Vanadium Flow Battery Systems for Renewable Energies and Grid Controls

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Agenda

1. **Company profile**
2. **Vanadium flow battery (VFB)**
3. ***VFB for Renewables and grid control***

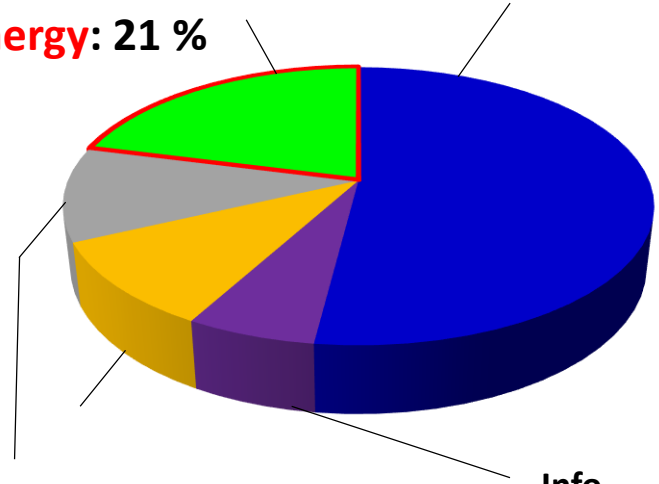
Company Profile

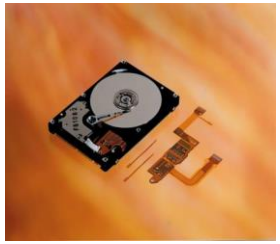
Company profile

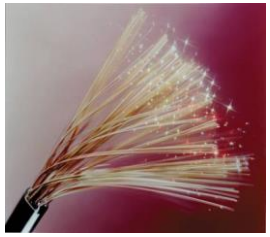
Corporate Name	Sumitomo Electric Industries, Ltd. ➔ SEI
Established	1897
Capital	$1.3 Billion
Headquarter	Osaka & Tokyo, Japan
President & CEO	Masayoshi Matsumoto
Group Companies	353 (Consolidated) (115 in Japan, 238 Overseas)
Employees	182,773 (Consolidated)
Business Performance	Consolidated Sales $23 Billion
Business Areas	Automotive, Electric Power Cables & Equipment, Information & Communications, Electronics, Industrial Materials

Business fields

Portfolio – Segment & Sales percentage







Energy Solutions

Energy Storage

Flow Battery

Renewable Energy

CPV

Power Transmission

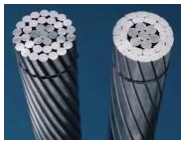
Super-conductor Cable

Energy Management System

High Voltage AC & DC XLPE Cable

Smart Home

Smart Distribution Board



High Capacity Conductor

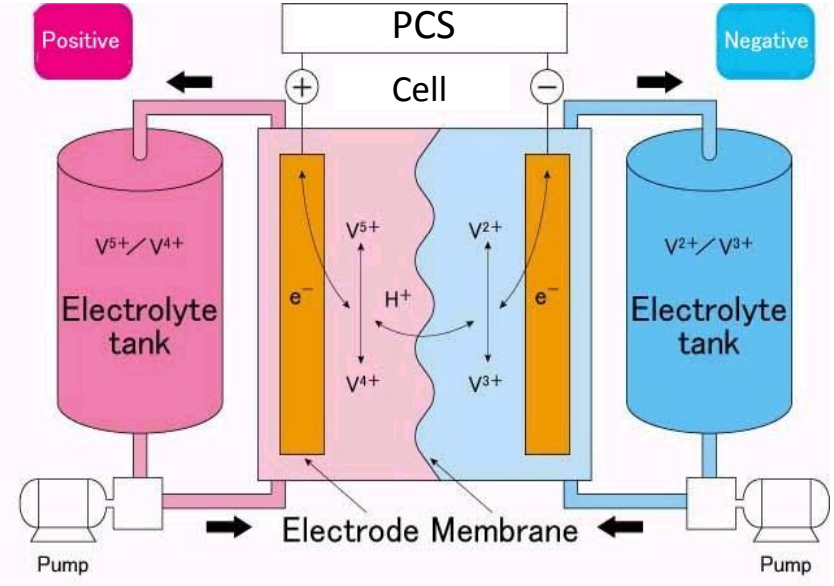
Home Gateway

Vanadium Flow Battery

Vanadium flow battery (VFB) system

➢ **SEI started R &D on flow batteries in 1985. Current model is vanadium type.**

Principles



Positive Reaction

$$VO^{2+} + H_2O \underset{\text{Discharge}}{\overset{\text{Charge}}{\rightleftharpoons}} VO_2^{+} + e^- + 2H^+$$

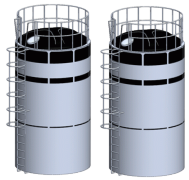
(Tetravalent) (Pentavalent)

Negative Reaction

$$V^{3+} + e^- \underset{\text{Discharge}}{\overset{\text{Charge}}{\rightleftharpoons}} V^{2+}$$

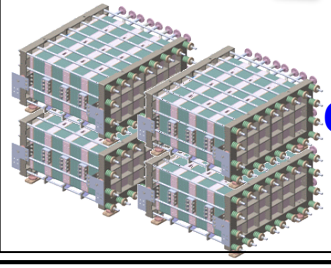
(Trivalent) (Diatomic)

Spatial Separation btw. Power & Energy



Electrolyte tank
- energy component
kWh

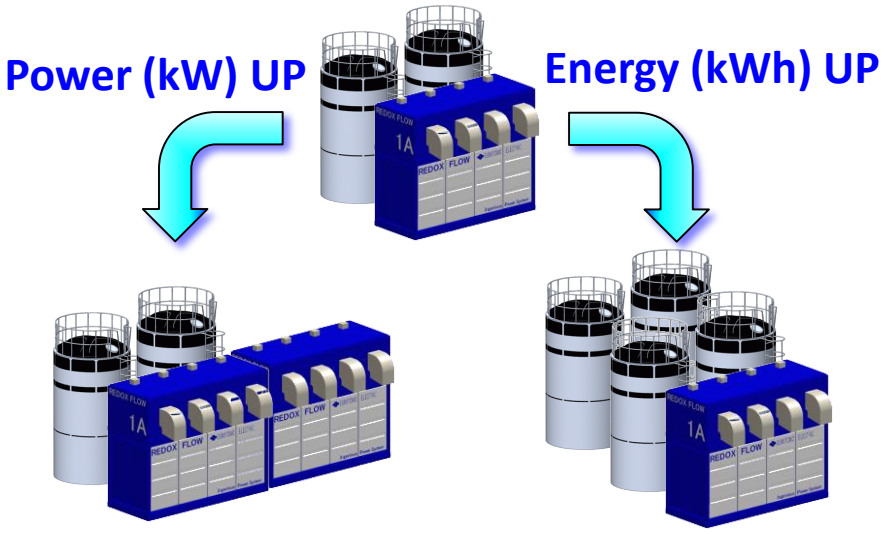
20 FT Shipping Container



Cell Stacks
- power component
kW

Features of the VFB for large scale system

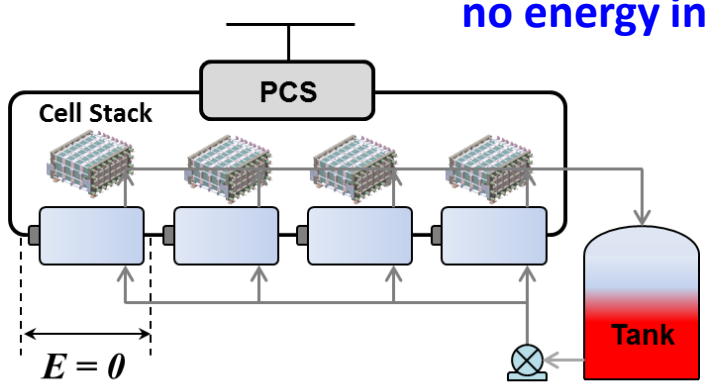
Design flexibility



Safety – mitigation of abnormal energy release

☺ Incombustible material (cell / electrolyte)
☺ Shutdown of Electrolyte (pumps stop)

no energy in cell



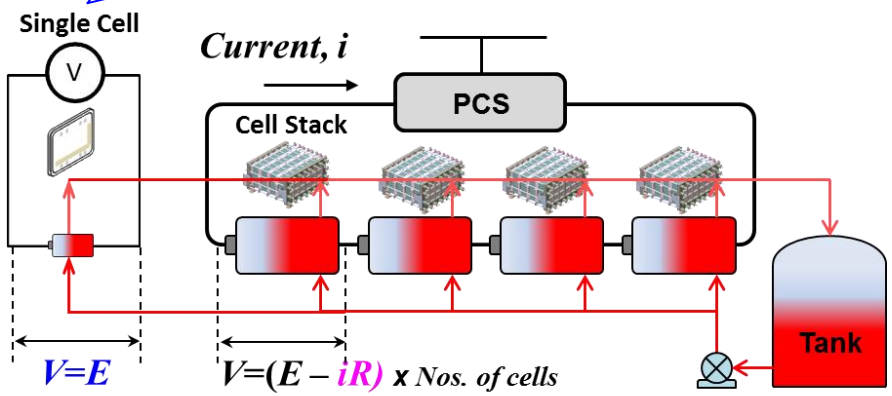
Balanced charge level

➢ Cell stacks share electrolyte each other.
⇨ Each cell stack has same SOC.

Direct monitoring of SOC during operation

➢ Electromotive force "E" can be monitored **w/o "iR drop"**.
⇨ SOC can be directly measured even during charging or discharging.
(*) E vs SOC follows the Nernst equation

- **W/ : Hydraulic connection**
- **W/O: Electrical connection**



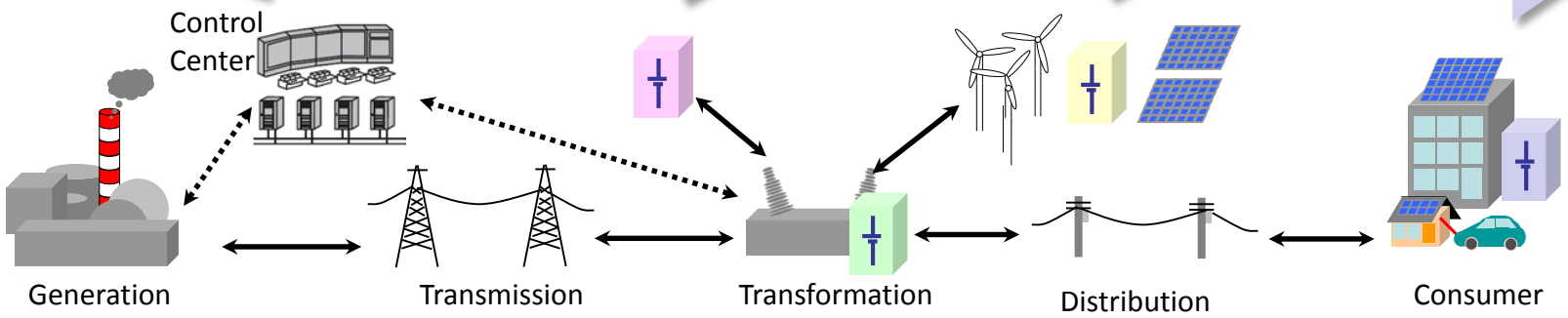
Track records

Utility, ISO
- Frequency Regulation
- Surplus Power Adjustment

Servicer, PPS
- Ancillary Service
- Frequency Regulation

IPP
- Output Smoothing
- Planned Operation

Consumer
- LL, Peak Cut - UPS
- Emergency Use …

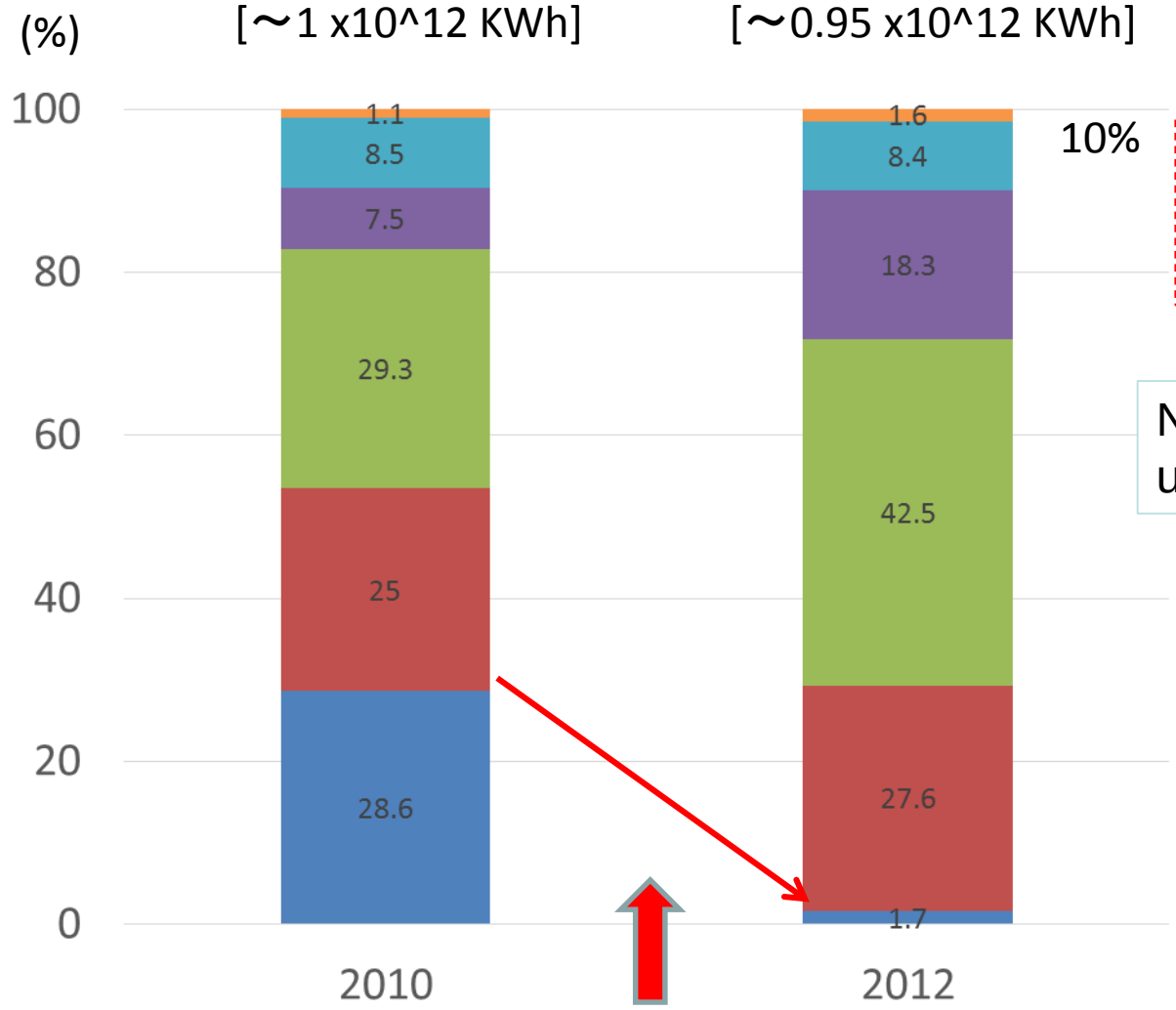


Customer	Application	Capacity	Install
Electric Power Co.	R&D, Substation	450kW x 2H	1996
Office Building	LL	100kW x 8H	2000
Electric Power Co.	R&D	200kW x 8H	2000
NEDO	Wind	170kW x 6H	2000
Contractor	PV (R&D)	30kW x 8H	2001
Factory	UPS / Peak Cut	1500kW x 1H	2001
Developer	UPS / Peak Cut	250kW x 2H	2001
University	LL / Peak Cut	500kW x 10H	2001
Lab.	Peak Cut	42kW x 2H	2001
Electric Power Co.	R&D	100kW x 1H	2003
Office Building	LL	120kW x 8H	2003
Railroad Co.	UPS / Peak Cut	30kW x 3H	2003

Customer	Application	Capacity	Install
Research Center	LL	170kW x 8H	2004
Office Building	R&D	100kW x 2H	2003
Data Center	UPS / Emergency Use	300kW x 4H	2003
Office Building	LL / Emergency Use	100kW x 8H	2004
University	LL / Emergency Use	125kW x 8H	2004
Museum	LL / Emergency Use	120kW x 8H	2005
Electric Power Co.	PV / Grid Control (R&D)	100kW x 4H	2005
IPP	Wind	4000kW x 1.5H	2005
SUMITOMO	PV / EMS	1000kW x5H	2012
Contractor	PV / EMS	500kW x 6H	2014
Electric Power Co.	Grid Control	15000kW x 4H	2015

VFB for Renewables and Grid Control

Share of electric power source in Japan



Renewables' share

Energy Basic Plan **@2010**

→ 13.5% by 2020

20% by 2030

New Energy Basic Plan under discussion

Fukushima on 11th March, 2011

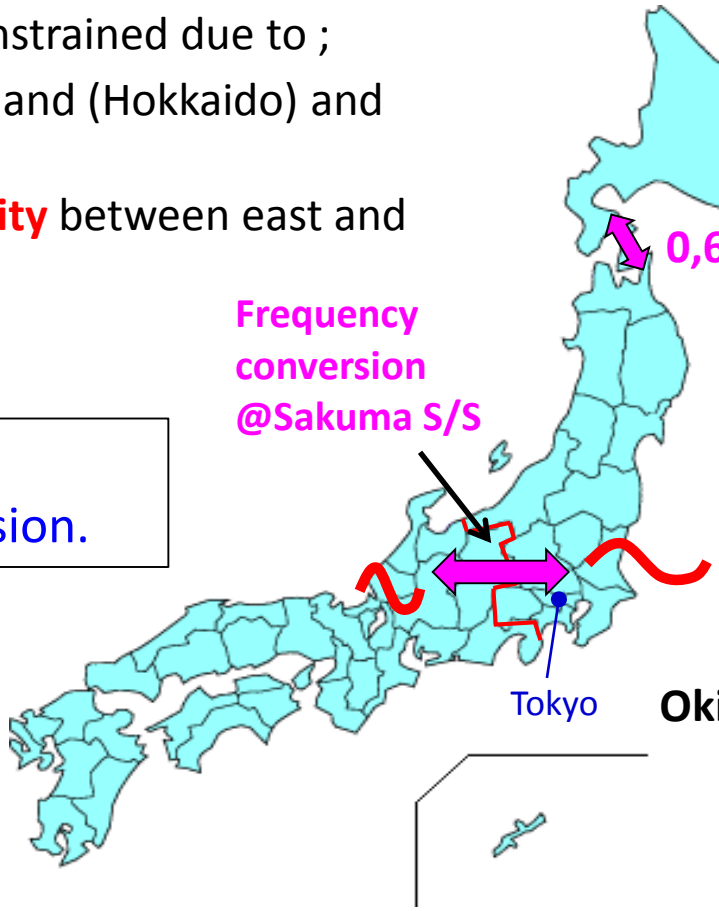
Source: METI

Grid conditions in Japan

- Suitable area for renewables is scattered to north and south area, specially Hokkaido is the most attractive place.
  But, allowable renewables capacity is limited due to weak grid connection.
- Nationwide grid connection is constrained due to ;
  - **TL capacity** between north island (Hokkaido) and main island,
  - **Frequency conversion capacity** between east and west area.

Smart control of the grid is inevitable for renewables expansion.

Battery



Hokkaido
- 5,5 GW
- **50 Hz**
- 1 utility

East area
- 73 GW
- **50 Hz**
- 2 utilities

West area
- 96 GW
- **60 Hz**
- 6 utilities

Okinawa
- 1.4 GW
- 60 Hz
- 1 utility

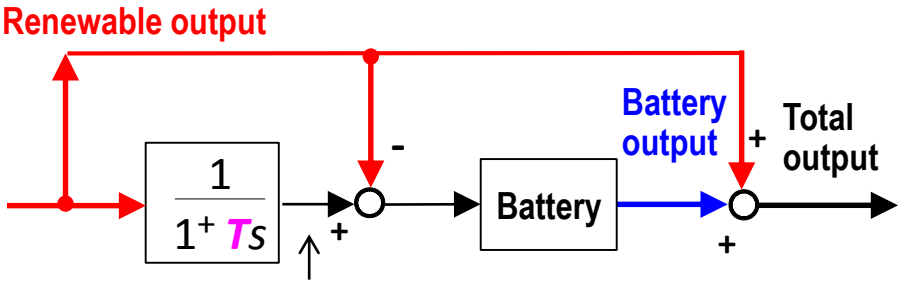
Major projects

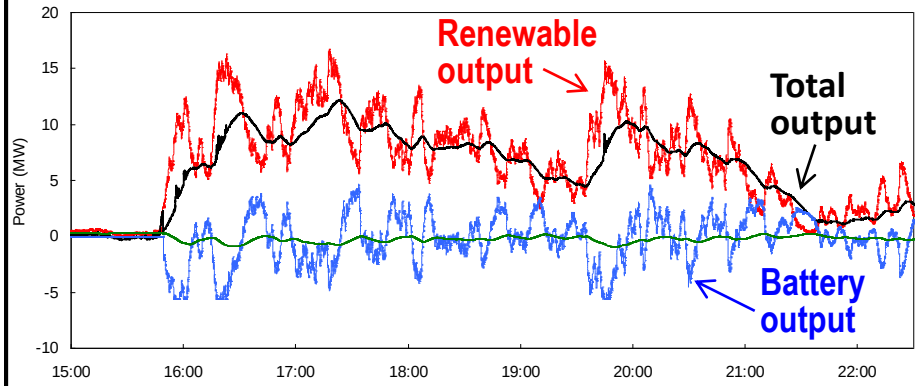
Operation	2003-2008	2012 ～	Under constr., 2015～
Application	**Co-located with WT**	**Behind the meter**	**Grid Control**
Location	Tomamae Wind Villa (NEDO PJ)	Sumitomo Electric Yokohama Works	Hokkaido Electric Power Co. (METI PJ)
Application	・Stabilizing Wind Farm Output for Grid Integration	・Renewable Integration ・Demand Side Management ・Demand Response	・Frequency Regulation ・Mitigation of surplus Renewable generation
Capacity	**6 MW / 6 MWh**	**1 MW / 5 MWh**	**15 MW / 60 MWh**
Notes	・Wind farm: 31MW ・270,000 switches / 3 years 	・Gas generator: 3.6MW ・CPV : 100kW ・EVERYDAY DSM 	・Controlled by utility's control center ・Multi-applications 

Stabilizing renewables

Control principle

- Renewables is smoothed with first-order lag element.
- Time constant ***T*** is deciding parameter how renewable's output is smoothed.
  (**Larger T provides more stabilized output.**)

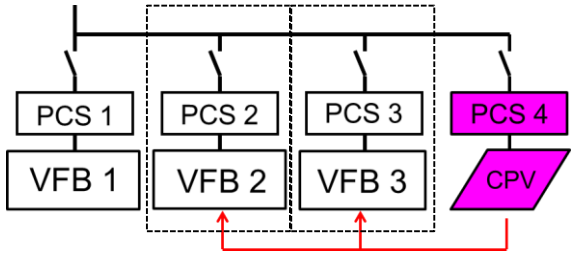


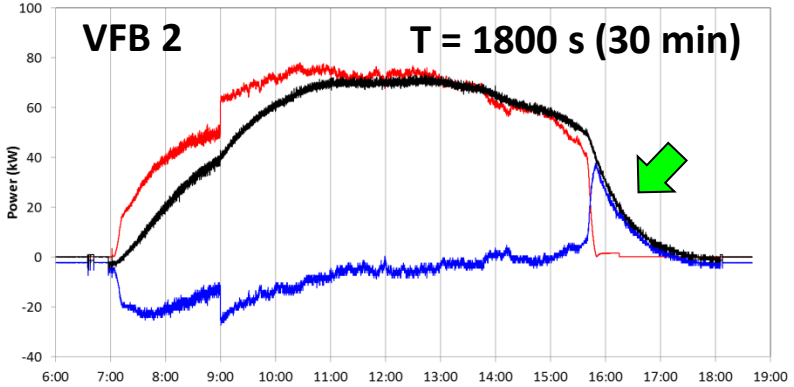


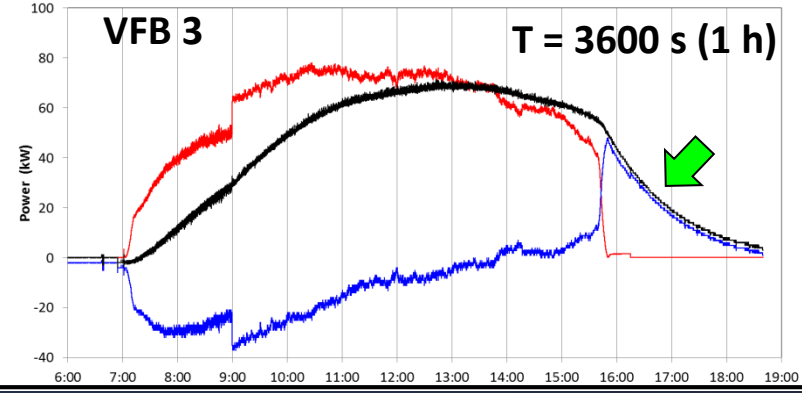
- Time constant ***T*** is changeable to provide variable ramp rate control of renewables.
  (**Variable time constant control**)

Experimental results (T vs. Smoothing effect)

- Same PV output signal is sent to no.2 & 3 with different T.

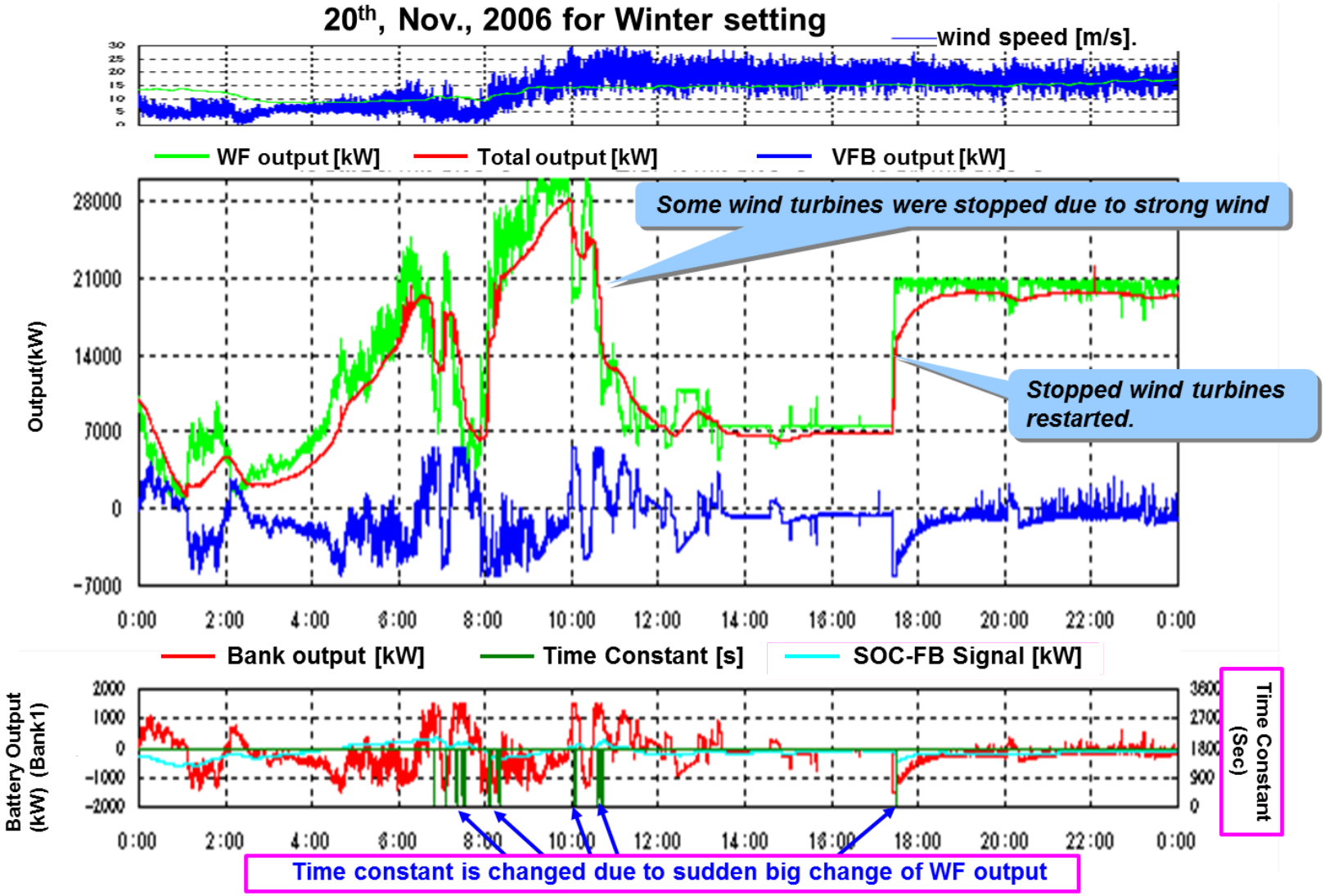






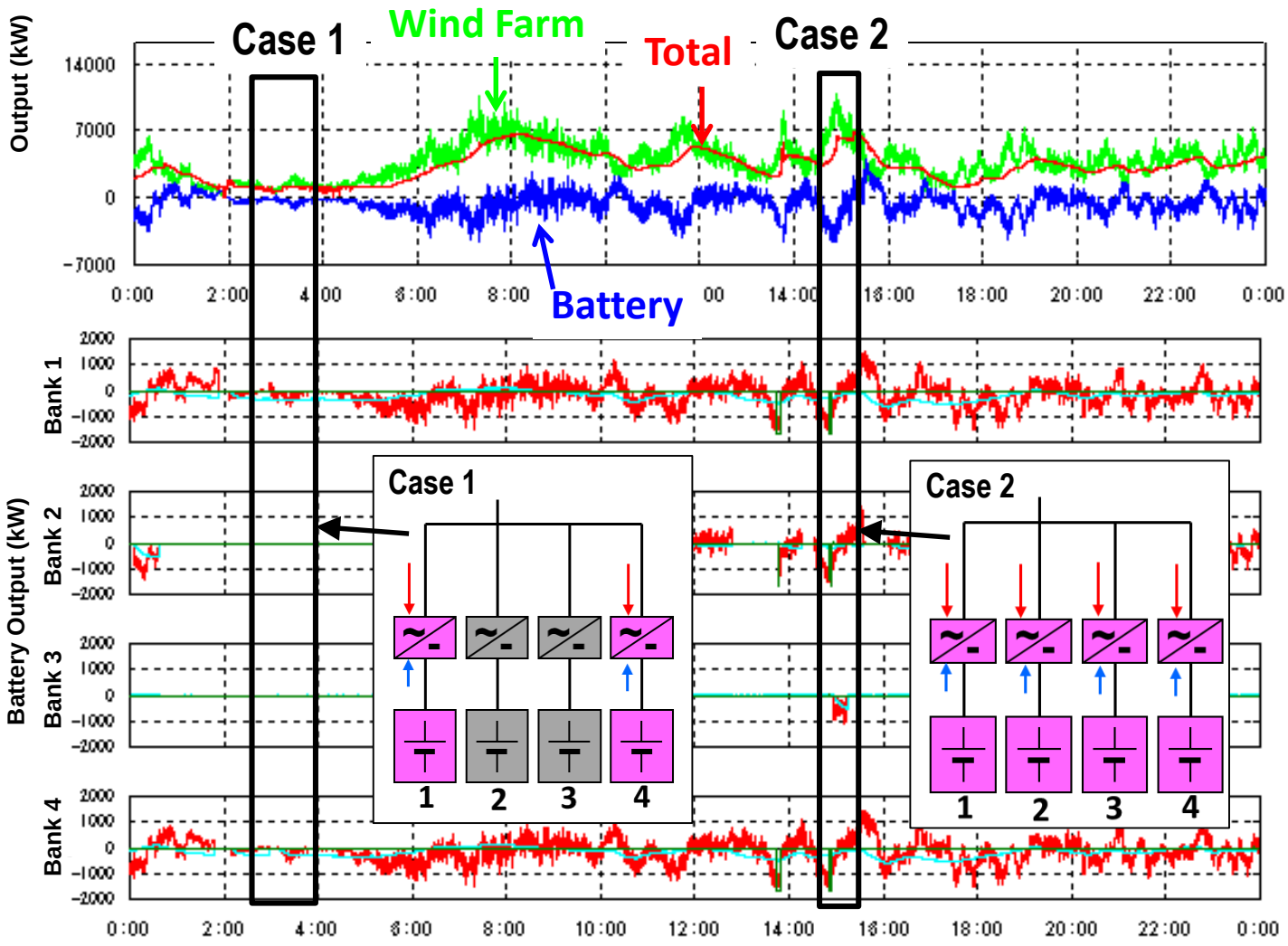
Experimental operation data

- *Stabilizing WF + Variable time constant*
- *Output capacity ratio : WF 31 MW vs VFB 6MW*



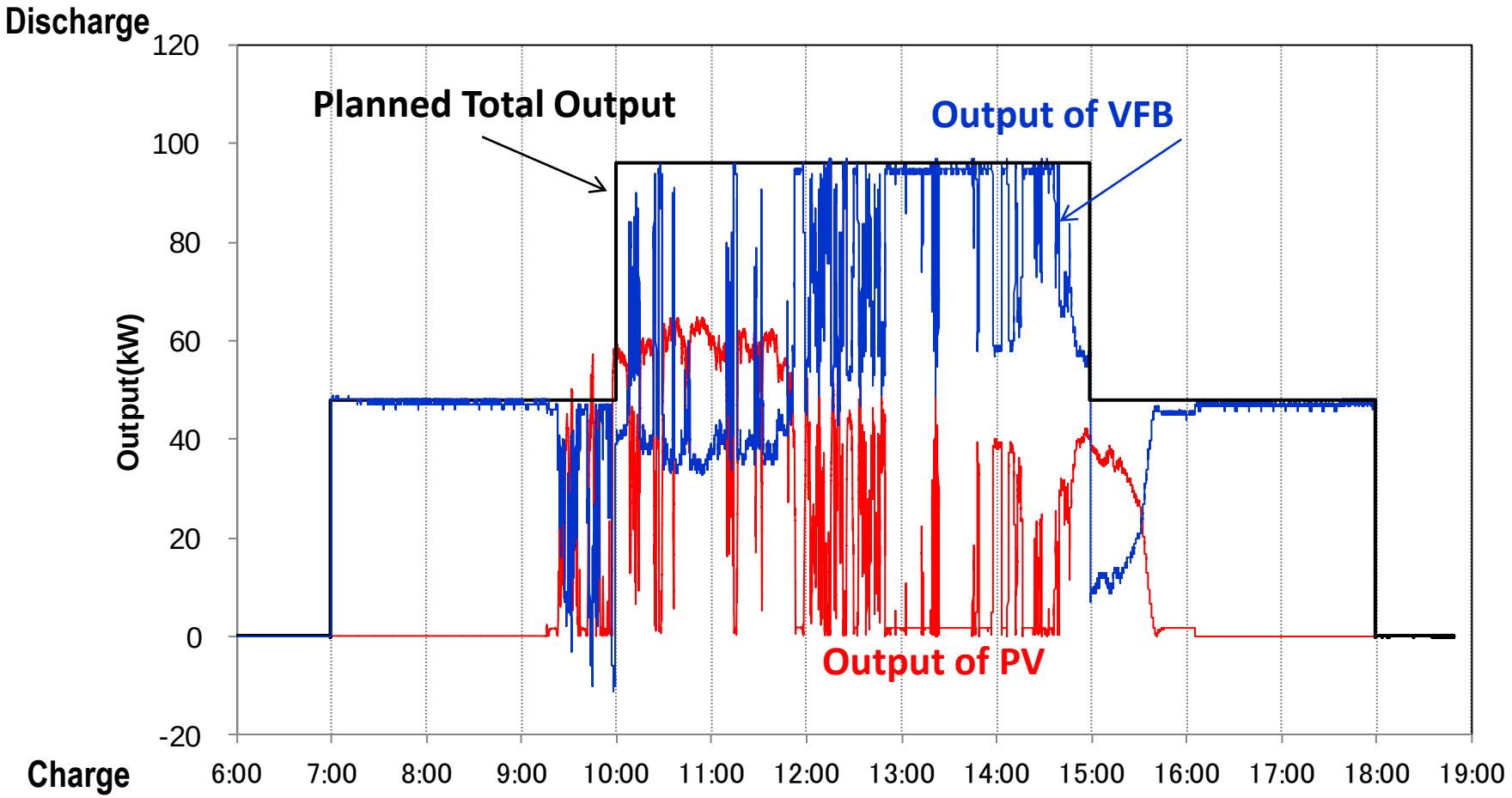
Reducing auxiliary power – Bank selection control

- While variation of WF output is small, some banks stop to reduce auxiliary power (e.g. pumps). Operation order is decided considering SOC levels.



Planned operation of renewables

- Renewable's output is not stable to use it as a predictable power source.
- The VFB works with renewables to adjust the total output as per planned.

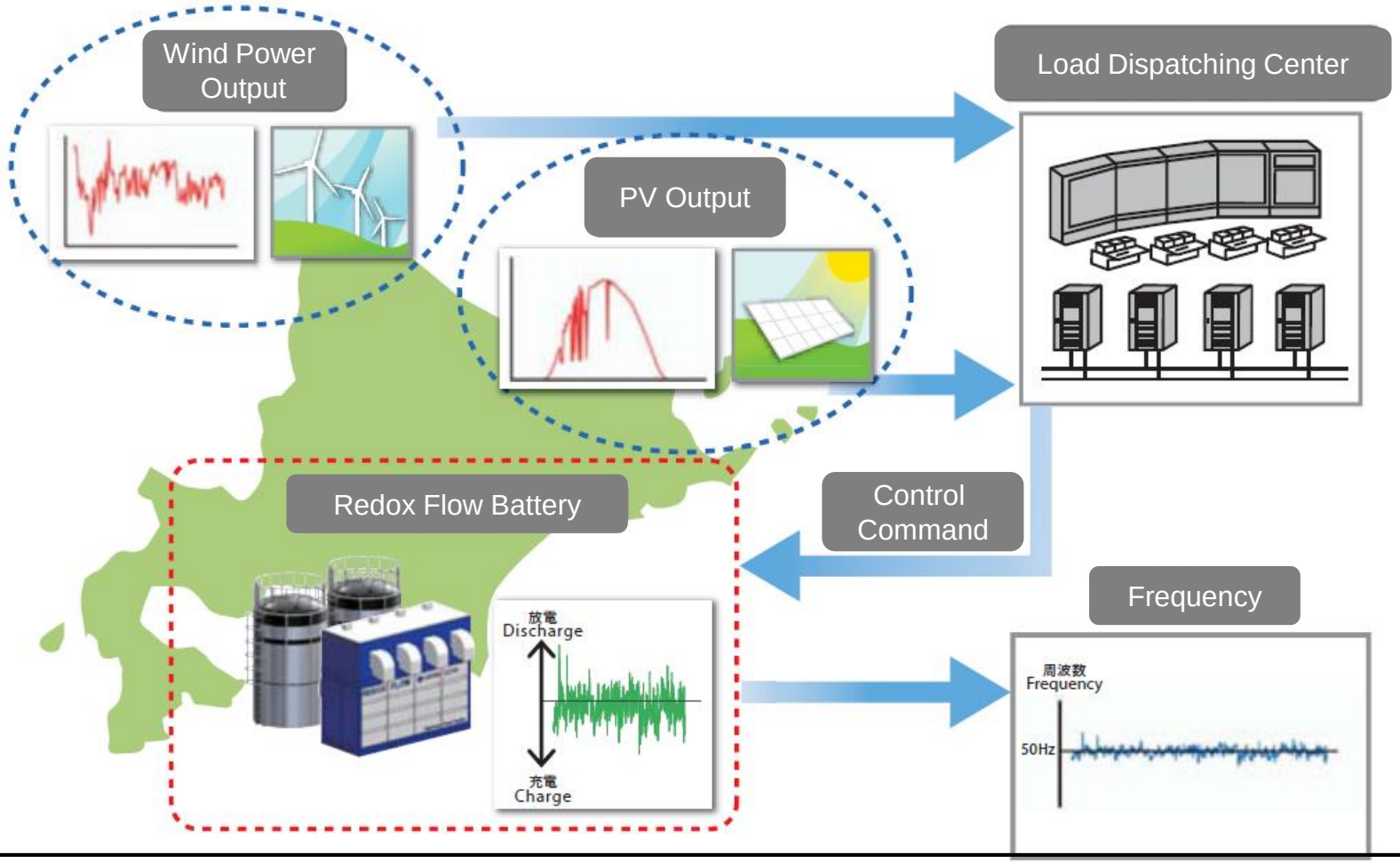


Grid control application (HEPCO/SEI　METI Project)

- Capacity　: 15MW, Energy : 60MWh
- Fund : Ministry of Economy, Trade and Industry (METI)
- Awarded company : Hokkaido Electric Power Company
  Sumitomo Electric Industries, Ltd.
- Field evaluation of battery system for grid-control
  → Engaged in practical use
- Operation will start in 2015

Operation plans

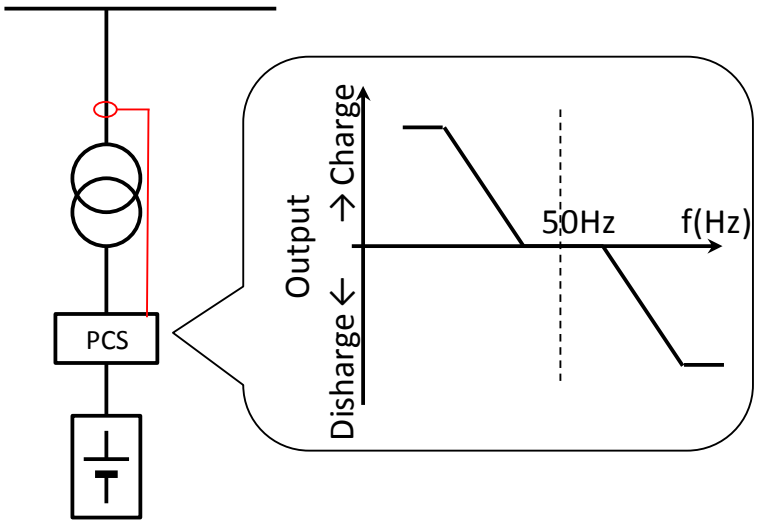
- Application: Multi application for grid control
  (Governor-Free, Primary and secondary regulation & Surplus Power Adjustment)

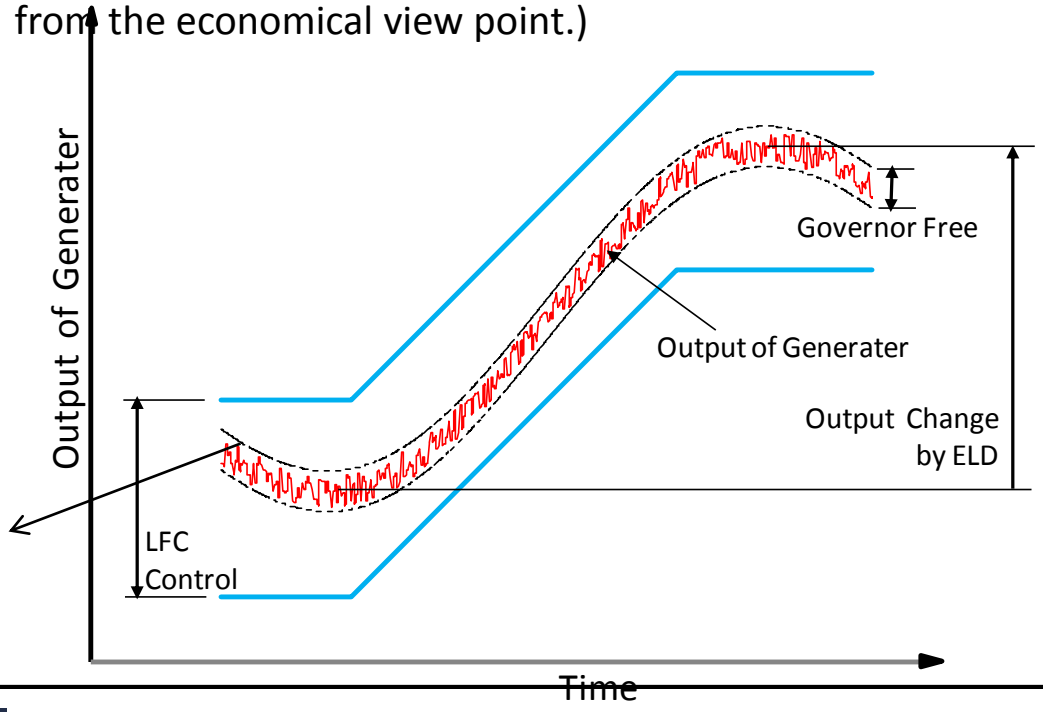


Frequency controls

Three Level Frequency Control will be performed in this Project.

	Speed	Energy
➢ ***Governor Free Operation*** adjusting sub second order miss-match of D/S balances which can't be followed by LFC.	**Very fast**	**Small**
➢ ***Fast Frequency Regulation (LFC:Load Frequency Control)*** second order operation by the command from control center	**Fast**	**Medium**
➢ ***Time Shift (ELD:Economical Load Dispatch)*** ***similar to Secondary regulation*** More than several 10 minutes adjustment (Power source is dispatched from the economical view point.)	**Not fast**	**Large**





Summary & Acknowledgment

Summary

- VFBs for renewables application have been successfully developed and evaluated.
- New project to use the VFB in grid control, with ever-large system of 60 MWh was launched.

Acknowledgement

- Ministry of Economy, Trade and Industry (METI)
- New Energy and Industrial Technology Development Organization (NEDO)
- Central Research Institute of Electric Power Industry (CRIEPI)
- The Institute of Applied Energy
- Hokkaido Electric Power Co., Inc. (HEPCO)
- Electric Power Development Co., Ltd. (Communication Name; J-Power)

Thank you for your attention.

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