

Redox Flow Battery

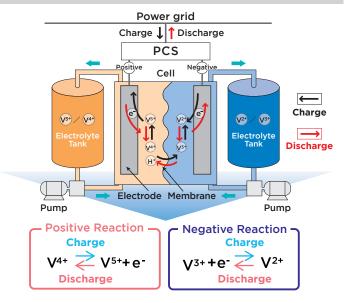
Long Duration Energy Storage (LDES)



Technology Fundamentals and Key Features

Principle

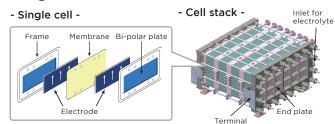
Redox: Reduction/Oxidation of active materials Flow: Flowing active materials with pumps from tanks



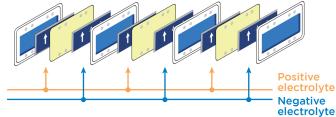
- The reactions are associated with only the changes in valences of the vanadium ions.
- Because the valence changes do not deteriorate the electrolyte, electrolyte can be used semi-permanently.

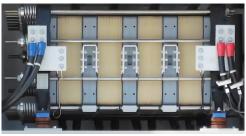
Configuration

Single cell & Cell stack



Cell stacking





Actual cell stack in battery container

Features

Long Lifetime

- >20-year design life
- Unlimited charging / discharging cycle
- Significantly low degradation of capacity
- Reusable electrolyte after decommissioning

Easy Operation / Operability

- Available Depth of Discharge (DoD): 0 100%
- Available State of Charge (SoC): 0 100%
- No unbalanced capacity across the cell stacks
- Accurate & real-time SoC monitoring

Fire Safety / Tough Environmental Conditions

- No thermal runaway
- Non-flammable electrolyte
- Designed for extremely hot, dusty and cold environmental conditions







Type of Redox Flow Battery(RFB)

Type of Redox Flow Battery

Low Life-Cycle Cost

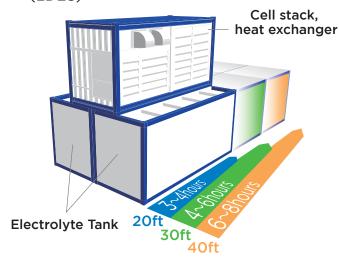
- Low CAPEX per kWh: Lower unit cost (\$/kWh) for longer duration systems
- Low OPEX: No need for replacement of cell stacks or electrolyte
- Significant salvage value: Reusable electrolyte of long duration systems

Footprint Reduction

Minimized installation with the two-storey model: the top is battery container and the bottom two are electrolyte tank containers.

Design Flexibility

- Separation of power (MW) and energy (MWh)
- Easy to build long duration energy storage (LDES)



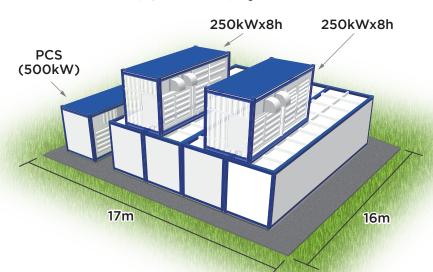


Type (hours)	Output	Capacity	Size (LxWxH)
20ft (3~4h)	250kW	750kWh ~1,000kWh	6.1mx4.9mx6m
30ft (4~6h)	250kW	1,000kWh ~1,500kWh	9.1mx4.9mx6m
40ft (6~8h)	250kW	1,500kWh ~2,000kWh	12.2mx4.9mx6m

Capacity (duration) is expandable for more than 8h.

Example of Layout

Example of layout for 500kWx8h (4,000kWh) system



Sample footprint

Output	Capacity	LxW
1MW	4MWh	15m×17m
1MW	6MWh	21m×17m
1MW	8MWh	27m×17m
10MW	40MWh	85m×27m
10MW	60MWh	103m×27m
10MW	80MWh	131m×27m

Grid-scale Project for Utility in Japan

Hokkaido Electric Power Network Project

- Customer: Hokkaido Electric Power Network, Inc.
- Location: Minami-Hayakita Substation (Hokkaido Electric Power Network)
- Power and Energy: 17MWx3h (51MWh)
- Application: Enhancing grid control for new 162MW wind turbines (e.g. Frequency regulation, Renewable generation smoothing)
- Commencement of Operation: Apr. 2022
- Operation term: 21 years







Large Scale Flow Battery Demonstration for Grid Control with Hokkaido Electric Power Network

- Customer: Hokkaido Electric Power Network, Inc.
- Location: Minami-Hayakita Substation (Hokkaido Electric Power Network)
- Power and Energy: 15MWx4h (60MWh)
- Objective: Urgent demonstration project of a large scale power storage system, subsidized by METI (Ministry of Economy, Trade and Industry).
- Application: Frequency regulation, Renewable generation smoothing
- Term: 2013 to 2018 (Demonstration term)
- Commencement of Operation: Dec. 2015 (Commercially operational since 2019)





Floor 1: Tank, Pump and PCS

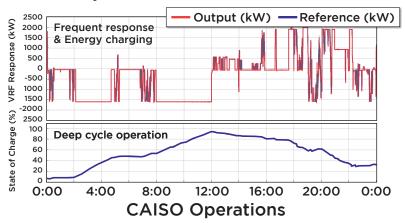


Floor 2: Cell stack and heat exchanger

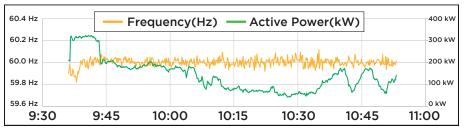
Grid-scale Project for Utility in US

Flow Battery Pilot Project for Grid Applications in California (NEDO project)

- Customer: Utility in California
- Location: San Diego, California, US
- Power and Energy: 2MWx4h (8MWh)
- Application: Multiple uses of electricity market (CAISO) operation, Microgrid,
 - Peak shaving, Renewable firming
- Term: 2015 to 2021 (Demonstration term)
- Commencement of Operation: Mar. 2017 (Commercially operational since 2022)
- First installation of grid-scale Flow Battery in the US with UL certified Cell Stack (UL1973) in 2017
- First Flow Battery have been operated in the California Independent System Operator (CAISO) markets in 2018
- Market participation in both Energy and Ancillary Services (AS)
- Operation with features of 0-100% Usable SoC, Unlimited Cycle Life



First Flow Battery engaged in a microgrid operation on actual power distribution line independent of external grids in 2021



Microgrid Operation

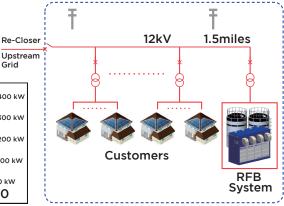






Microgrid Area

Grid



Project in Africa & Europe

UNIDO Morocco Project

Customer: UNIDO / MASEN

Location: Ouarzazate, Morocco

Power and Energy: 125kWx4h

(500kWh)

Application: Microgrid demonstration,

Renewable generation

smoothing

Commencement of Operation:

Jul. 2019

Designed for extreme hot and dusty

environmental conditions





John Cockerill Project

Customer: John Cockerill

Location: Seraing, Belgium

Power and Energy: 500kWx3.4h (1,700kWh)

Application: Microgrid,

Peak shaving,

Peak cut operation, Demand response

Commencement of Operation:

Oct. 2018





Project in Asia

Taiwan Power Research Institute Project

Customer: Taiwan Power

Research Institute

Location: Taipei, Taiwan

Power and Energy: 125kWx6h

(750kWh)

Application: Microgrid demonstration

Commencement of Operation:

Feb. 2017



Obayashi Corporation Project

Customer: Obayashi Corporation

Location: Tokyo, Japan

Power and Energy: 500kWx6h (3,000kWh)

Application: Peak reduction, Excess renewable power management

Commencement of Operation: Jan. 2015



Yokohama Works Megawatt-class Energy Storage Project

- Yokohama Works,
 Sumitomo Electric Industries, Ltd.
- Location: Yokohama, Japan
- Power and Energy:500kWx5h, 250kWx5h, 250kWx5h(5,000kWh)
- Application: Peak cut operation,Factory energymanagement
- Commencement of Operation: Jun. 2012





