

The early Vanadium Redox Flow Battery development projects and Commercialization

by

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and
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and
LE SYSTEM Inc.

History of V Battery (VRF battery) Development at Kashima-kita Electric Power Corporation

National Project

1993: Selected as NEDO New Sunshine Project
1997: Project successfully completed

1989 Information on VRFB obtained from ETL of MITI
1990 Technical Consultancy Agreement with ETL
1992 Basic patent obtained from UNSW
1993-1998 Collaboration research with Prof. Maria, S. Kazacos of UNSW

Electrolyte manufacturing method

1990: Research start
1994: Large-scale experimental equipment constructed
1996: 3m³/day equipment constructed

Battery device development

1992: 500W device developed
1993: 10kW device manufactured
1997: 1000 cycles of continuous operation
200kW battery completed

Considers commercialization:

1993-1999: Mitsubishi Group
1999-2000: Mitsui & Co.
2001-2002: Hitachi Group

2002: Technology transferred to Sumitomo Electric Industries
Four people were seconded to SEI until 2004 to conduct business development studies

V Battery Video



Targets and operating results of 200kW battery

Items	Targets	Results
Output power	200kW-4Hr	Achievement
Current Density	80mA/cm ²	80mA/cm ²
Current Efficiency	95%	93%
Power Efficiency	80%	80%
Voltage Efficiency	84%	86%
Number of charges/discharges	1500 cycle	650 cycle
Mode of operation	unmanned, continuous operation	Achievement



Early commercialization and field trials at Sumitomo Electric Industries (SEI)

Sumitomo Electric Industries's RF Battery Development Program

Year	85 - 90	91	92	93	94	95	96	97	98	99	00	01
Cell Stack	10kW											
Module	Fe-Cr		60kW									
Scale up				V-V		450kW						
Field Test						Advanced Design		20kW ~ MW				
Sales												Start

Supply Records of Sumitomo Electric Industries

Place	Applications	Specifications	Delivery
Office building	Load leveling (Demonstration)	100kW x 8h	2000/02
Wind power station	Stabilization of wind turbine output (Field test)	170kW x 6h	2000/12
Semi-conductor factory	1) Voltage sag protection 2) Load leveling	1) 3000kW x 1.5sec. 2) 1500kW x 1h	2001/02
Golf course	Load leveling (Photovoltaic hybrid system)	30kW x 8h	2001/04
South Africa	Load leveling (Field Test)	250kW x 2h	2001/05
University	Load leveling	500kW x 10h	2001/07
Italy	Load leveling (Field Test)	42kW x 2h	2001/12

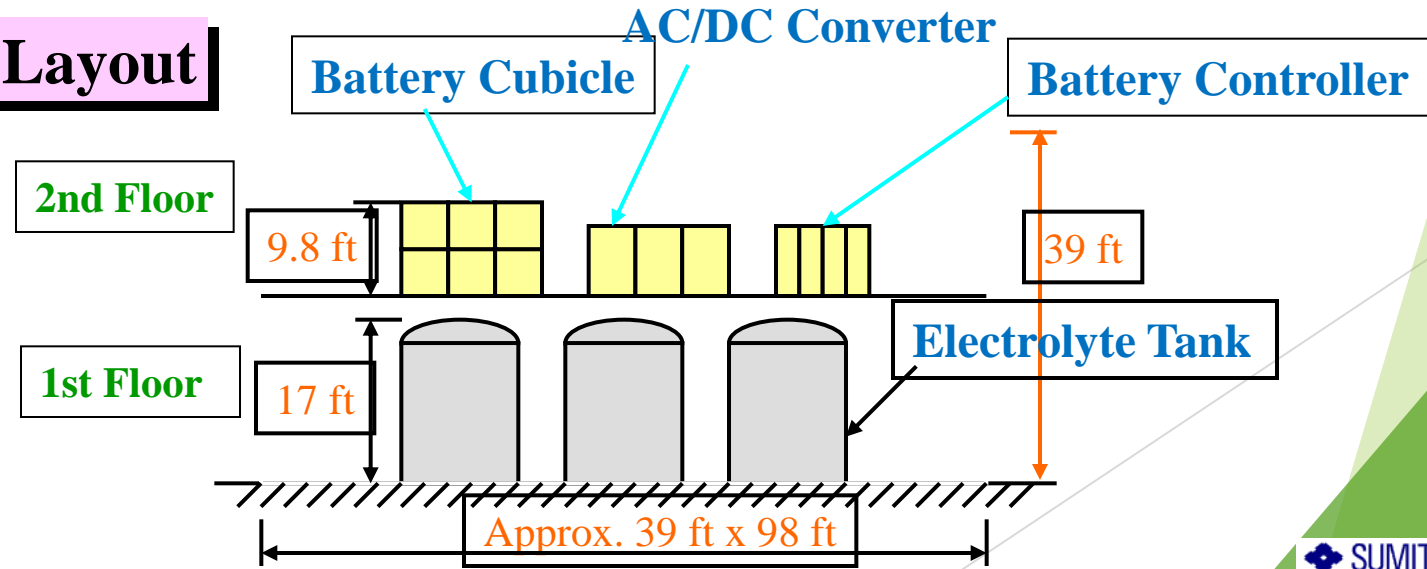
Application to Semi-Conductor Factory

2001)

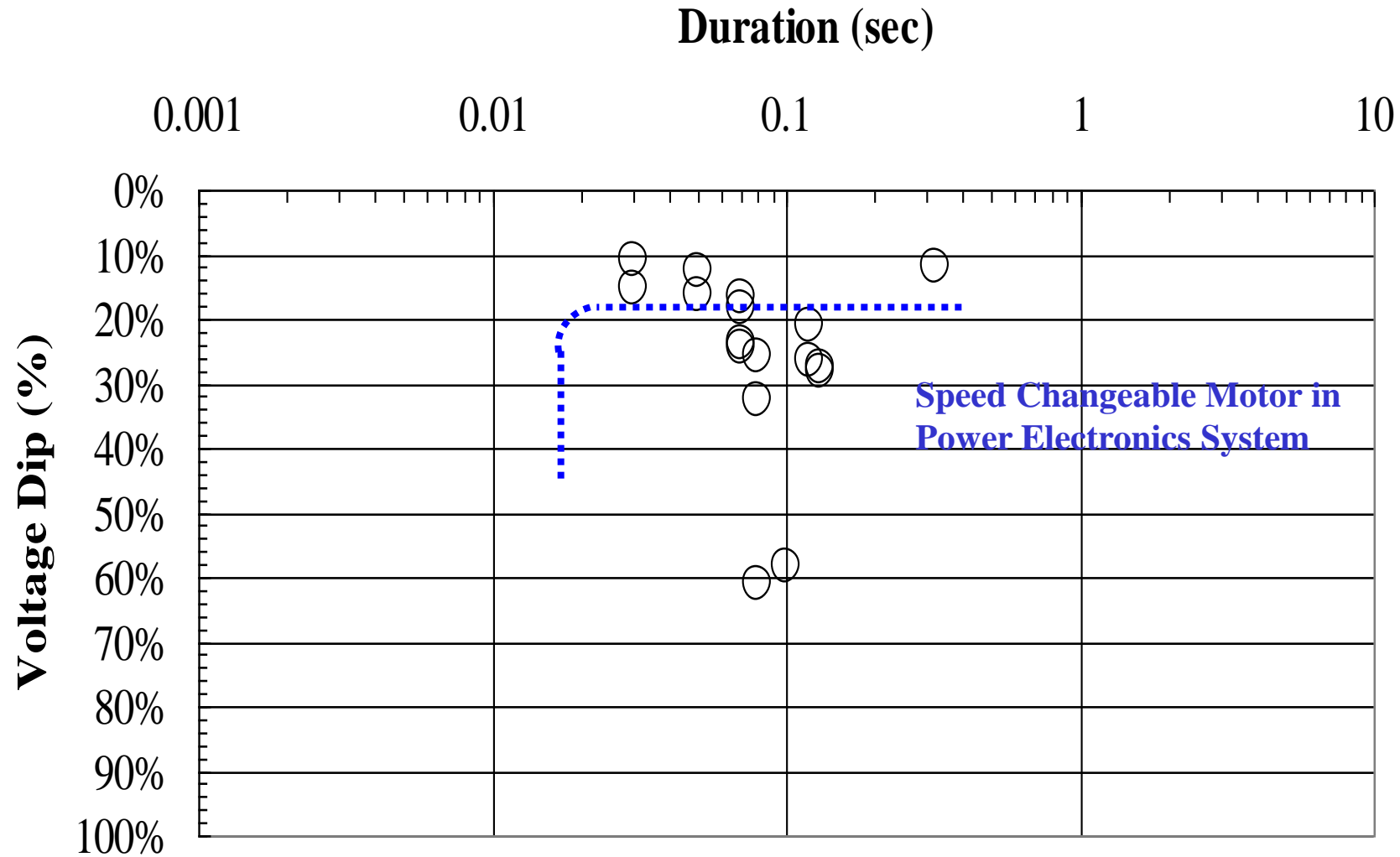
Specifications

Function	Purpose	Output	
(1) Voltage Sag Protection	Protection of Important Load	3MW x 1.5sec	
(2) Load leveling	Reduction of Electricity Charge	1.5MW x 1hour	Everyday

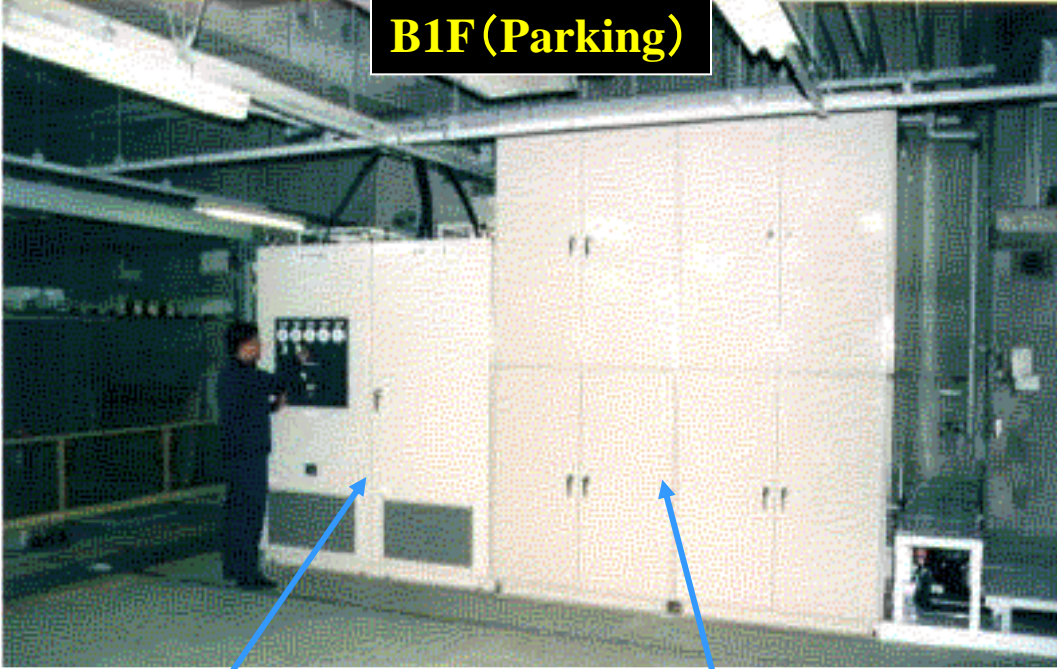
System Layout



Records of voltage-sag compensated by VRB system



Application of RF Battery to Office Building



B1F (Parking)

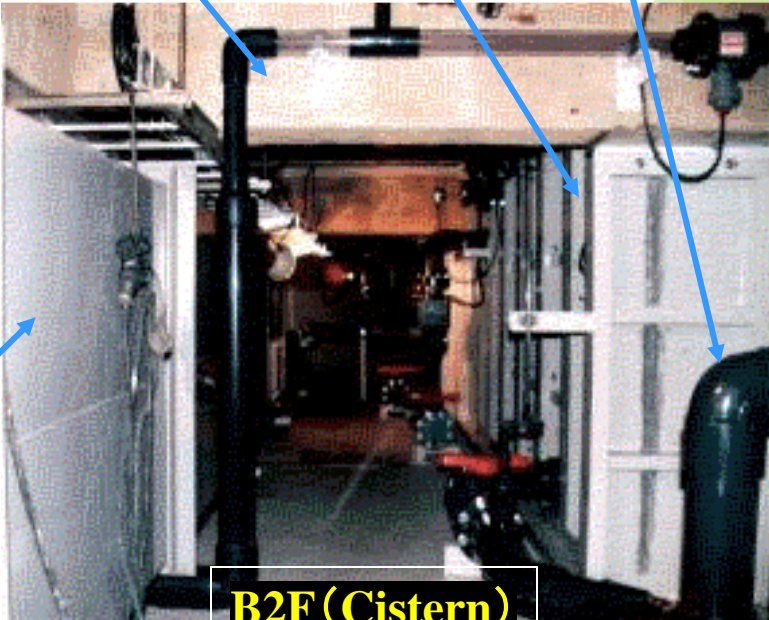
AC/DC Converter

Battery Cubicle

Capacity	100kW-8h
Place	SEM,Osaka
Start of operation	February 2000

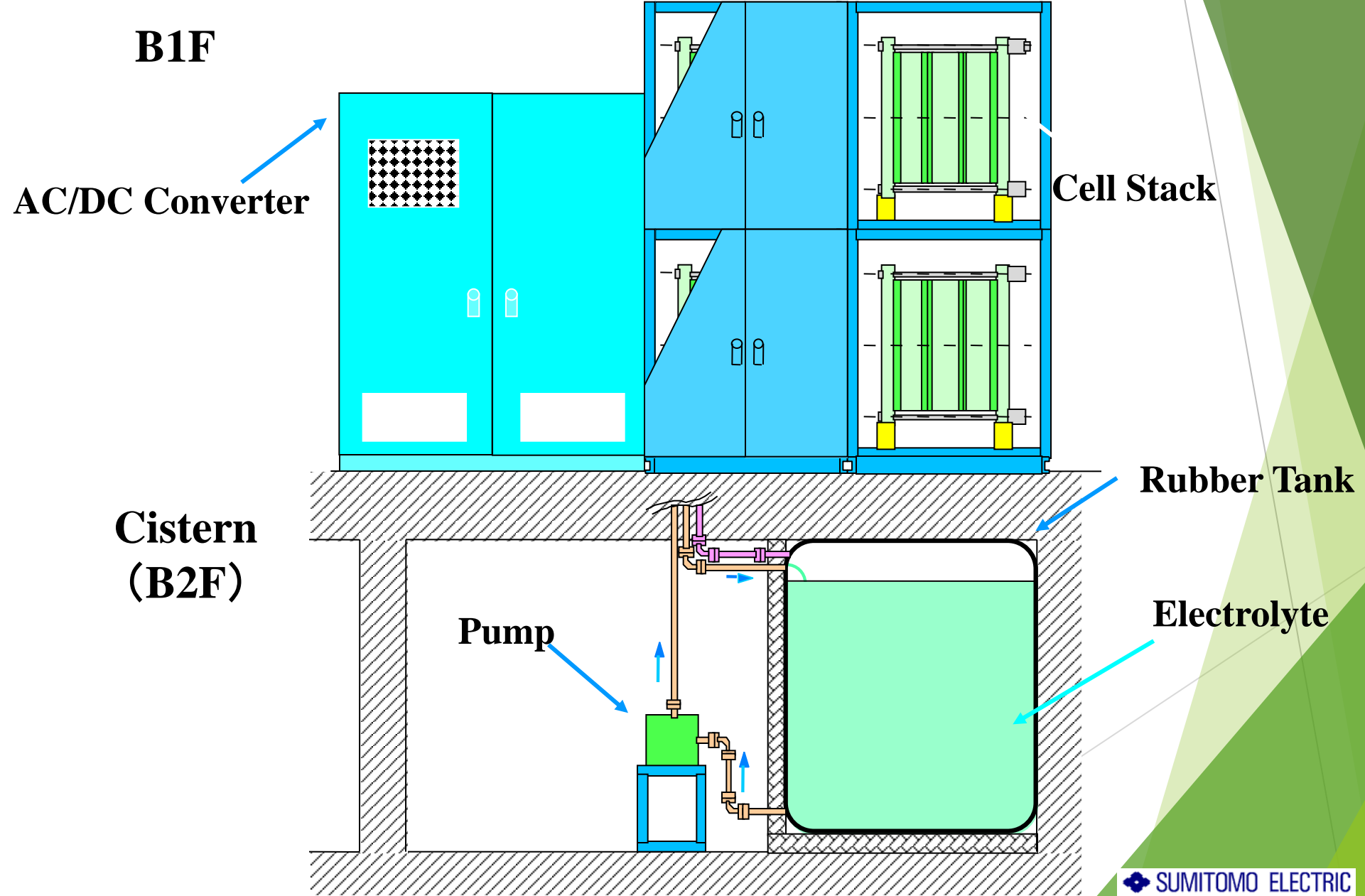


Beam Rubber Tank Pipe for Electrolyte

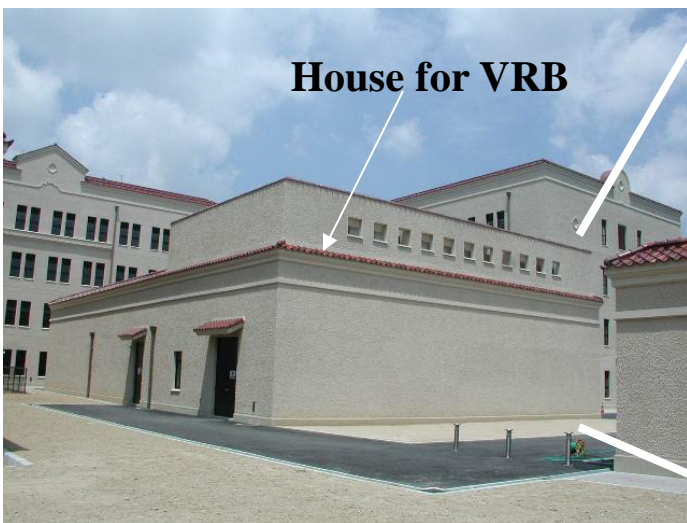


Air conditioning duct

B2F (Cistern)



Application to University

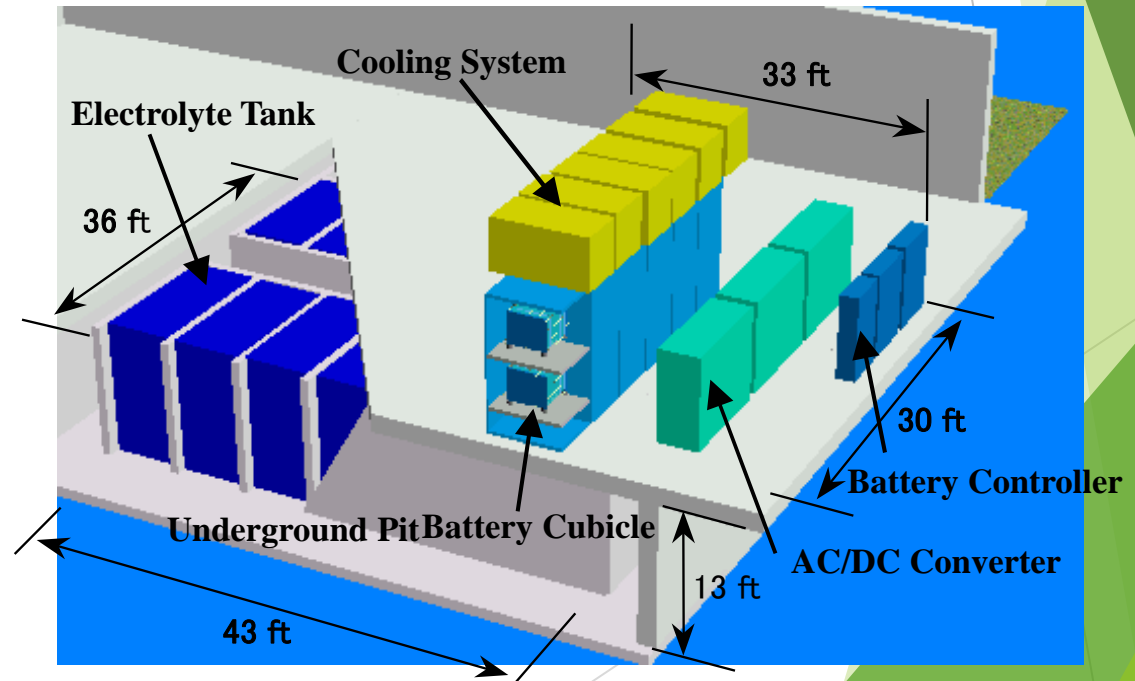


<Specifications>

Load leveling 500kW × 10h

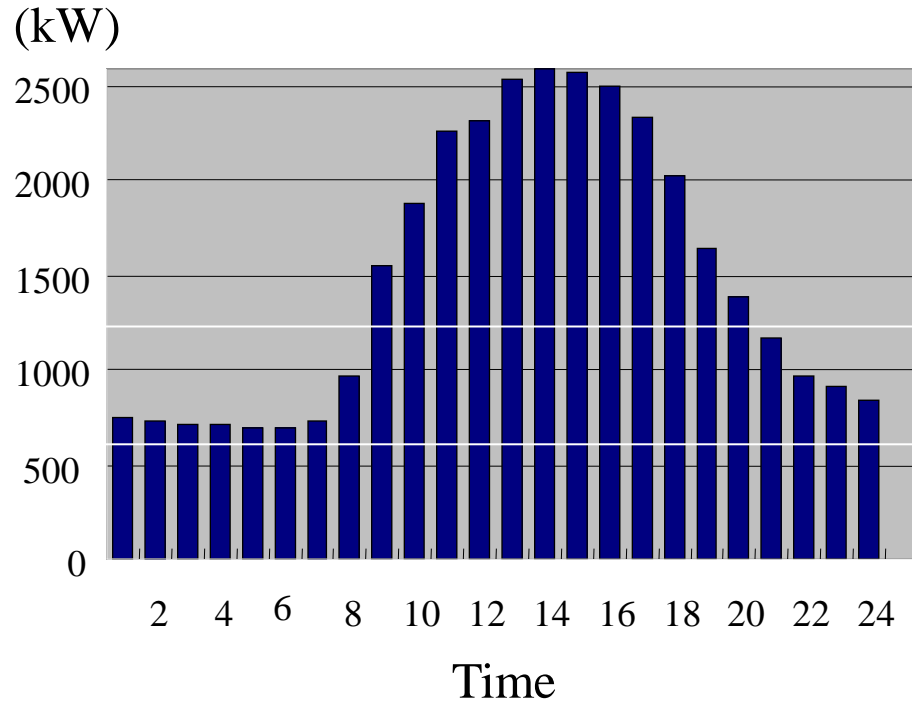
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Operation → July 2001

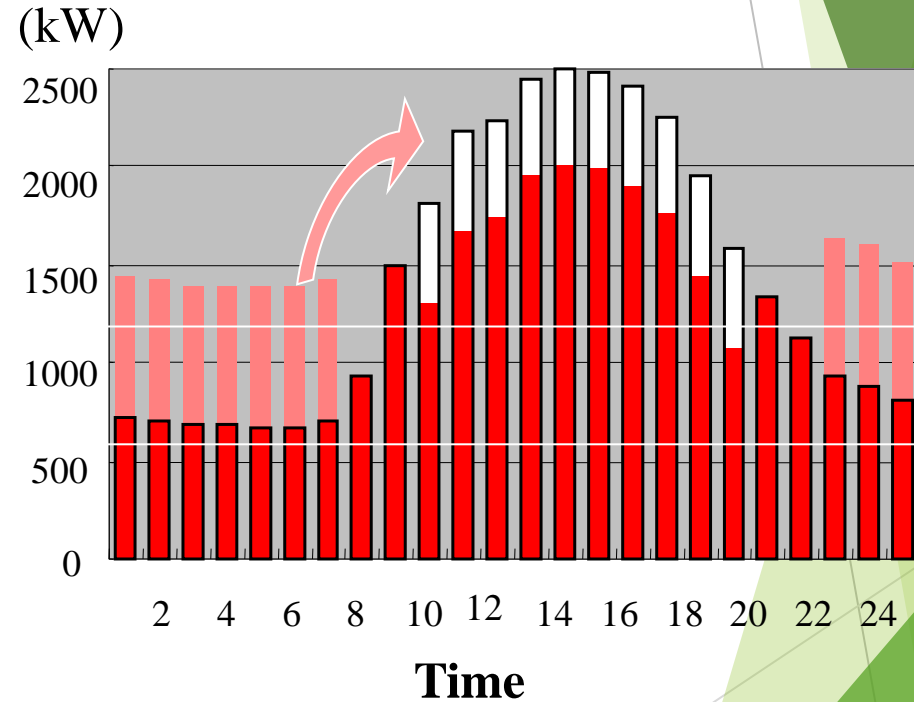


500kW-10Hrs VRB System

Before load-leveling by VRB



After load-leveling by VRB



Charging

Discharging

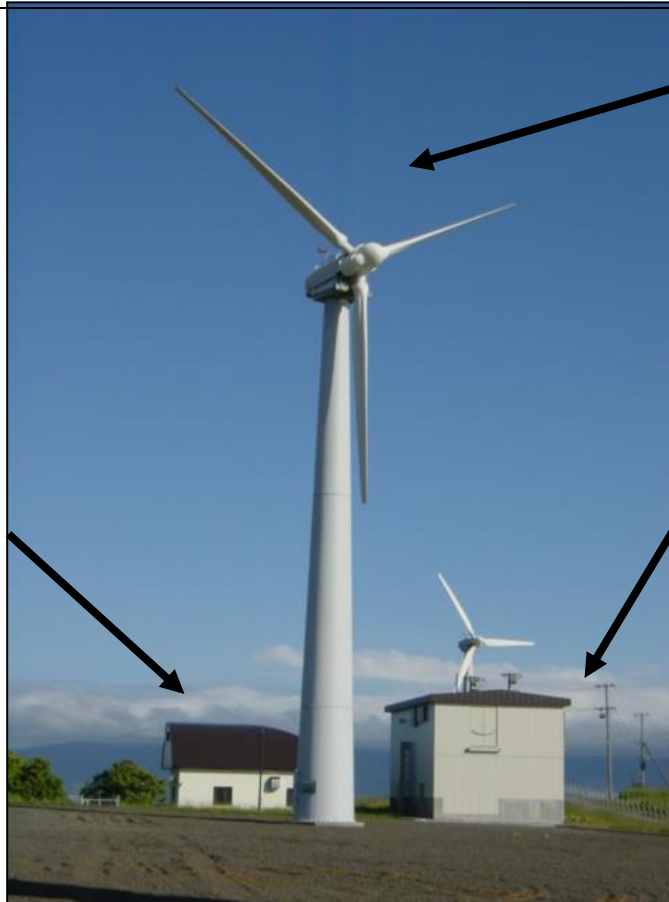
Application to Wind Power Station (NEDO Project)

Place : Tomari Wind Hills of Hokkaido Electric Power Co.,Inc.

Wind Turbine : 275 kW

VRB : 170 kW-6h

Control Room
of Wind Turbine
System

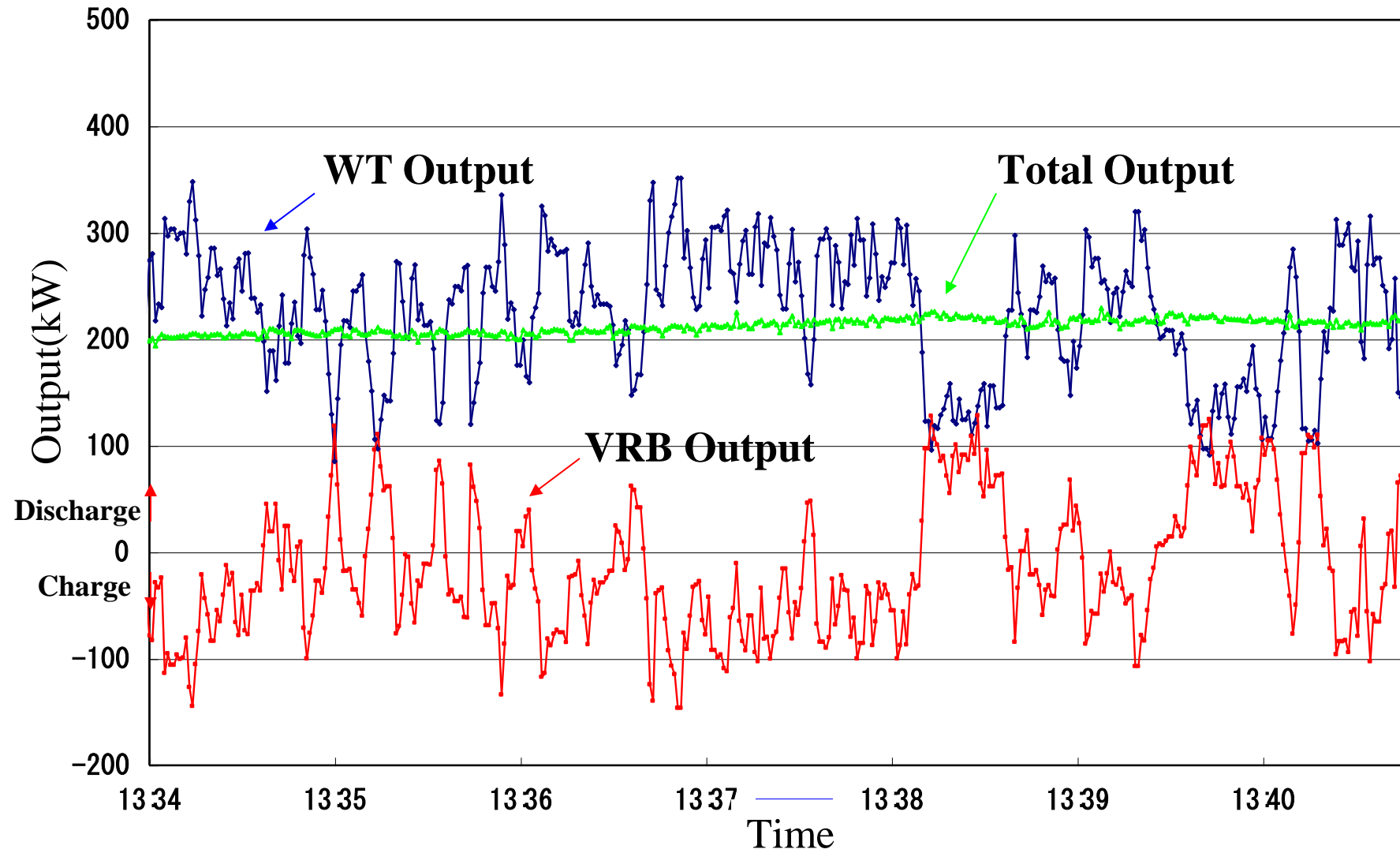


Wind Turbine

House for
VRB

Results for Stabilization of Wind Turbine Output

• 2001/04/03
• $\Delta T=8\text{min}$



VRB for CESI (Italy)

<Purpose>
 ▪ Load leveling

<Specification>
 ▪ 42kW x 2h

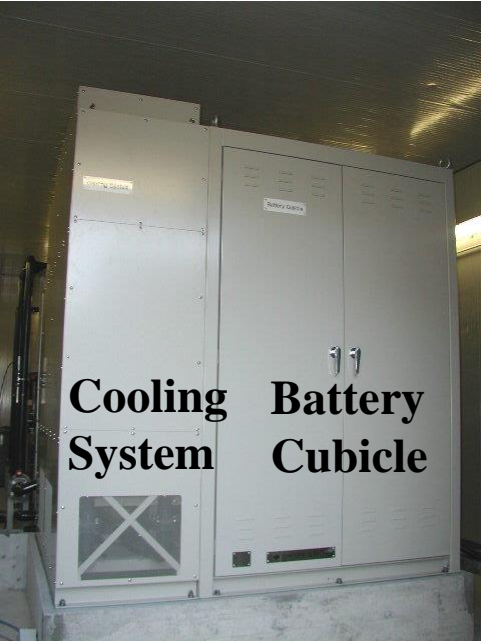
<Operation>
 ▪ Dec. 2001



House for VRB



(On the roof)



Cooling System Battery Cubicle

(Inside the house)



Electrolyte Tank



(2F Control Room)

Battery Controller

AC/DC Converter

HighChem Company, Ltd.

Confidential



A Chemical Material Trading & Manufacturing Company

Established : April 8, 1998

Number of Employees : 603 (consolidate as of Jan. 2024)

Locations : Japan (HQ, 5 bases, 2 Labs.), China (12 bases, 2 Labs.), USA (1 base), Europe (1 base)

Consolidated Sales of 2023 : 123,986 Mil. Yen (1,231 Mil. AUD)

HighChem's Battery Business Fields

Trading of Battery Raw Materials / Production of Solvents

Trading of Battery Systems, Battery Cells and Modules

Trading of Battery Manufacturing Machines / Licensing of Production Technology

(Under development) V-RFB Manufacturing of Cells, Electrolyte, Battery Systems



Blade Battery Cells



6 MWh Containers

HighChem's Battery R&D

Battery Material R&D Center Established : August 2023

V-RFB R&D team : 6 members (4 PhDs) including;

Dr. Kenzo Hanawa, General Manager (former Showa Denko V-RFB Leader)

Dr. Kanji Sato, Special Technical Advisor (Pioneer of V-RFB)



HighChem Tokyo R&D Center

HighChem's V-RFB development

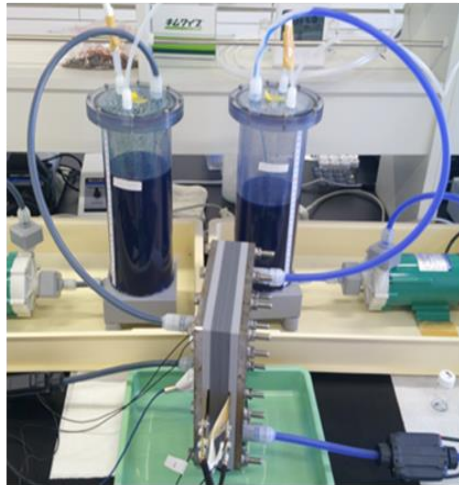
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V-RFB Development target in HighChem

1. Low resistivity, high output V-RFB cells stacks
 2. Vanadium electrolyte production / Vanadium extraction technology
- To be on market by 2026

High Performance Cell Technology



Laboratory cell stack
100 cm² x 3 cells

(Charging : 200 mA/cm²)

Output current density (mA/cm ²)	Energy Efficiency
200	85%
400	80%
600	74%
800	67%

Resistivity : 0.43 Ωcm² @ 45°C

Cell Production Technology



Product prototype cell stack
5 kW (442 cm² x 40 cells)

LE System Company Profile

Company name	LE System Co., Ltd
Establishment	October 13, 2023 (Date of business succession: December 1, 2023)
Business activities	RnD, manufacturing, and sales of electric power storage devices, etc.
Location	NT Building, 1-47-1 Oi, Shinagawa-ku, Tokyo, Japan
Stated capital	JPY 30,000,000
Representative Director	Nagayoshi Ho



CORE TECHNOLOGY

- Vanadium recovery
- VRFB electrolyte production
- Battery cell design
- VRFB operational system

- ✓ RS Technologies has established a new subsidiary and acquired the entire business of the former LE System starting from December 15th.
- ✓ The origin of the technology of the former LE System can be traced back to the research on “energy conservation and non-fossil energy” by NEDO¹ and JST² in the 1970s and 1980s, and it has received support including investment from INCJ³.
- ✓ The Tsukuba Technical Center was founded in 2013 as a centre for research and development. In 2021, the largest electrolyte production facility for VRFB in Japan was built in Namie, Fukushima.

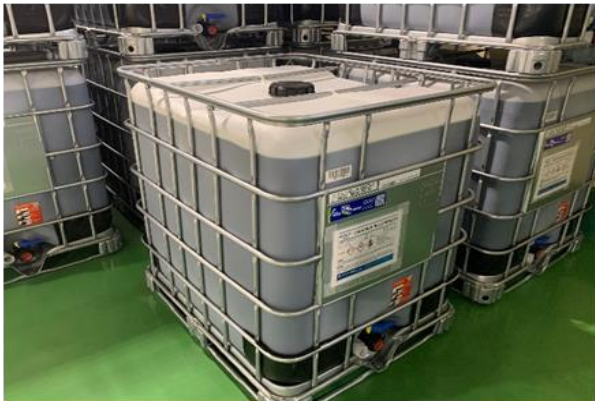
1.NEDO(New Energy and Industrial Technology Development Organization、新エネルギー・産業技術開発機構)

2.JST(Japan Science and Technology Agency、科学技術振興機構)

3.INCJ(Innovation Network Corporation of Japan、産業革新機構)

Namie Plant

REFERENCE) NAMIE PLANT



- In 2021, the electrolyte plant with 5,000 m³/year production capacity was completed
- In December 2022, the plant successfully obtained certification by complying with Sumitomo Electric's electrolyte requirements and production management system.
- Our current plans involve setting up a manufacturing facility in China that can produce 100,000 m³/year.

Summary

- **Kashima-Kita Electric Power corporation signed a technical guidance agreement with the Ministry of International Trade and Industry's ETL in 1990 to develop batteries using by-products of thermal power plants, and conducted joint research with the University of NSW patent license in 1992 and 1993.**
- **Kashima-kita developed a technology to produce vanadium electrolytes from vanadium and sulfuric acid, which are by-products of thermal power plants, and succeeded in the first demonstration operation of a 200 kW-4 hour VRF battery in 1997.**
- **Sumitomo Electric Industries, Ltd., the company to which the technology was transferred, examined the commercialization of early VRF batteries.**
- **Field tests were conducted for road leveling of commercial buildings and universities, adjustment of output fluctuations of wind power and solar power generation, and instantaneous shutdown of semiconductor factories, and the usefulness of VRF batteries was verified.**



Thank you for your attention.!