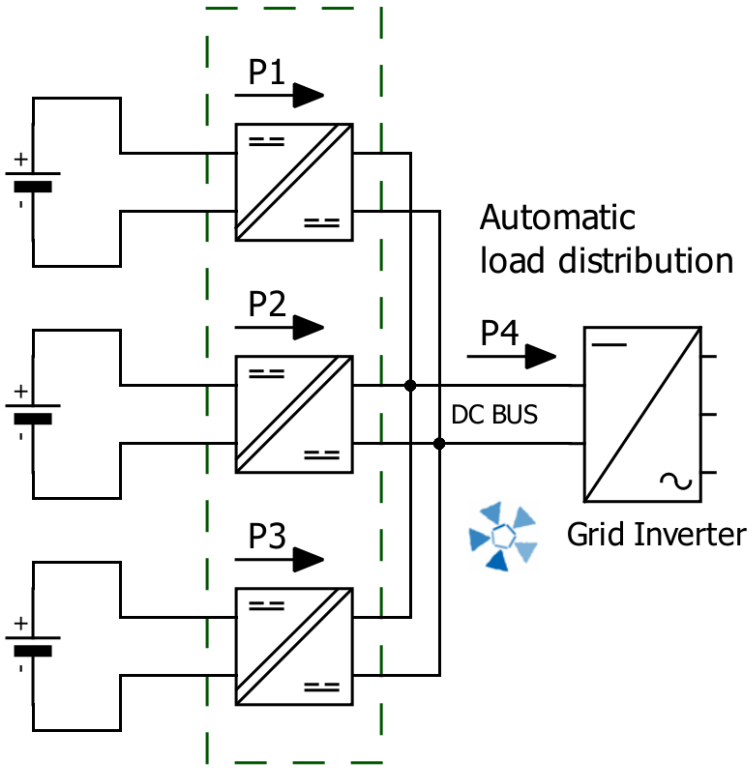
Isolated vs transformer-less DC/DC converters

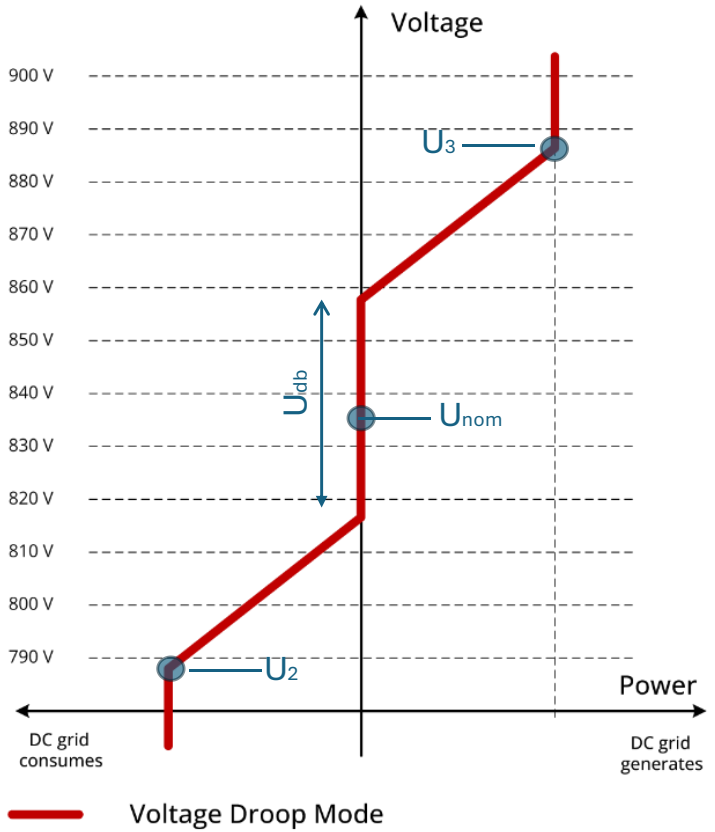
	Isolated converter	Transformer-less converter
Voltage of battery (ideally)	< 400 V	> 400 V
System resilience to Ground faults	High	Low
Efficiency of converter	Up to 98.5 %	Up to 99.5 %
Efficiency of stacks	Higher (low voltage)	Lower (more losses)
€/kW	Higher	Lower



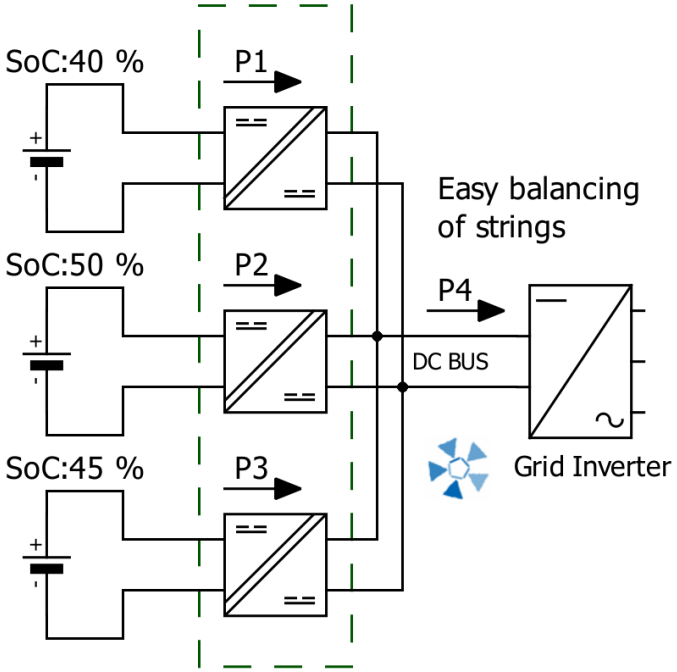


Automatic load distribution in DC – Voltage droop

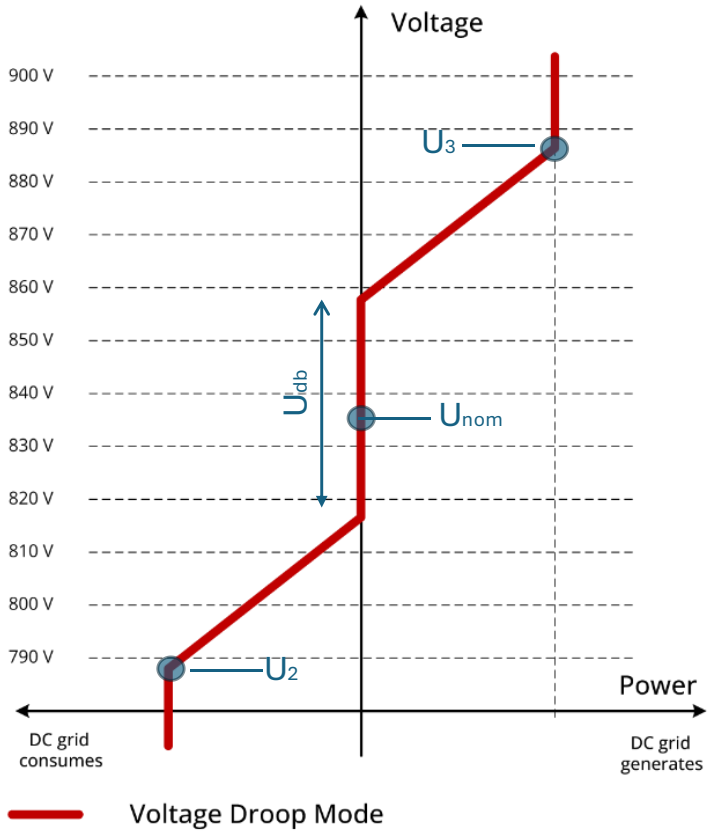


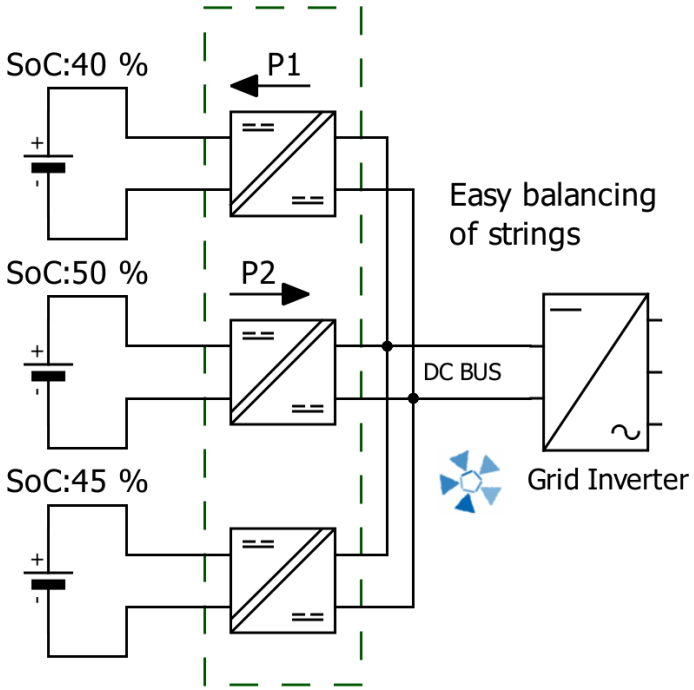


Automatic SoC balancing in DC – Voltage droop



U_2 – U_3 slightly modified





U_{nom} slightly modified

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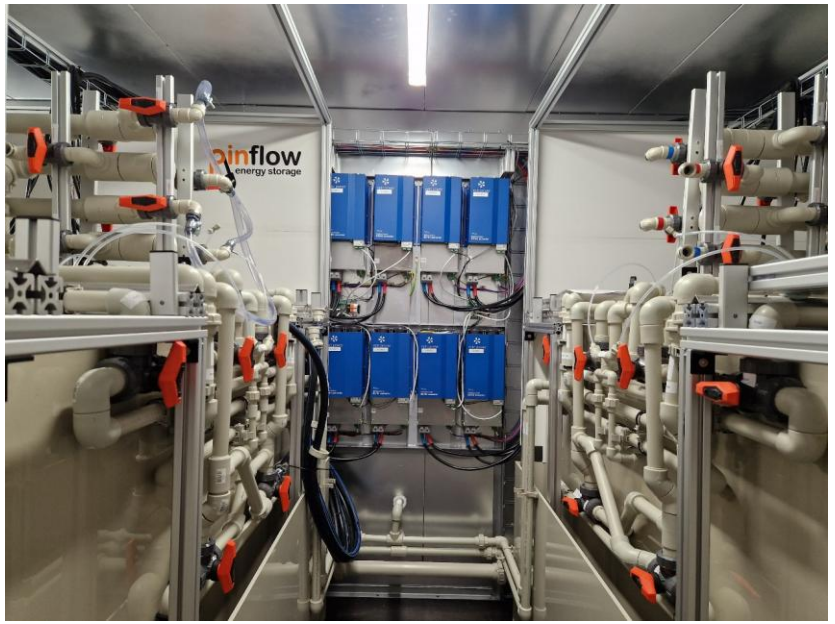
Example of installations

CSIC – Spain
50 kW – 100 kWh



Pinflow – Czech Republic
100 kW – 250 kWh

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Raúl Ramón
rramon@epicpower.es

elincom

Danny Langbroek
d.langbroek@elincom.nl

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