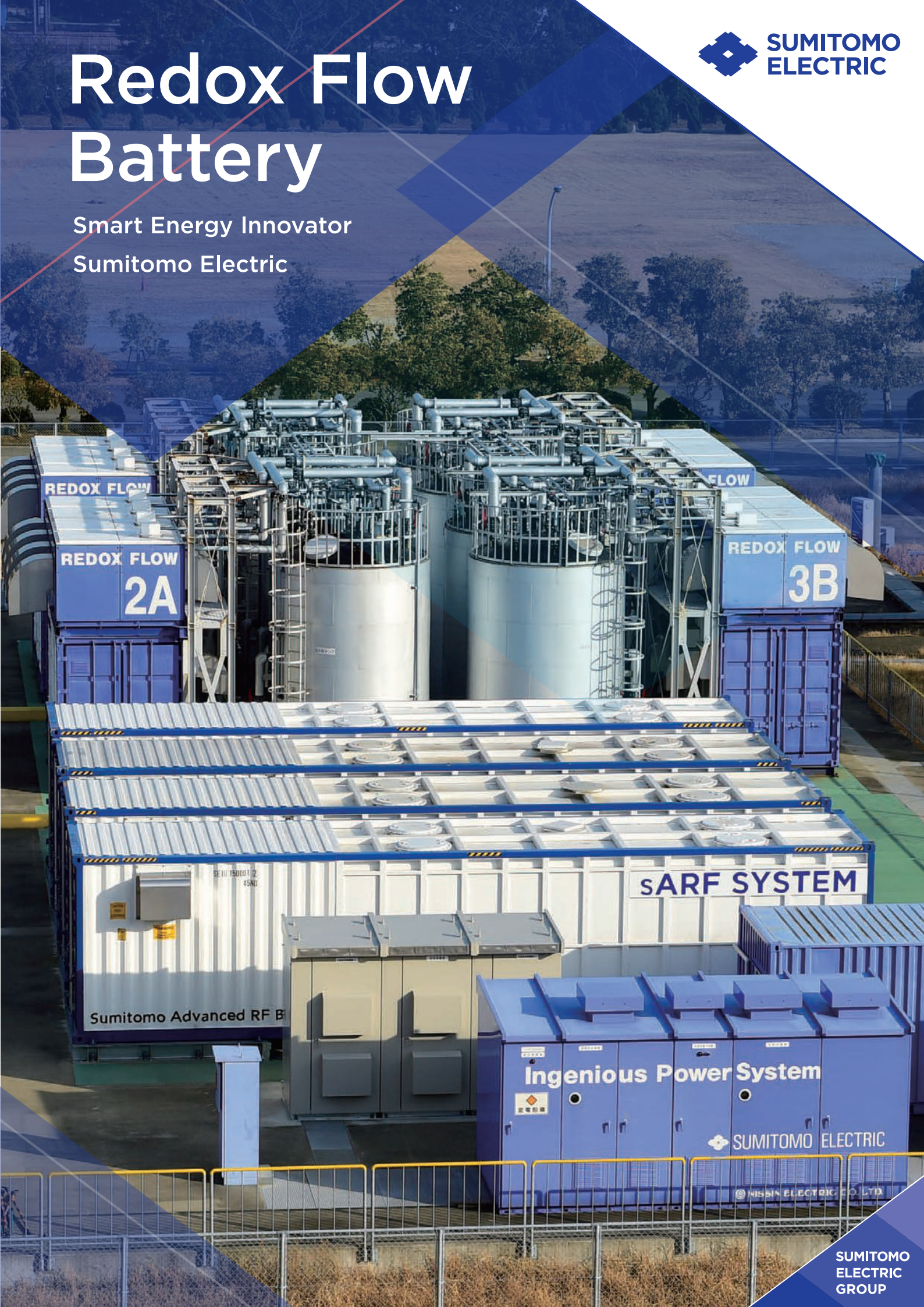
SUMITOMO ELECTRIC

Redox Flow Battery

Smart Energy Innovator

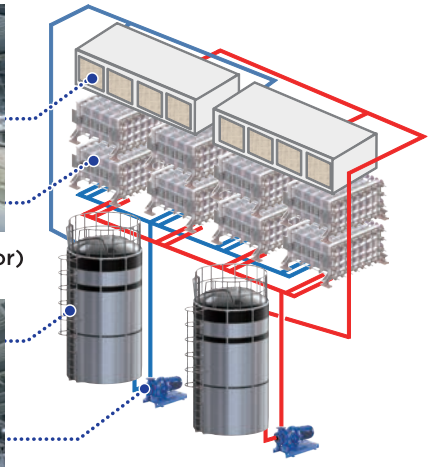
Sumitomo Electric



SUMITOMO ELECTRIC GROUP

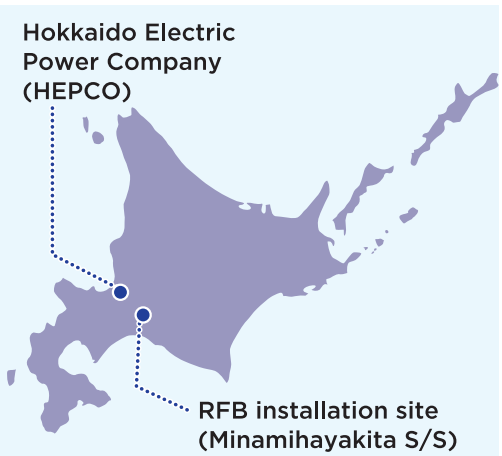
Grid Applications of Redox Flow Battery (RFB) System

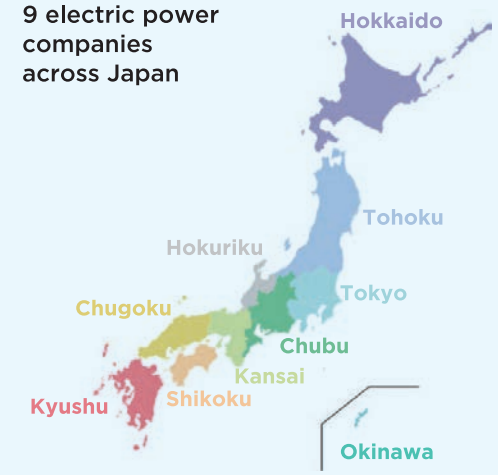
World largest operational flow battery system in Hokkaido, Japan (As of May, 2017)



Cell stacks, Heat exchangers (2nd Floor)

Tanks, Pumps, PCS (1st Floor)





Project Overview

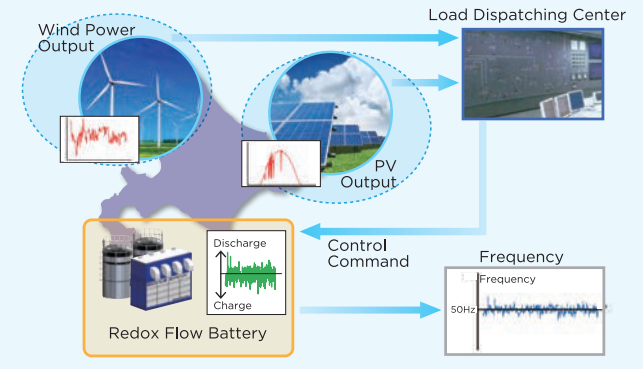
» **System Output and Capacity**
15 MW × 4 h (60 MWh)

» **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 × 4 h (8 MWh)

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

» Start of Operation
March, 2017

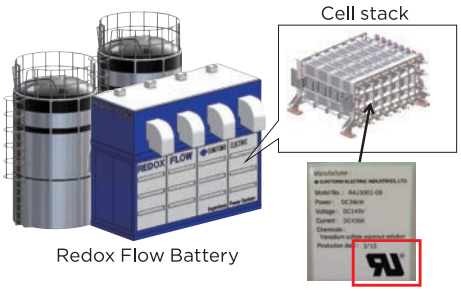
» Project Location
San Diego, California (USA)

» Collaborating Partner
San Diego Gas & Electric Company (SDG&E)

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.



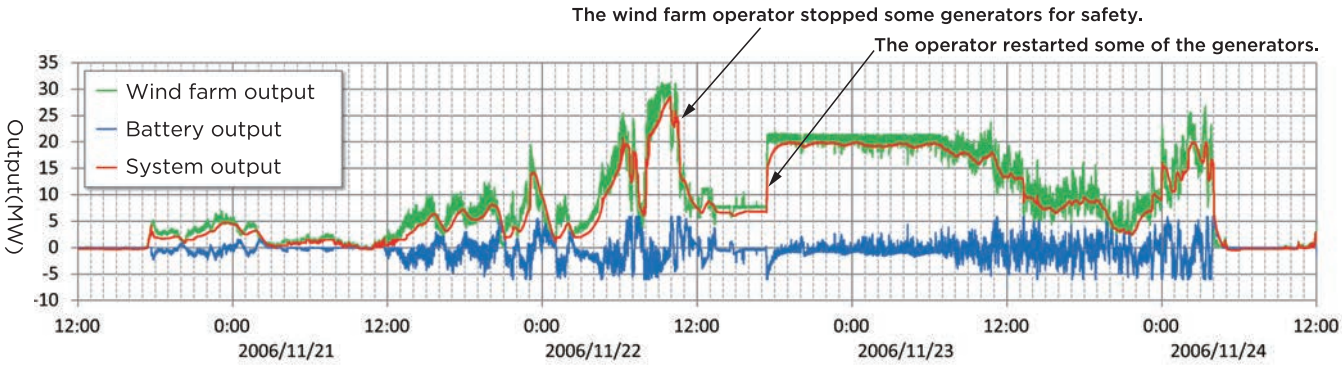
Redox Flow Battery System for Wind Farm Output Stabilization in Tomamae, Hokkaido (Japan)

» System Output and Capacity
4 MW×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)

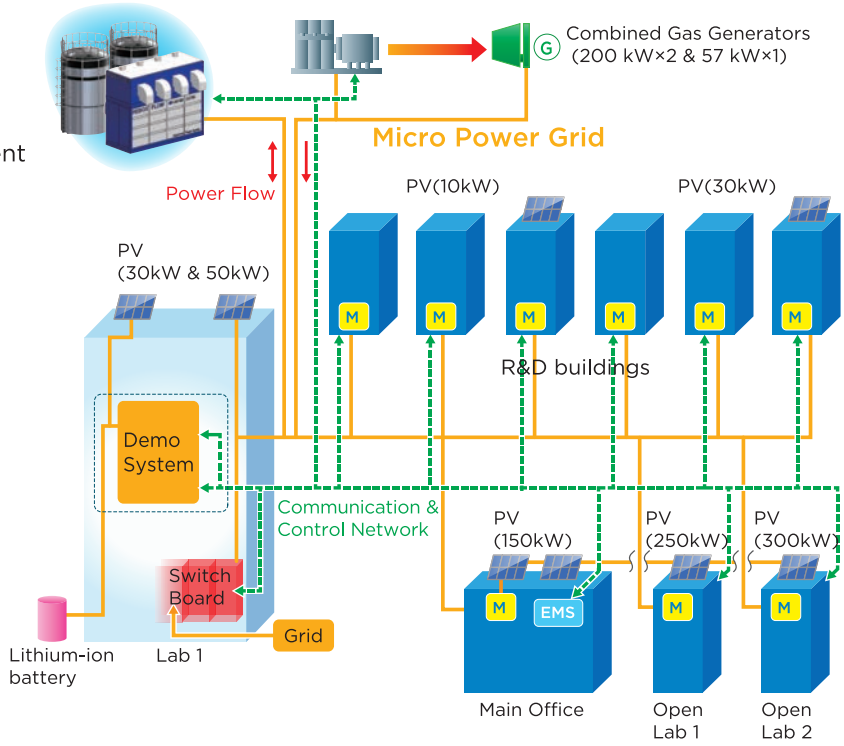
» **Applications**
(1) Grid-connected Mode
— Peak reduction
— Excess renewable power management
(2) Island Mode
— Primary voltage source (Black start)

» **Start of Operation**
January, 2015

» **Project Location**
Tokyo, Japan

» **Collaborating Partner**
Obayashi Corporation

Redox Flow Battery (500 kW×6 h)



Microgrid Demonstration System

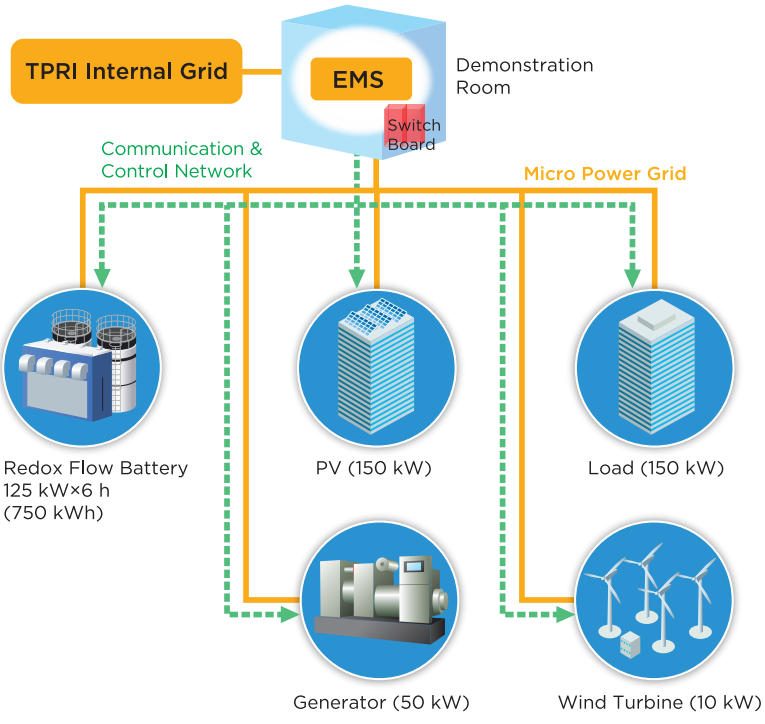
» **System Output and Capacity**
125 kW×6 h (750 kWh)

» **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

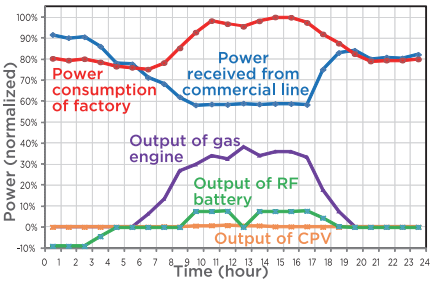
Factory Microgrid with RFB

» System Output and Capacity

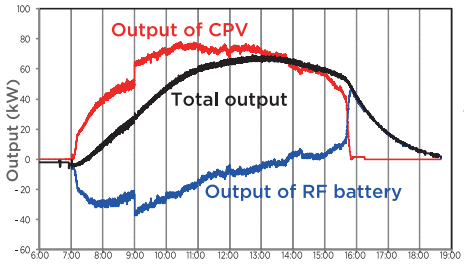
Plant Model: 500 kW×5 h (2,500 kWh)
Container Model: 500 kW×4 h (2,000 kWh)

» Applications

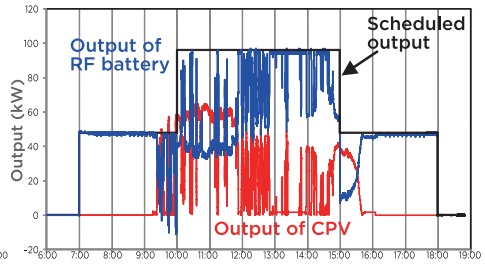
Peak reduction



Renewable generation smoothing



Stabilization of the system power output



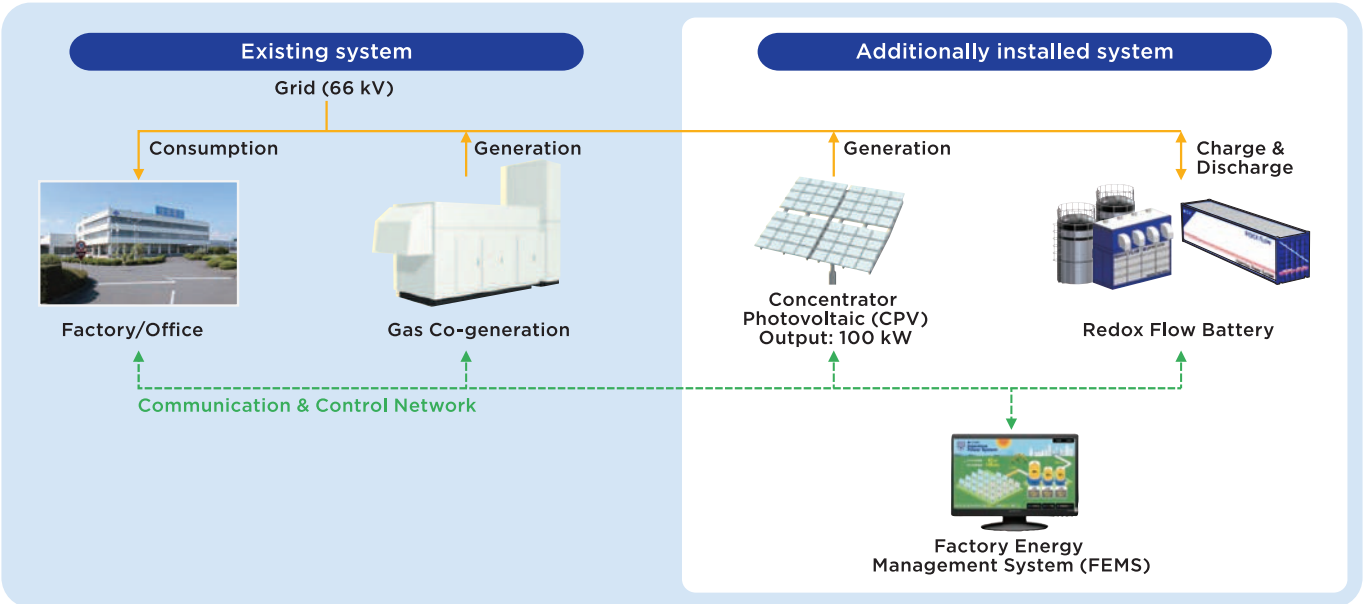
» Start of Operation

July, 2012

» Project Location

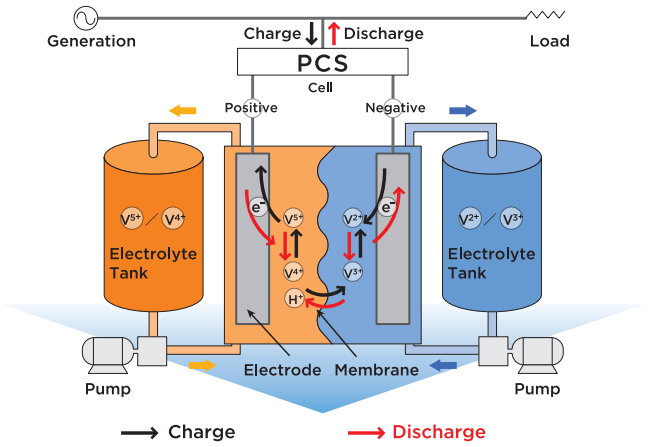
Yokohama, Japan

» System Configuration



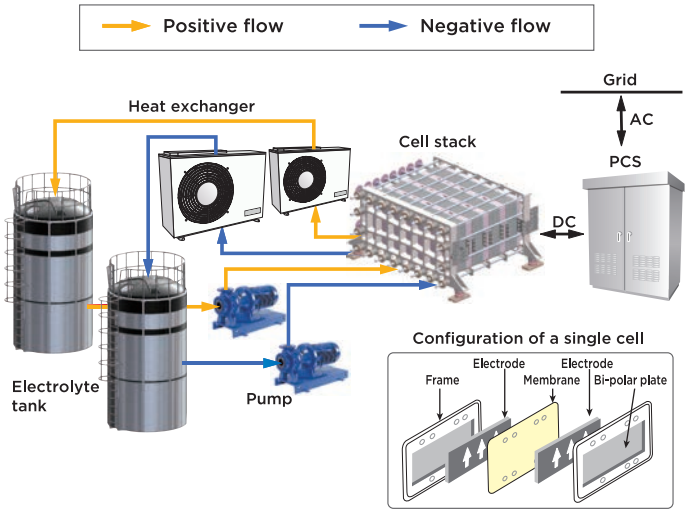
Principle of Redox Flow Battery (RFB) System
- Key Features -

Concept



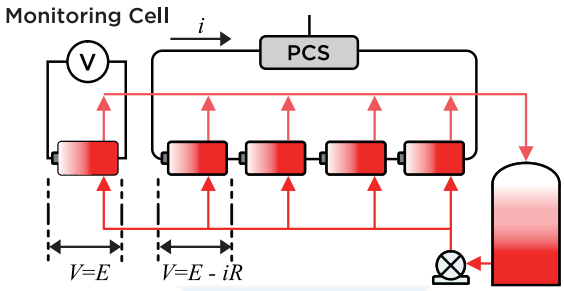
Redox: Reduction & Oxidation reactions
Flow: Electrolyte flows through electrochemical cells

System Configuration



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.



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

Feature 2: Fire Safety

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

» Electrolyte: Vanadium sulphate aqueous solution
- Non-flammable liquid
- The mixing of positive and negative electrolyte does not result in ignition.

» Cell stacks and pipes: Polyvinyl chloride (PVC)
- Non-explosive (Ignition point: 455°C)
- High self-extinguishing capability

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

Feature 3: Long-life operation

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

Positive Electrode
Charge
$V^{4+} \rightleftarrows V^{5+} + e^-$
Discharge

Negative Electrode
Charge
$V^{3+} + e^- \rightleftarrows V^{2+}$
Discharge

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

Feature 4: No operational constraint on cycle life

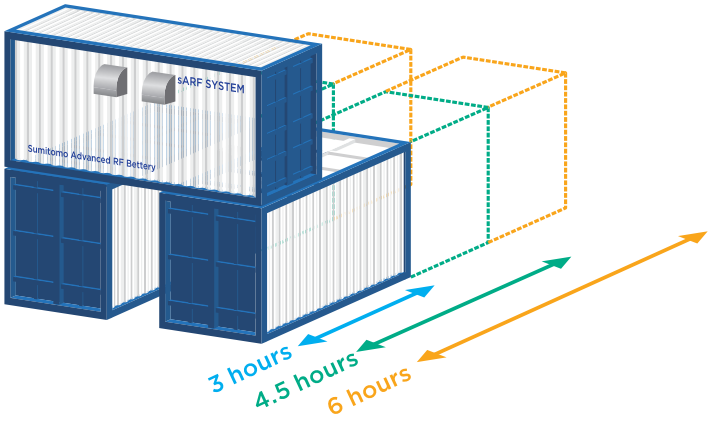
» No constraint of system operation on depth of discharge (DoD) and number of cycles

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

Highly capable of longlife multiple-cycle operations

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

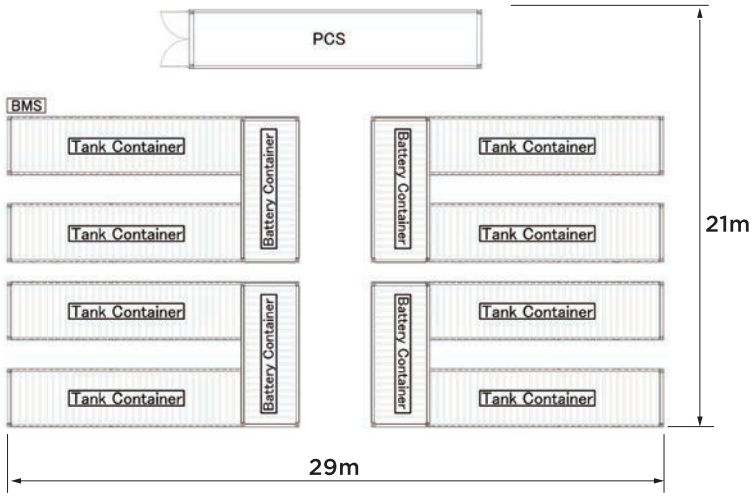
The two-storey design and increase in battery output reduce the installation area of our flow battery system.

Product Lineup

Basic Specification per Module	Output	Capacity	Dimensions	Weight
3 hours model	AC 250 kW	AC 750 kWh	6.1m×6.1m×6m	120 t
4.5 hours model	AC 250 kW	AC 1,125 kWh	9.1m×6.1m×6m	170 t
6 hours model	AC 250 kW	AC 1,500 kWh	12.2m×6.1m×6m	220 t

Example of System Layout

Example: 1 MW × 6h (6 MWh) Model



System Size & Installation Area

Output	Capacity	Installation Area
1MW	3MWh	21m×17m
1MW	4.5MWh	21m×23m
1MW	6MWh	21m×29m
10MW	30MWh	81m×34m
10MW	45MWh	112m×34m
10MW	60MWh	142m×34m

Sumitomo Electric Industries, Ltd.
Contact: Business Development Department, Energy System Division

Tel: +81 3 6406 2648 (Tokyo) +81 6 6466 5590 (Osaka)
Address: 1-1-3, Shimaya, Konohana-ku, Osaka, Japan
URL: http://global-sei.com/

SUMITOMO ELECTRIC