Redox Flow Battery
Smart Energy Innovator
Sumitomo Electric
Grid Applications of Redox Flow Battery (RFB) System

World largest operational flow battery system in Hokkaido, Japan (As of May, 2017)

Cell stacks, Heat exchangers (2nd Floor)

Tanks, Pumps, PCS (1st Floor)

Hokkaido Electric Power Company (HEPCO)

RFB installation site (Minamihayakita S/S)

9 electric power companies across Japan

Project Overview

» System Output and Capacity
15 MW x 4 h (60 MWh)

» Applications
(1) Short term frequency fluctuation controls
   - Free-governor control mode
   - Load frequency control
   - Renewable generation smoothing
(2) Long term frequency fluctuation control
(3) Excess renewable power management

» Start of Operation
December, 2015

» Project Location
Minamihayakita Substation, Hokkaido (Japan)

» Collaborating Partner
Hokkaido Electric Power Co., Inc.

Our battery system is in operation at the 66 kV side of the substation (Primary side: 275 kV).
Grid Applications of Redox Flow Battery (RFB) System

RFB System Integration in Transmission and Distribution Networks in California, USA

» System Output and Capacity
  2 MW x 4 h (8 MWh)

» Applications
  — Frequency control
  — Voltage control
  — Excess renewable power management
  — Ancillary services

» Start of Operation
  March, 2017

» Project Location
  San Diego, California (USA)

» Collaborating Partner
  Utility in California

UL Safety Certification

First company to achieve UL 1973 Flow Battery certification

Cell stacks of our redox flow battery obtained UL1973: the safety standard in USA for large-scale stationary batteries.

Redox Flow Battery System for Wind Farm Output Stabilization in Tomamae, Hokkaido (Japan)

» System Output and Capacity
  4 MW x 1.5 h (6 MWh)

» Application
  — Renewable generation smoothing
  — Stabilization of the system power output

» Project Term
  From 2005 to 2008

» Project Location
  Tomamae, Hokkaido (Japan)
Behind-the-meter Applications of Redox Flow Battery (RFB) System

**Applications for Load Leveling and Emergency Power Supply**

- **System Output and Capacity**
  500 kW×6 h (3 MWh)

- **Applications**
  - (1) Grid-connected Mode
    - Peak reduction
    - Excess renewable power management
  - (2) Island Mode
    - Primary voltage source (Black start)

- **Start of Operation**
  January, 2015

- **Project Location**
  Tokyo, Japan

- **Collaborating Partner**
  Obayashi Corporation

**Microgrid Demonstration System**

- **System Output and Capacity**
  125 kW×6 h (750 kWh)

- **Applications**
  - Renewable generation smoothing
  - Energy cost optimization
  - Demand response
  - Stand-alone operation

- **Start of Operation**
  February, 2017

- **Project Location**
  Taipei, Taiwan

- **Collaborating Partner**
  Taiwan Power Research Institute
Behind-the-meter Applications of Redox Flow Battery (RFB) System

Factory Microgrid with RFB

» System Output and Capacity
  Plant Model: 500 kW×5 h (2,500 kWh)
  Container Model: 500 kW×4 h (2,000 kWh)

» Applications
  - Peak reduction
  - Renewable generation smoothing
  - Stabilization of the system power output

» Start of Operation
  July, 2012

» Project Location
  Yokohama, Japan

» System Configuration

Existing system
Grid (66 kV)
- Consumption
- Generation
  - Factory/Office
  - Gas Co-generation
  - Communication & Control Network

Additionally installed system
- Generation
  - Concentrator Photovoltaic (CPV)
  - Output: 100 kW
- Charge & Discharge
- Redox Flow Battery
- Factory Energy Management System (FEMS)
Principle of Redox Flow Battery (RFB) System - Key Features -

**Concept**

Redox: Reduction & Oxidation reactions
Flow: Electrolyte flows through electrochemical cells

**System Configuration**

Positive flow  Negative flow

- Positive flow
- Negative flow

**Feature 1: Accurate Monitoring of SOC**

- The state of charge (SOC) can be monitored on a real time basis. It is directly measured during operation by electromotive force (voltage) at the monitoring cell.

**Feature 2: Fire Safety**

- Our redox flow battery consists of non-flammable materials and electrolyte.

**Feature 3: Long-life operation**

- No significant deposition of solution through chemical reactions in the Vanadium redox flow battery

**Feature 4: No operational constraint on cycle life**

- No constraint of system operation on depth of discharge (DoD) and number of cycles

- Depth of Discharge: 100%
- Unlimited number of cycles over lifetime

Easy monitoring & management of the available capacity even in a complex operation

Extremely low possibility of fire resulting from the flow battery materials and electrolyte

Long design lifetime of 20 years & Semi-permanent use of electrolyte

Highly capable of long life multiple-cycle operations

Monitor Cell

\[ V = E - iR \]

Positive Electrode: \( V^{4+} \rightarrow V^{3+} + e^- \) Charge

Negative Electrode: \( V^{3+} + e^- \rightarrow V^{2+} \) Discharge

Configuration of a single cell
Product Lineup & Layout

Overview

» Cost Reduction
The containerization of the flow battery reduces the cost of transportation and local commissioning.

» Lifetime & Cycle-basis Economic Values
Benefits stacking from multiple battery services by unlimited number of cycles over its long lifetime

» Flexible Combination of Output & Capacity
Power intensive mode: Up to 200%
Design flexibility: Easy expansion of capacity

» Reduction in Installation Area
The two-storey design and increase in battery output reduce the installation area of our flow battery system.

Product Lineup

<table>
<thead>
<tr>
<th>Basic Specification per Module</th>
<th>Output</th>
<th>Capacity</th>
<th>Dimensions</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 hours model</td>
<td>AC 250 kW</td>
<td>AC 750 kWh</td>
<td>6.1m×4.9m×6m</td>
<td>120 t</td>
</tr>
<tr>
<td>4.5 hours model</td>
<td>AC 250 kW</td>
<td>AC 1,125 kWh</td>
<td>9.1m×4.9m×6m</td>
<td>170 t</td>
</tr>
<tr>
<td>6 hours model</td>
<td>AC 250 kW</td>
<td>AC 1,500 kWh</td>
<td>12.2m×4.9m×6m</td>
<td>220 t</td>
</tr>
</tbody>
</table>

Example of System Layout

Example: 500 kW × 3h (1,500 kWh) Model

<table>
<thead>
<tr>
<th>System Size &amp; Installation Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output</td>
</tr>
<tr>
<td>1MW</td>
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<tr>
<td>1MW</td>
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<tr>
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<tr>
<td>10MW</td>
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