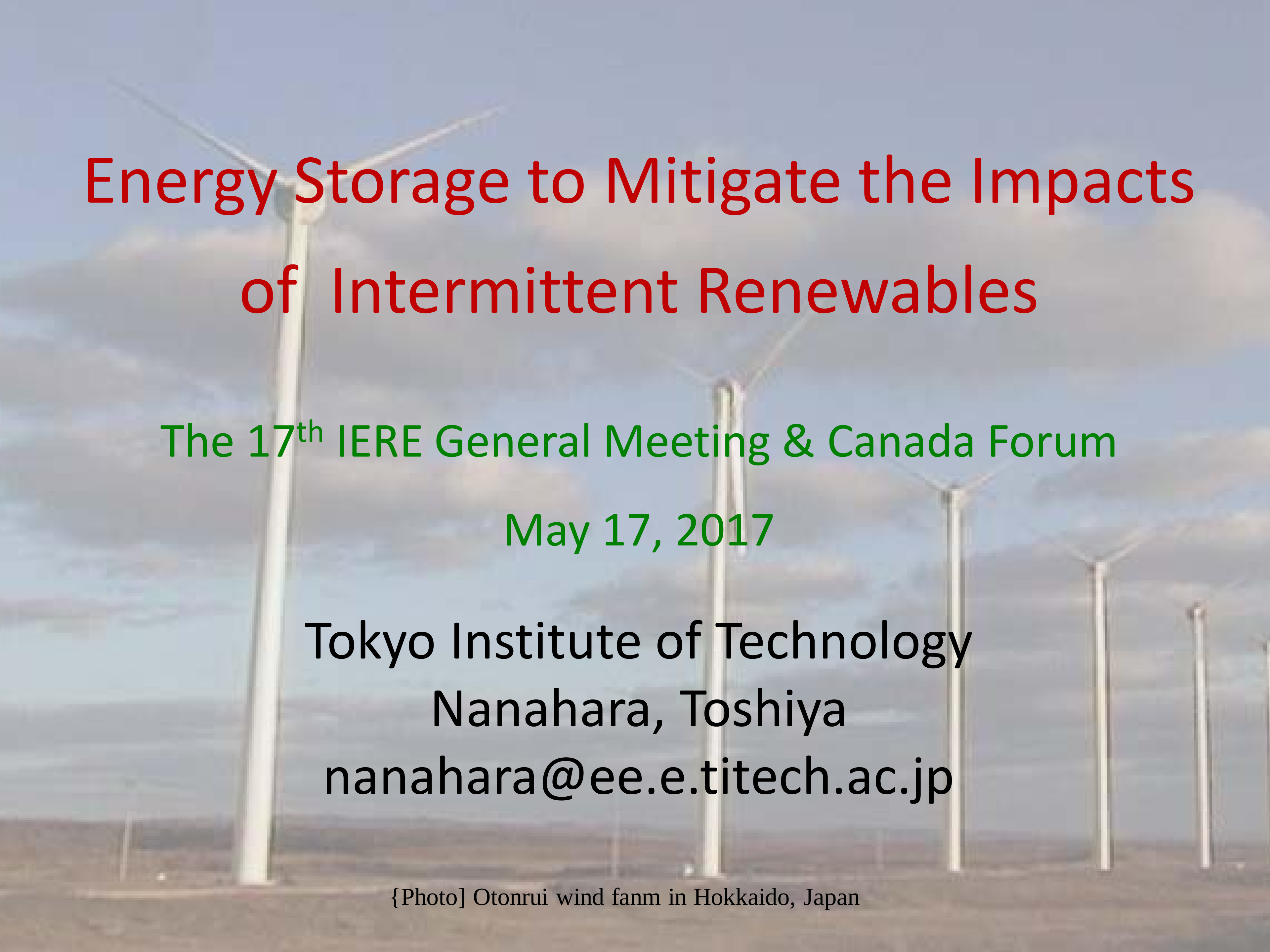
Energy Storage to Mitigate the Impacts of Intermittent Renewables

The 17th IERE General Meeting & Canada Forum

May 17, 2017

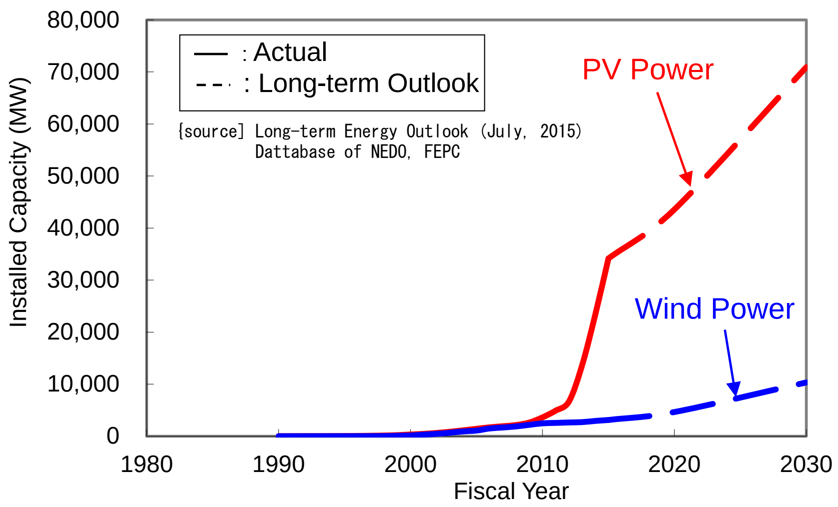
Tokyo Institute of Technology
Nanahara, Toshiya
nanahara@ee.e.titech.ac.jp



{Photo] Otonrui wind fanm in Hokkaido, Japan

Background: Renewables and ESS

- Significant increase of PV and wind power (Renewable Energy Sources: RES) causes various concerns in a power system including those in supply-and-demand balance of a power system.
- Energy storage systems (ESS) can offer a promising option to mitigate the concerns.
- However, elaborate studies are required to make it an efficient and economic option.



[Capacity of RES in Japan]

東京工業大学
Tokyo Institute of Technology

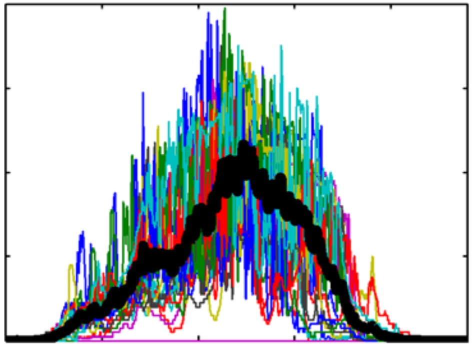
Energy Storage Systems : Many Choices

[Objectives]

- Absorbing surplus power,
- Compensating fluctuations of intermittent RES,
- Supporting decrease of system inertia, etc.

[Locations]

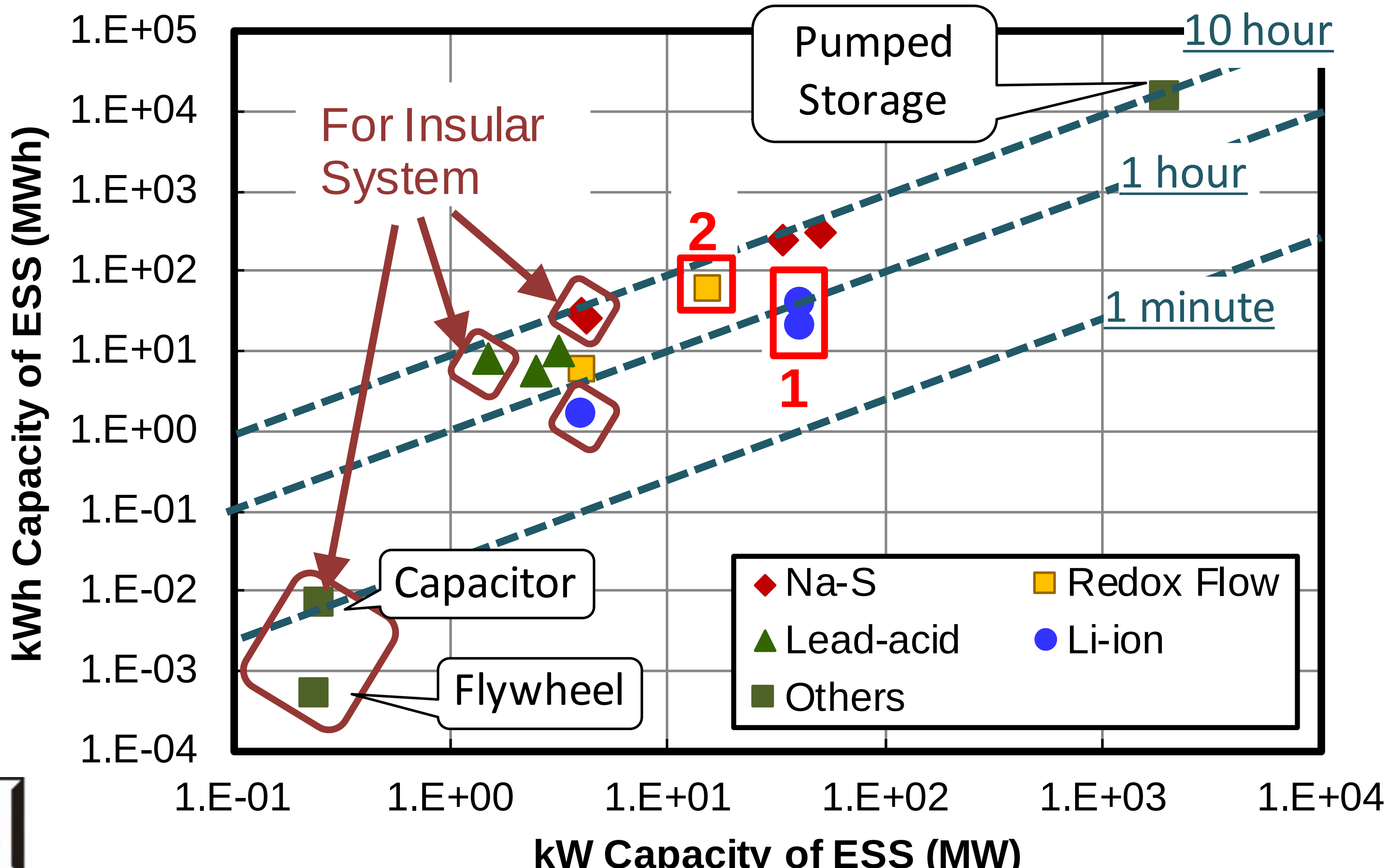
- Power systems (including insular systems)
- Wind and solar power stations,
- Customers including EV, etc.



[Types]

Battery (Li-ion, Na-S, Redox-flow, Lead-acid, Ni-H etc.), Flywheel, Capacitor, Pumped storage, CAES, Hydrogen, etc.

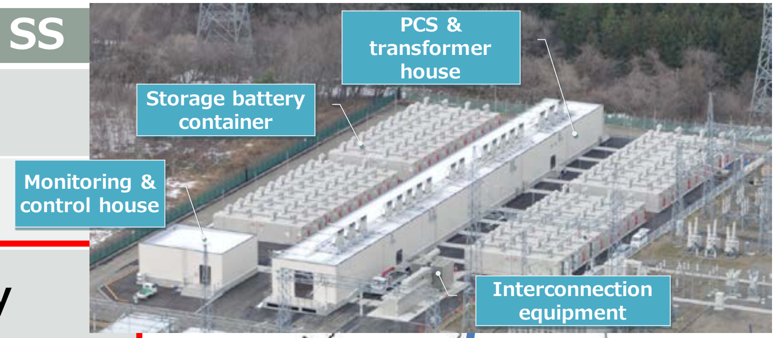
Sample Large-Scale ESS in Japan

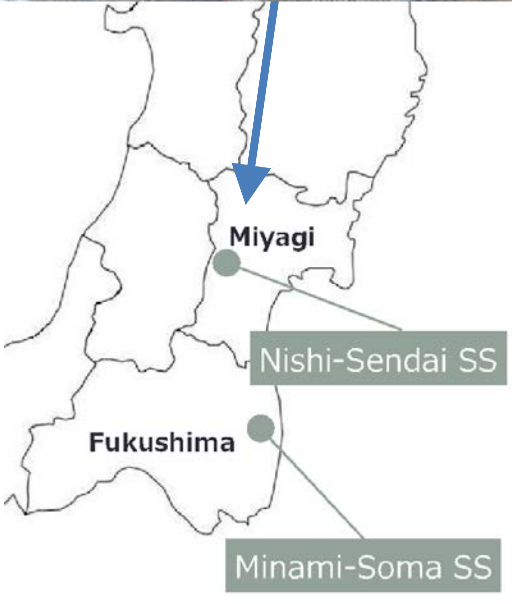


東京工業大学
Tokyo Institute of Technology

(1) Li-ion Battery in a Power System

	Nishi-Sendai SS	Minami-Soma SS
Area	About 6,000m^2 (100m×60m)	About 8,500m^2 (100m×85m)
Start of operation	Feb. 2015	Feb. 2016
Battery Type	**Lithium-ion Battery**	**Lithium-ion Battery**
Manufacturer	Toshiba	Toshiba
System Performance	**Capacity : 20,000kW (short-time 40,000 kW) Energy : 20,000kWh**	**Capacity : 40,000kW Energy : 40,000kWh**
Purpose	Compensate frequency fluctuation	Improvement of demand- and supply balance
Expectation effect	**Improvement of frequency stabilization**	**Expansion of the acceptable capacity**
Verification	・Load frequency control with storage battery	・Improvement of demand-and supply balance ・Voltage fluctuation control with reactive power control

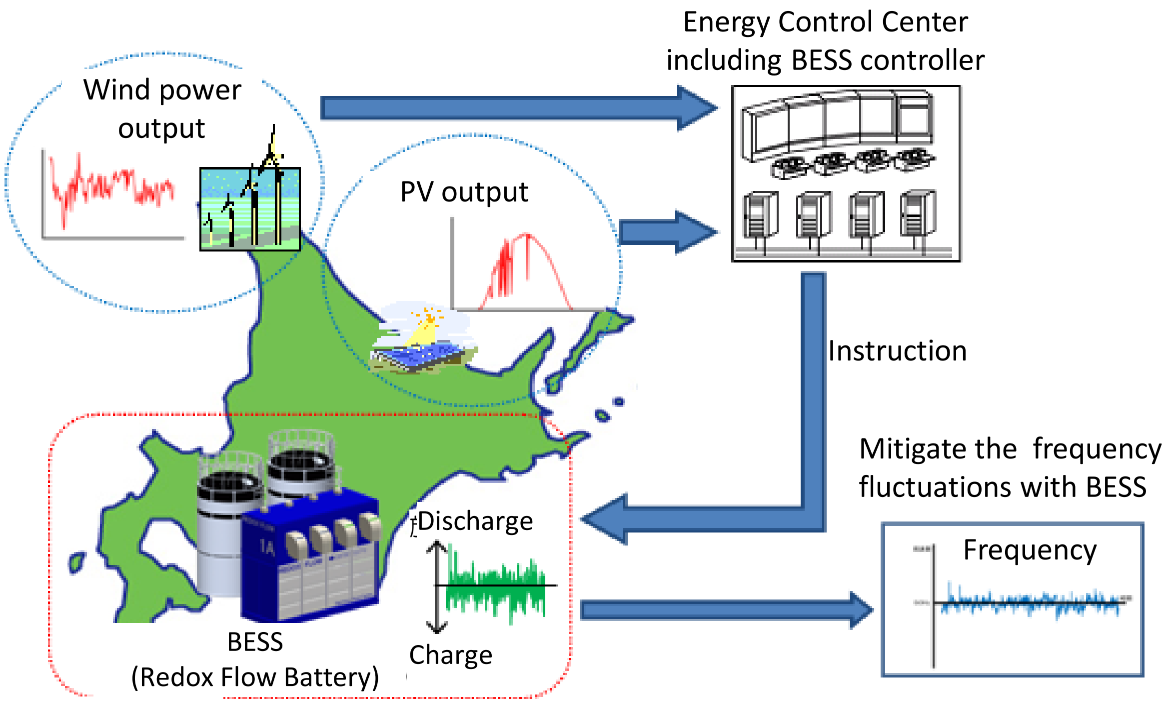


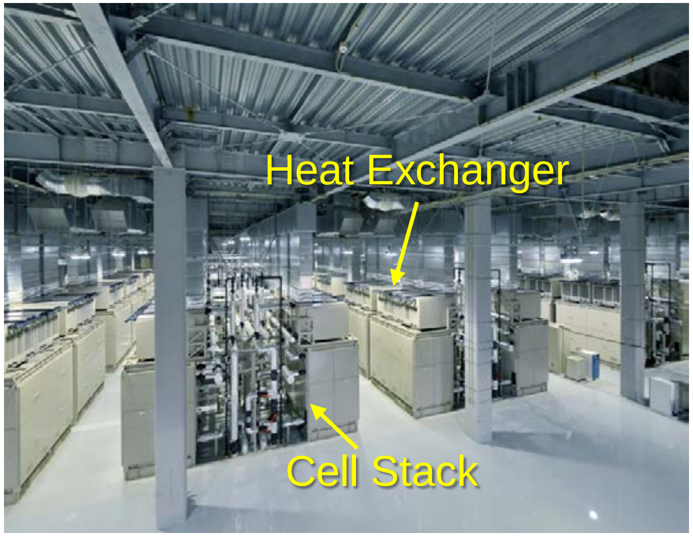


[Photo, Figure, Table] By the courtesy of Tohoku Electric Power Co.

(4) Redox Flow Battery in a Power System

Rating of the Redox-Flow Battery: 15MW, 60MWh





[Photo, Figure] By the courtesy of
Hokkaido Electric Power Co.

Challenges for BESS with Renewables

The response of BESS is enough fast. However, the following challenges could be vital for BESS in addition to cost reduction, life extension and safety:

- Large capacity, in particular to compensate long-term fluctuations
- Minimum size → Management of SOC
- Long stand-by time → Low auxiliary power
- Temperature management of battery cells
- Long duration of operation with low SOC
- Less burden for operation and maintenance

東京工業大学
Tokyo Institute of Technology

Concluding Remark

The ESS discussed here has enough fast response to mitigate various challenges caused by large-scale penetration of intermittent renewables. However, there remains room for further research:

- What is the objective to install ESS?
- How to optimize ESS in accordance with the objective?   The design of ESS is governed by the objective.
- How to operate ESS to maximize its efficiency as well as its expected life?

東京工業大学
Tokyo Institute of Technology

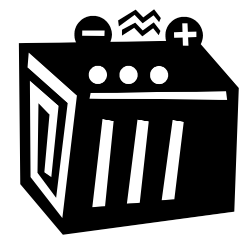
Thank you very much for your attention.

東京工業大学
Tokyo Institute of Technology

Dimensioning of BESS

The ratio of kWh capacity to kW capacity of Battery Energy Storage System (BESS) tends to be:

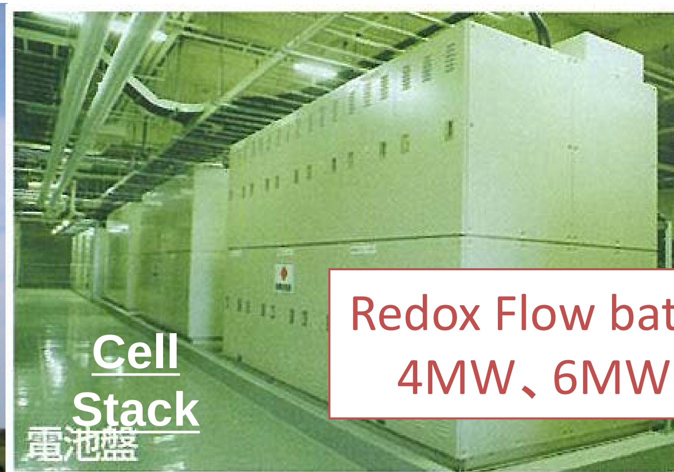
- Large for compensating long-term fluctuations – approximately proportional to the time constant in case of a wash-out filter;
- Large in case of absorbing surplus power,
- Small for an insular system , etc.

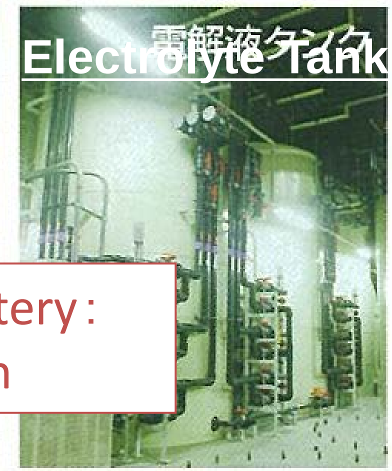


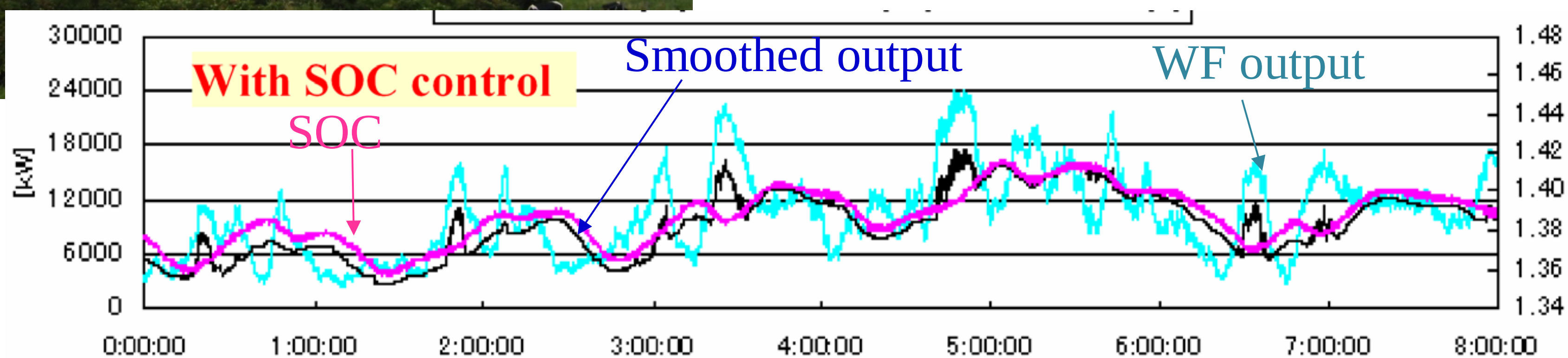
Whereas small ratio has an eminent advantage from the economical points of view, larger ratio is preferable to facilitate the operation of BESS.

東京工業大学
Tokyo Institute of Technology

(1) Redox Flow Battery in a Wind Farm





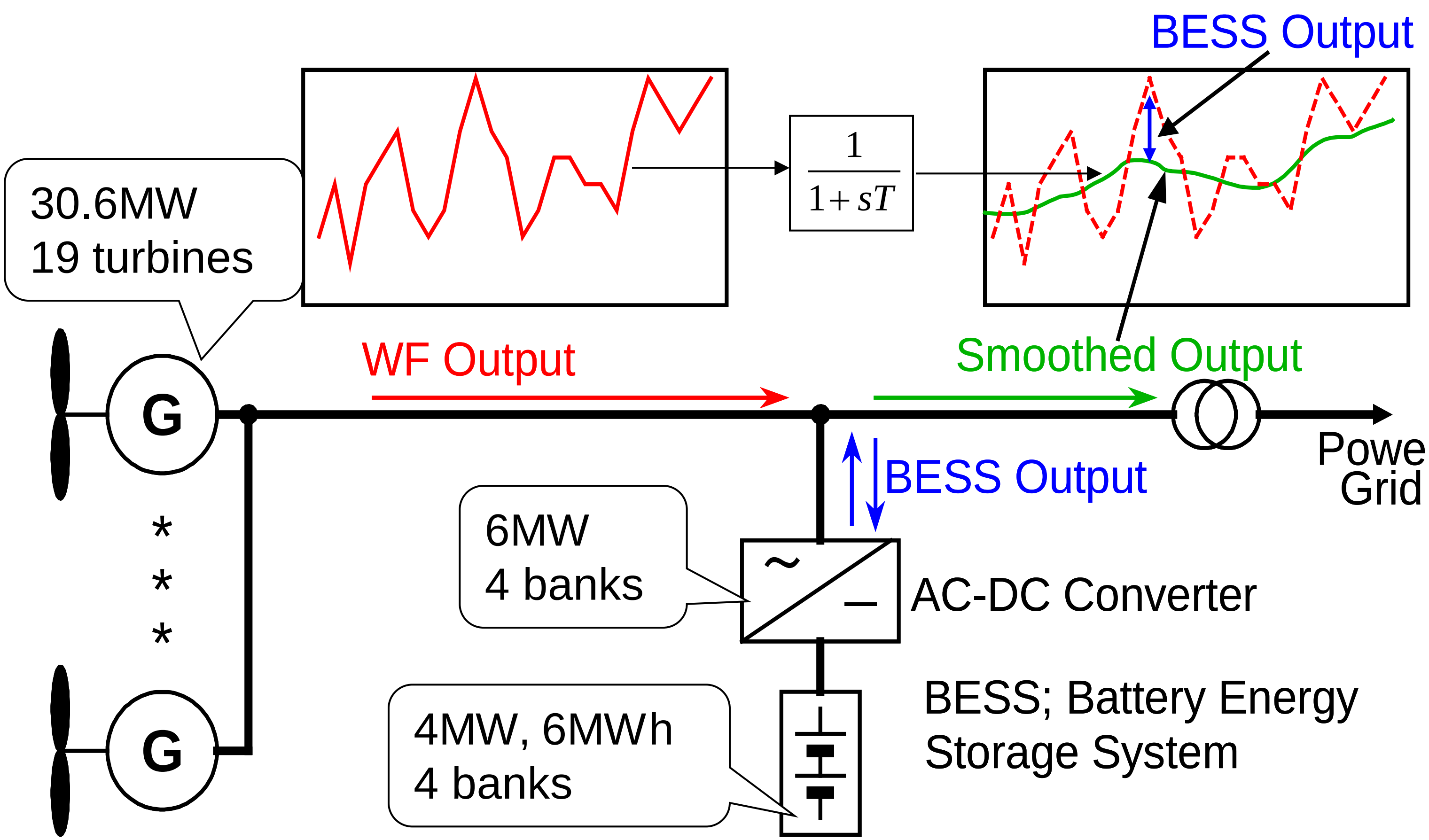


A control method for battery energy storage system was developed. Smoothing up to some ten minutes was pursued.

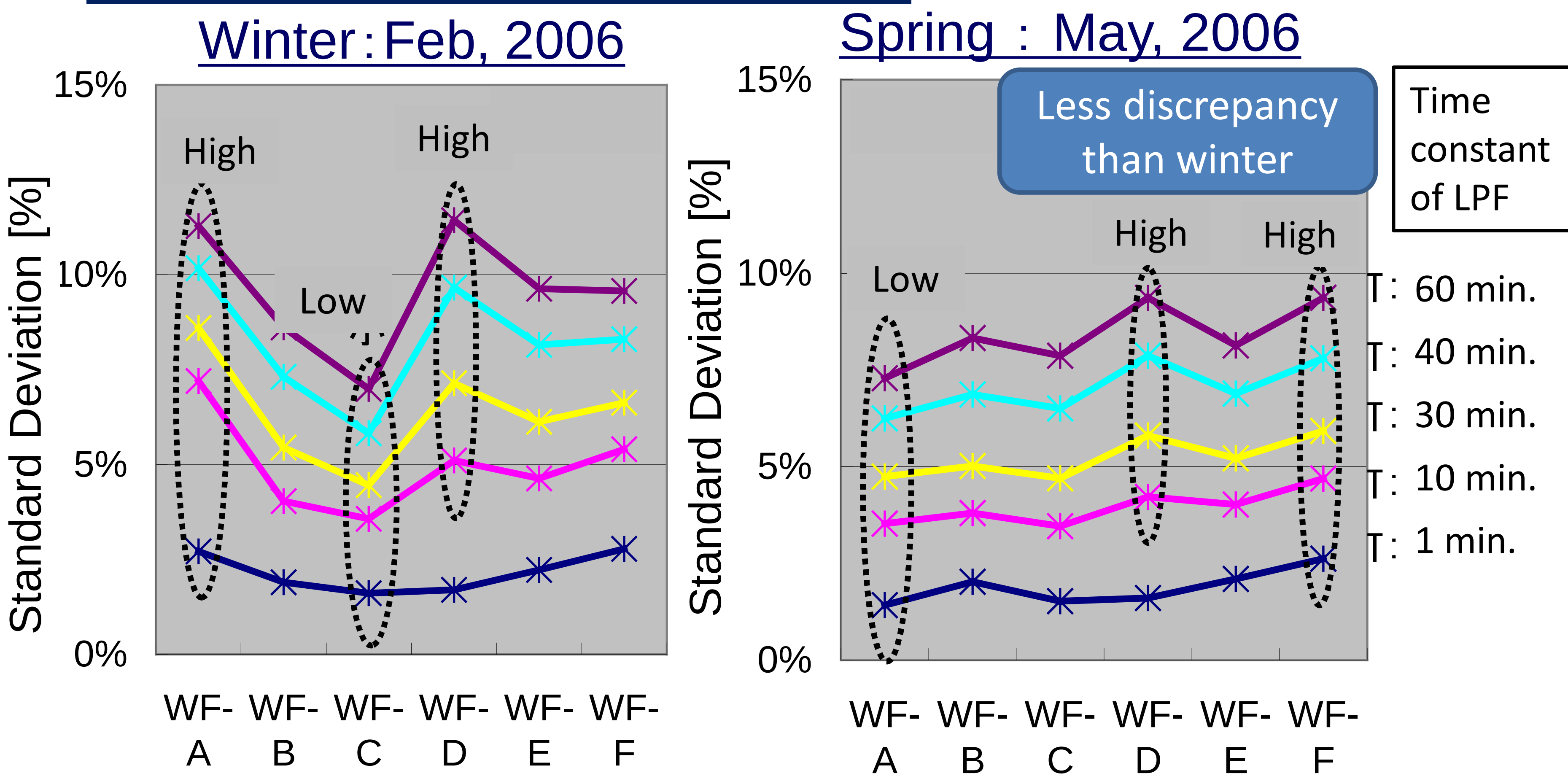
東京工業大学
Tokyo Institute of Technology

[Source] NEDO: Wind Power Stabilization Technology Development Project

Outline of a Hybrid System



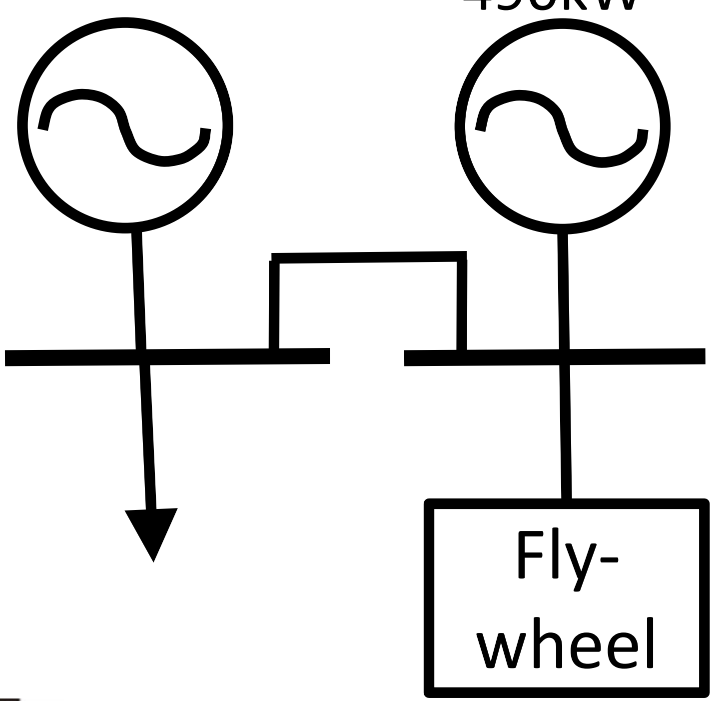
Low-Freq. Comp. of Wind Farm Output

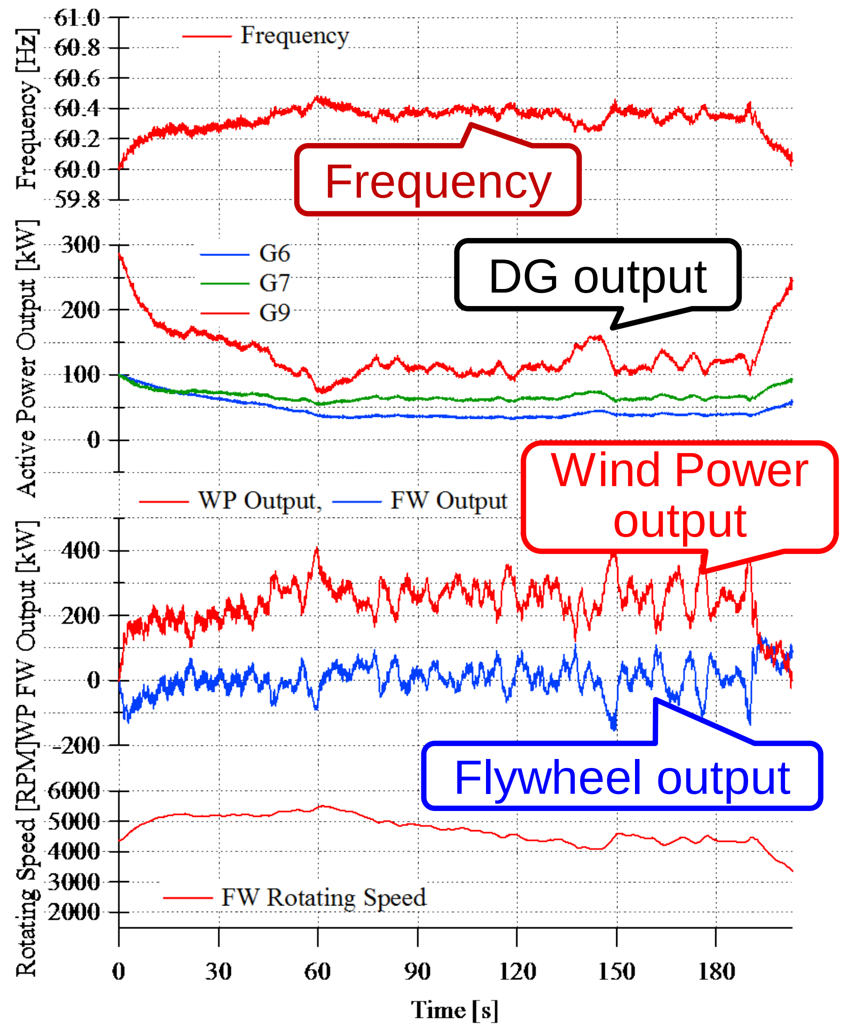


Output fluctuation characteristics considerably vary among wind farms.

[Source] NEDO: Wind Power Stabilization Technology Development Project

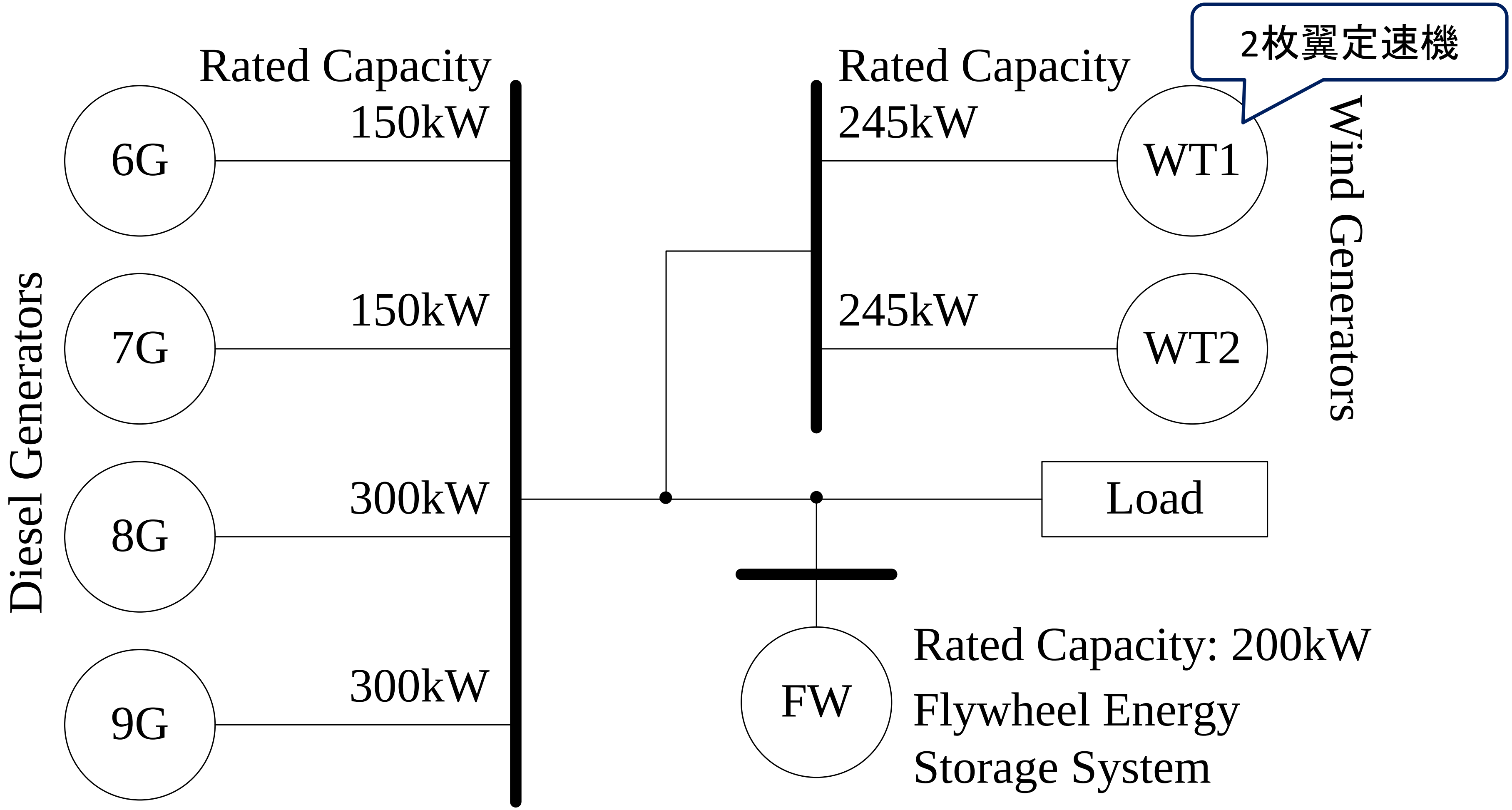
(2) Flywheel in an Insular System





[source]Yamashita, et al., Trans. B of IEE of Japan B, Vol131, No.5, 2011

2.2　電力貯蔵（離島系統のFW）

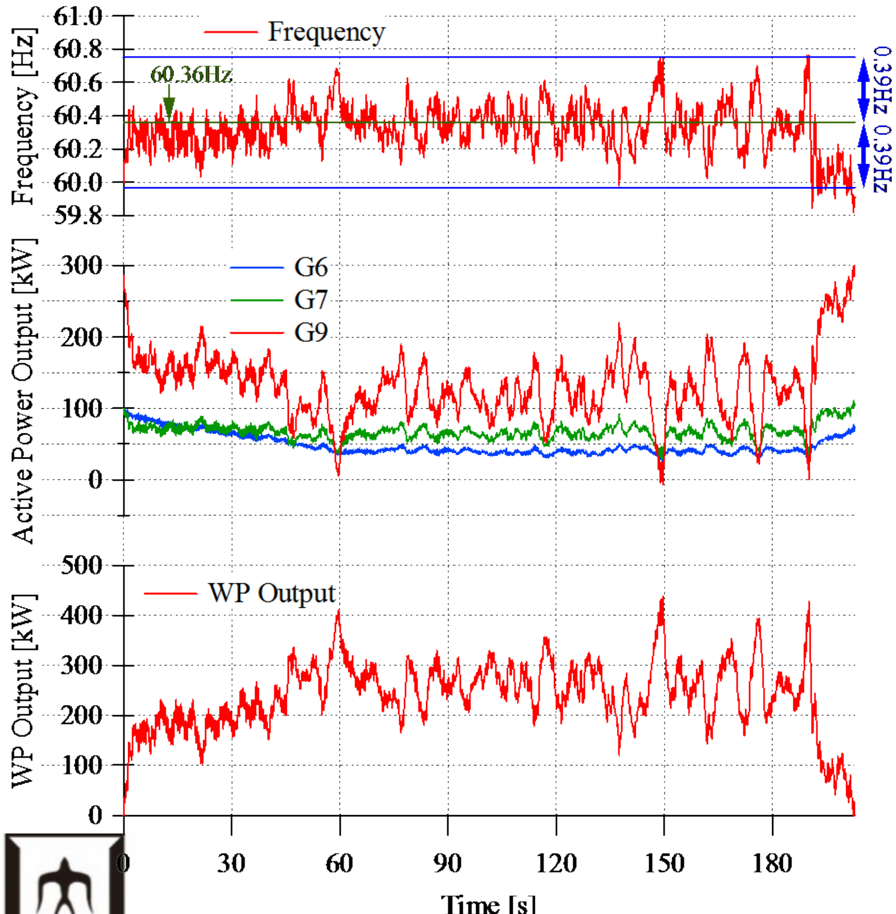


年最大電力≒600kW

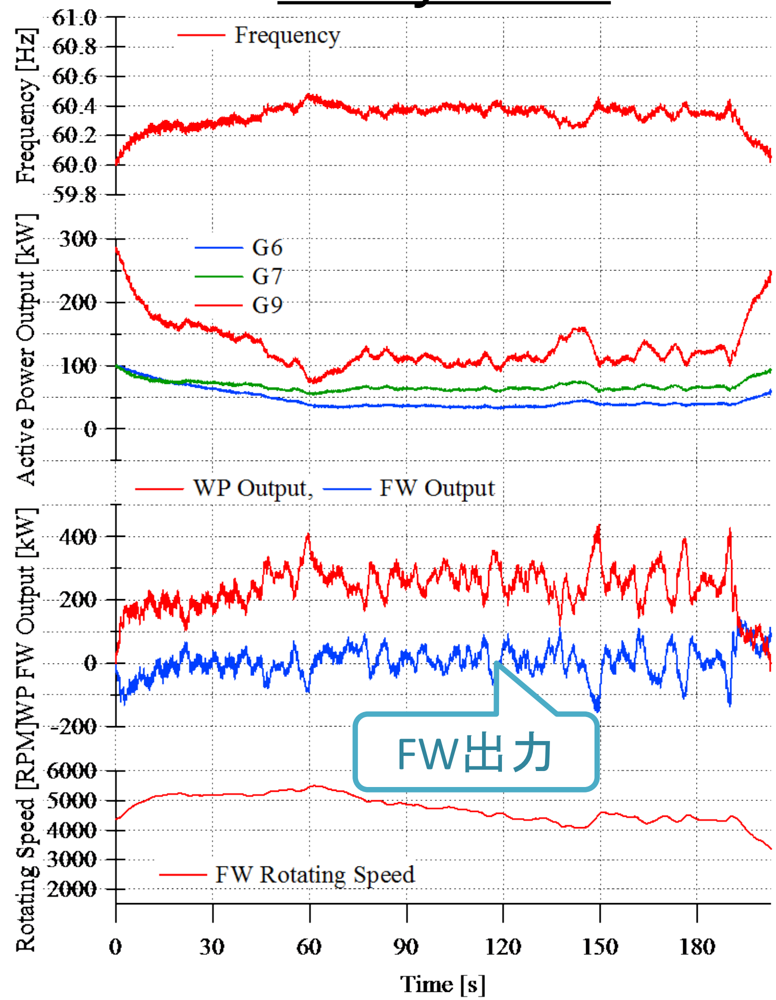
［出典］山下他，電学論B，Vol131，No.5，2011

(2) Flywheel in an Insular System

w/o Flywheel



w/ Flywheel

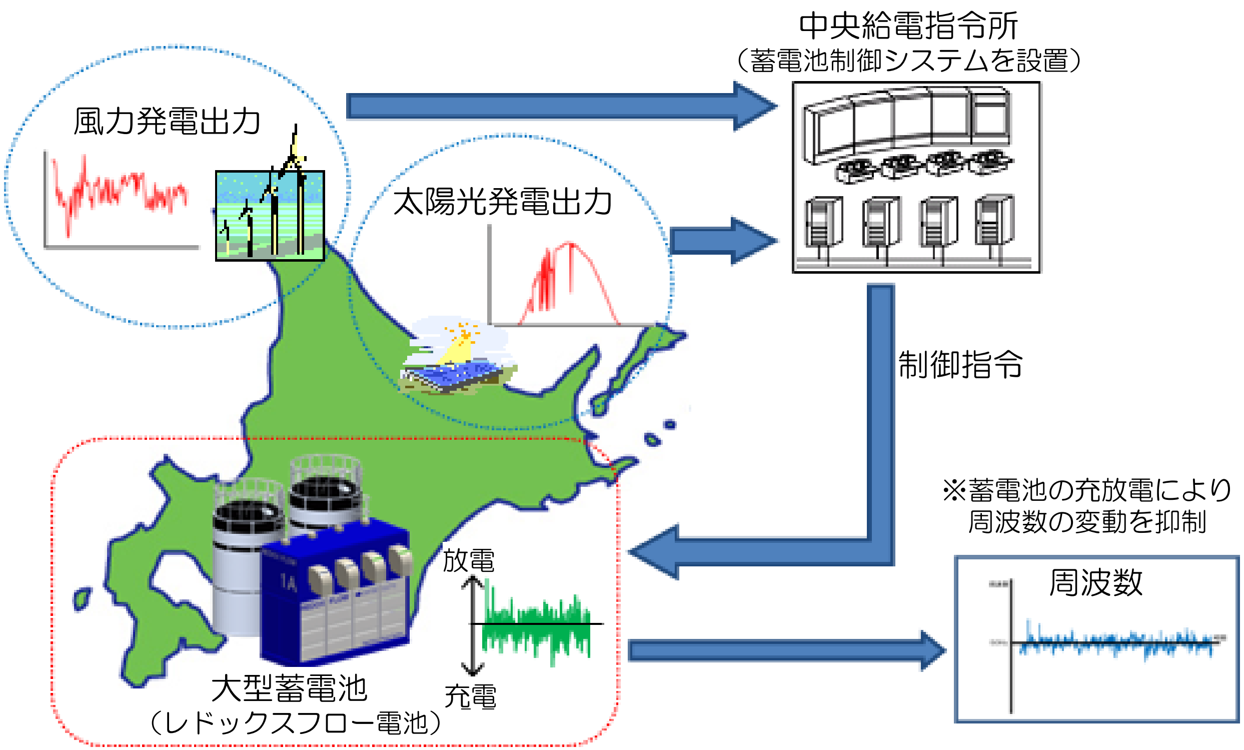


東京工業大学 Tokyo Institute of Technology

[source]Yamashita, et al., Trans. B of IEE of Japan B, Vol131, No.5, 2011

1．事業概要

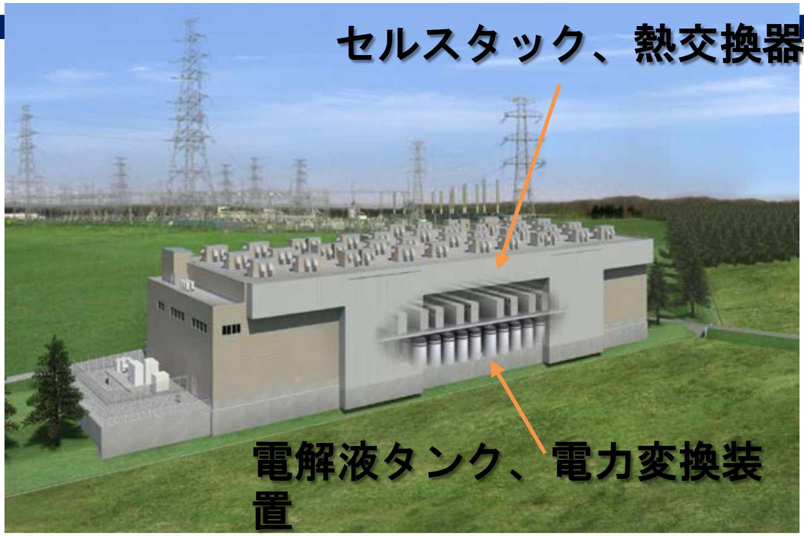
設置場所	北海道電力　南早来変電所　（北海道勇払郡安平町）
実証設備	レドックスフロー電池 定格出力：15,000kW 蓄電容量：60,000kWh
実証期間	2013年度～2018年度 （2015年12月25日に設備の運用を開始。2018年度まで実証試験を実施）
実証目的	再生可能エネルギーの出力変動に対する調整力としての性能実証および最適な制御技術の開発。

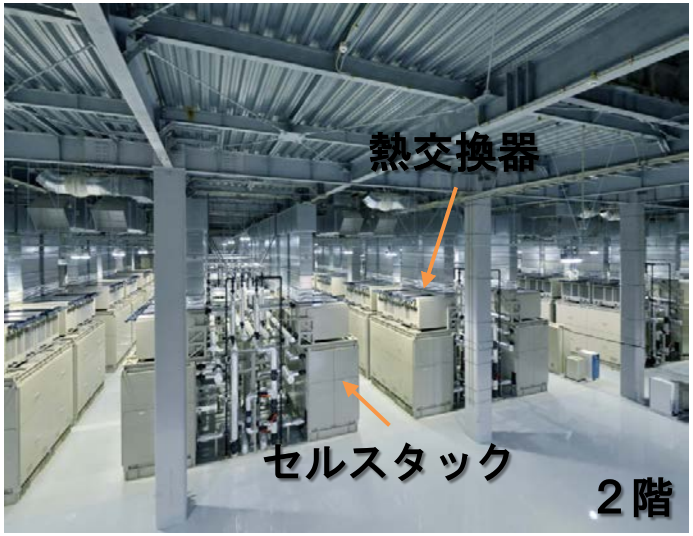


東京工業大学
Tokyo Institute of Technology

２．設備の外観

- １階に電解液タンク、電力変換装置、２階にセルスタック、熱交換器を設置。（設置面積：約５，０００m²）





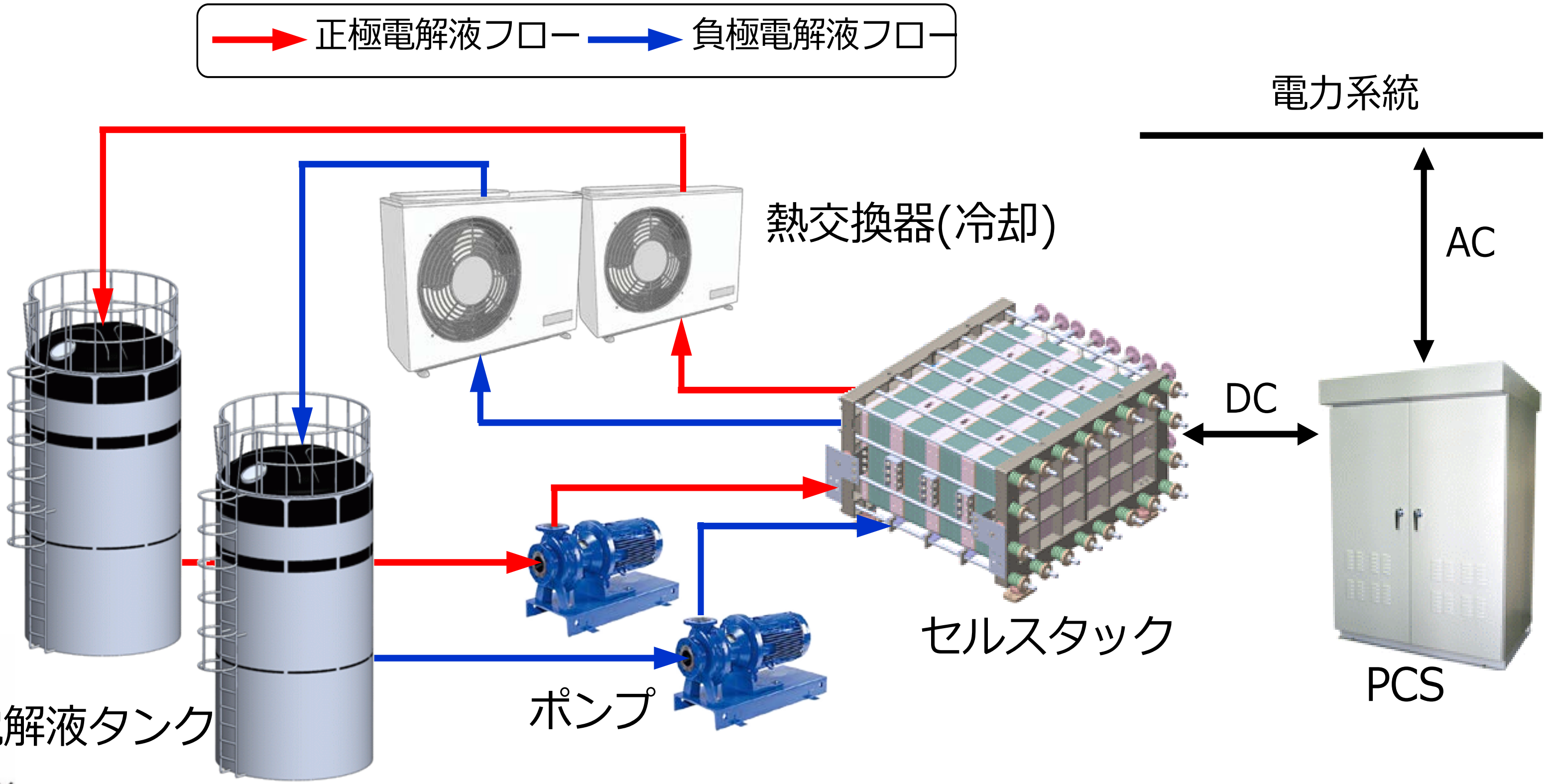
東京工業大学
Tokyo Institute of Technology

３．レドックスフロー電池の概要

●レドックスフロー電池は、正負極の電解液にバナジウムイオン水溶液を用いた電解液還流型の電力貯蔵用蓄電池です。

●下図に示すように電池反応を行うセルスタック、電解液を貯蔵する正負極のタンク、さらに電解液をタンクからセルへと循環するためのポンプ、配管等から構成されています。

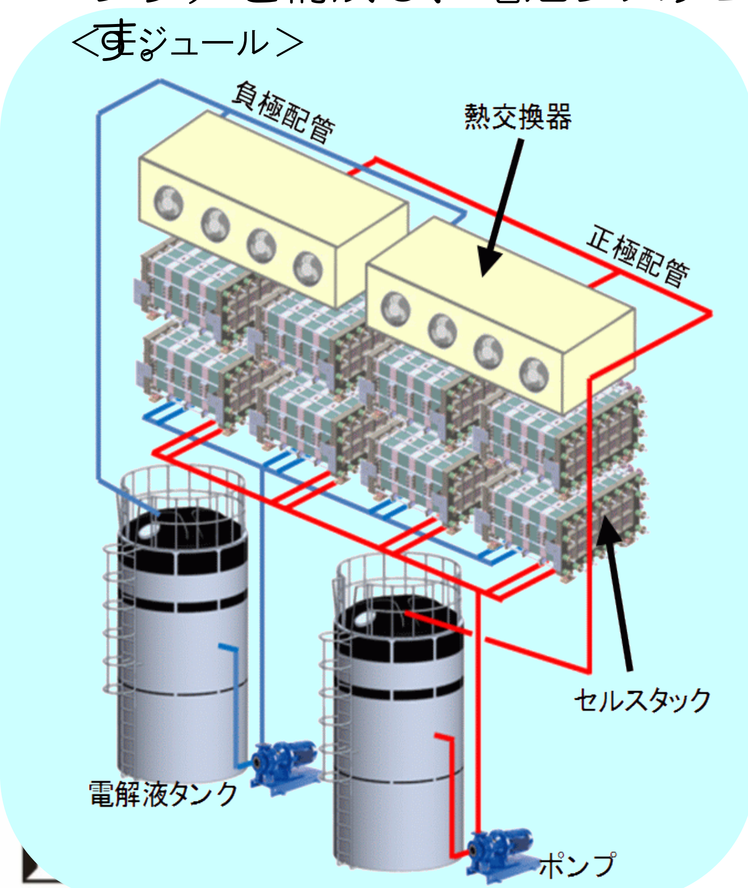
●電池設置後に、各種性能（容量、効率、保守性等）の評価を行います。

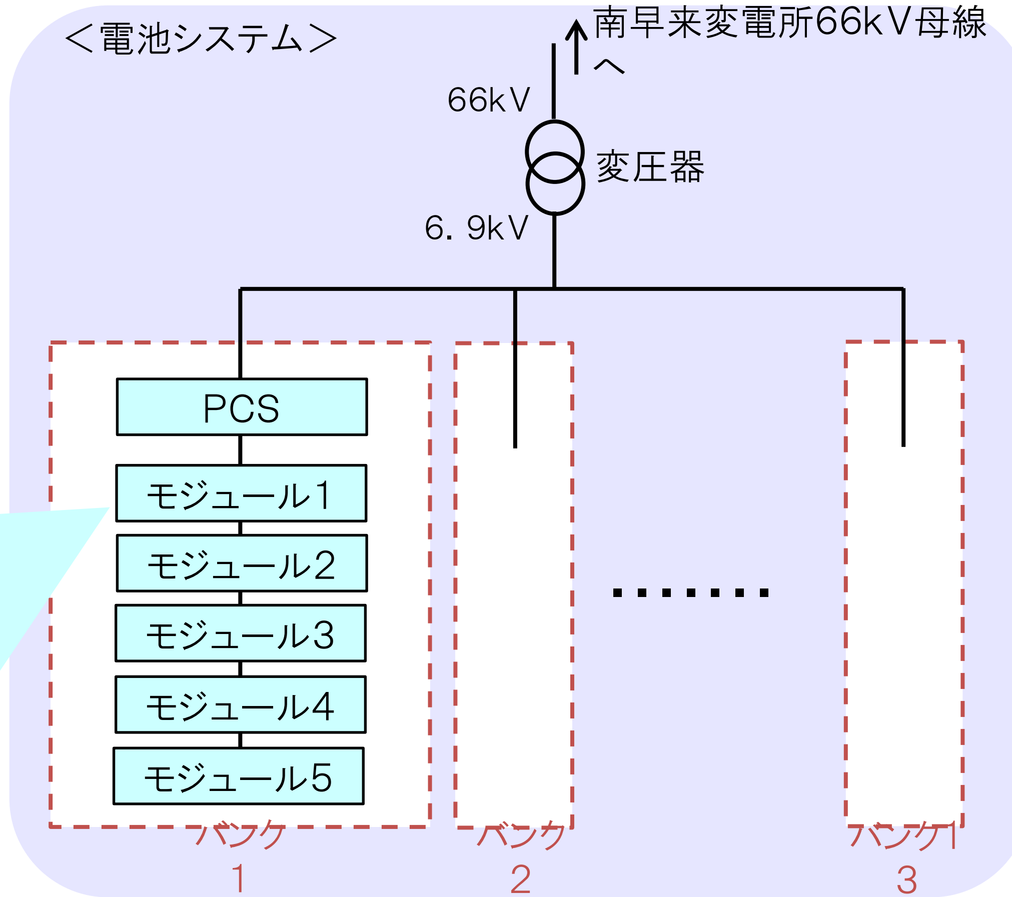


東京工業大学
Tokyo Institute of Technology

4．レドックスフロー電池システムの構成

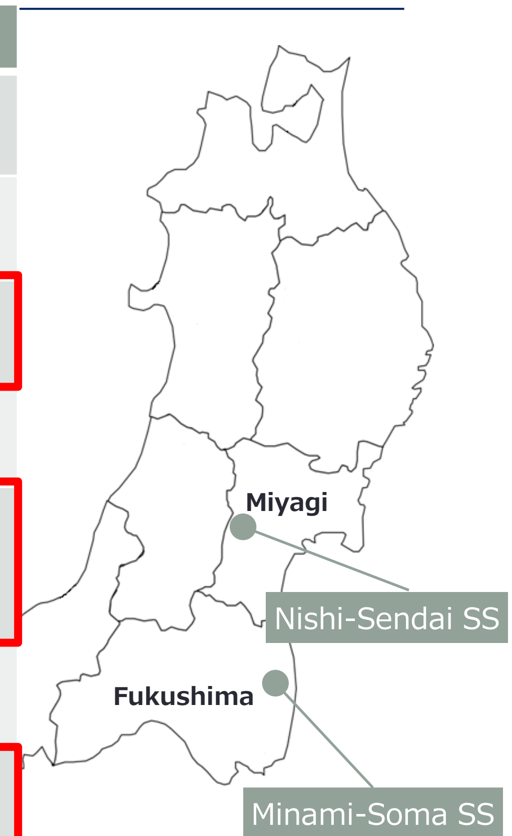
- 電池盤２面（１面あたりセルスタック４台内蔵）、熱交換器盤２面、電解液タンク２基、ポンプ２台、および配管により、電池の最小単位（モジュール）を構成します。
- ５組のモジュールと交直変換装置（ＰＣＳ）により、出力制御の最小単位（バンク）を構成し、電池システムは１３バンク（６５モジュール）から構成します。





Comparison of Battery System

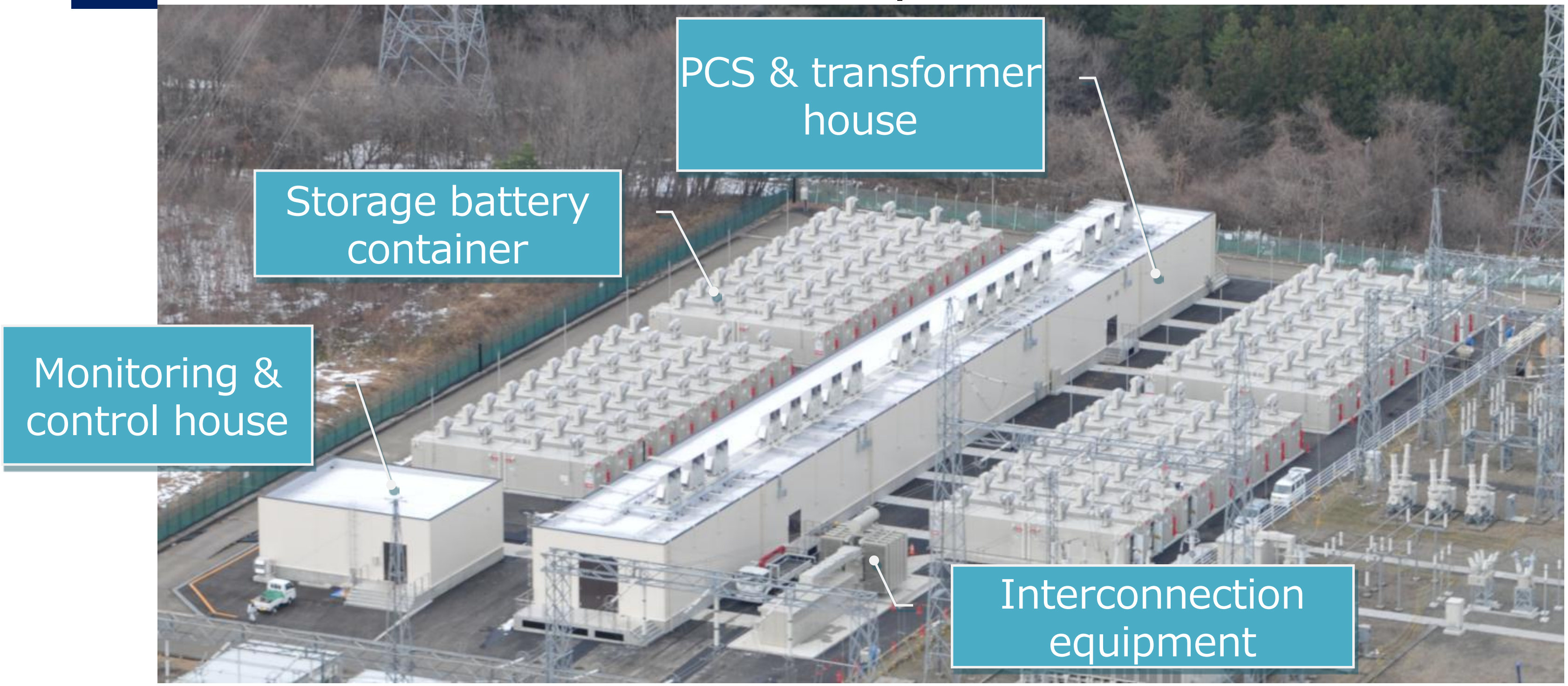
	Nishi-Sendai SS	Minami-Soma SS
Area	About 6,000m^2 (100m×60m)	About 8,500m^2 (100m×85m)
Start of operation	Feb. 2015	Feb. 2016
Battery Type	**Lithium-ion Battery**	**Lithium-ion Battery**
Manufacturer	Toshiba	Toshiba
System Performance	**Capacity : 20,000kW (short-time 40,000kW) Energy : 20,000kWh**	**Capacity : 40,000kW Energy : 40,000kWh**
Purpose	Compensate frequency fluctuation	Improvement of demand-and supply balance
Expectation effect	**Improvement of frequency stabilization**	**Expansion of the acceptable capacity**
Verification	･Load frequency control with storage battery	･Improvement of demand-and supply balance ･Voltage fluctuation control with reactive power control



Nishi-Sendai SS
Outline of Storage battery system（2）

より、そう、ちから。東北電力

Facilities picture



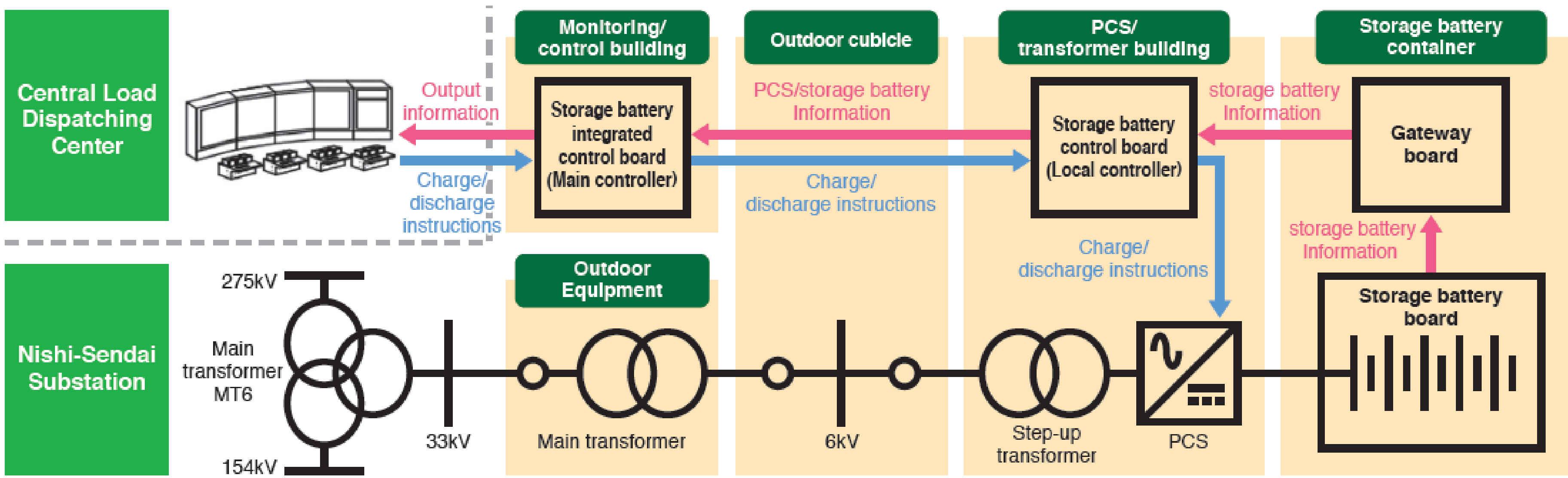
[outside]
・Storage battery container x80

[inside]
・Main controller(MC)
・PCS x80 unit
・Step-up transformer x20 unit

東京工業大学
Tokyo Institute of Technology

Nishi-Sendai SS
Outline of Storage battery system（５）

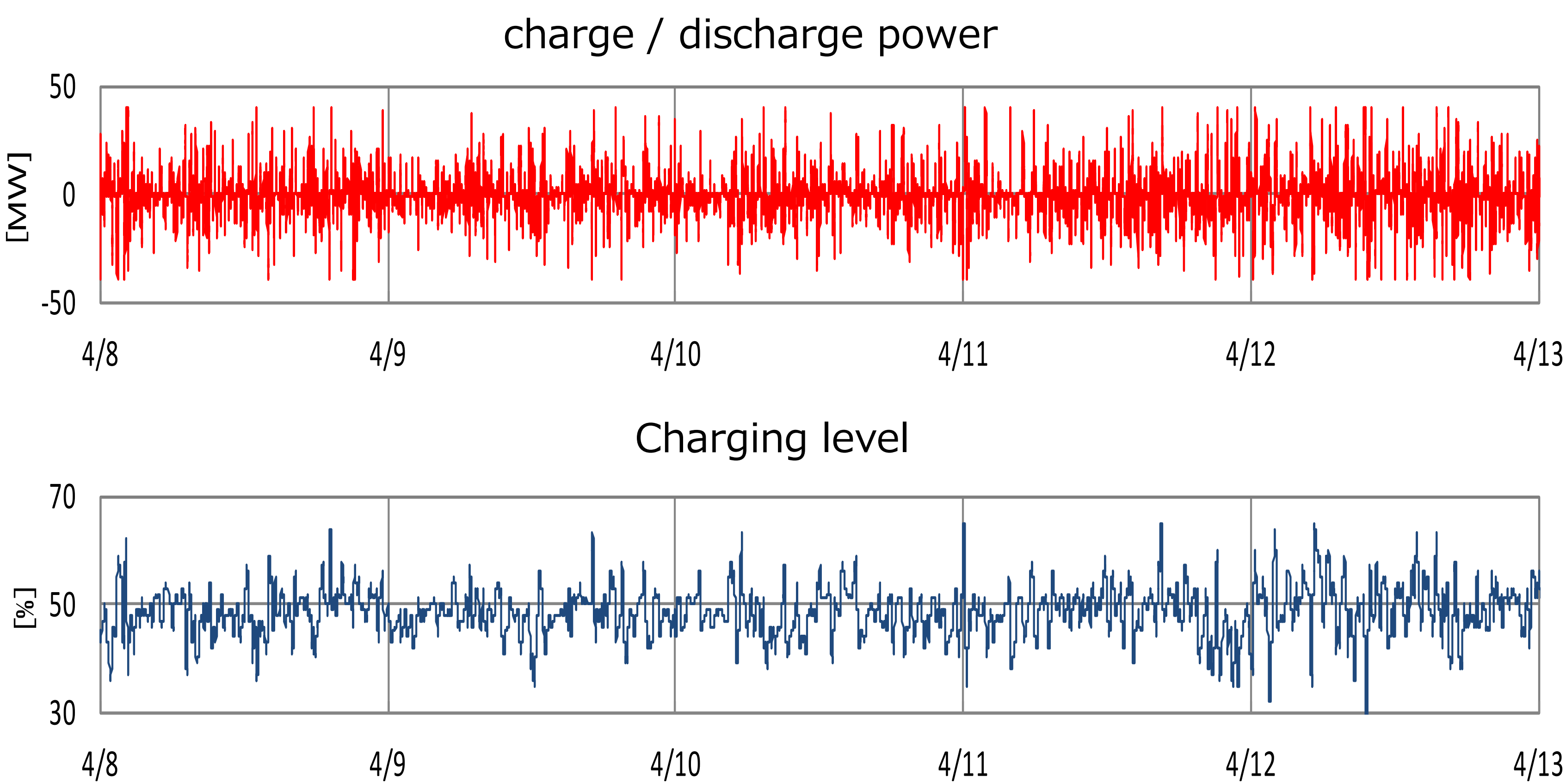
Image of control



東京工業大学
Tokyo Institute of Technology

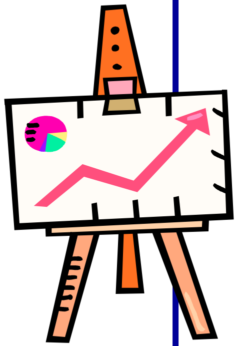
Outline of Nishi-Sendai Project（4）

- example of charge / discharge



Trend in Impacts of Wind Power

penetration	Area of impacts	Major Impacts
small	Local (Distribution)	•Power quality: eg,voltage
↓	↓	↓
	Sub-transmission	•Load flow: congestion
	↓	↓
large	System-wide (Transmission)	•System security, •Supply-demand-balance

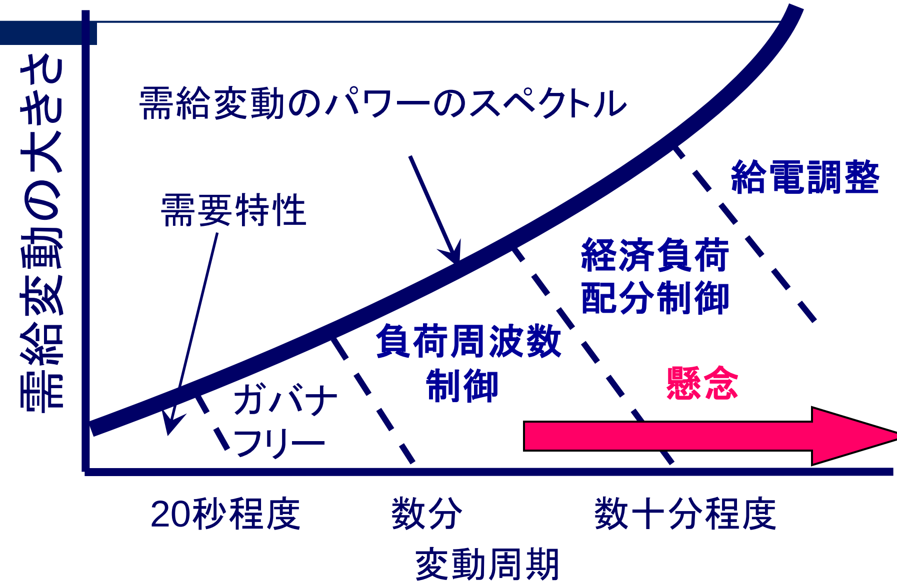


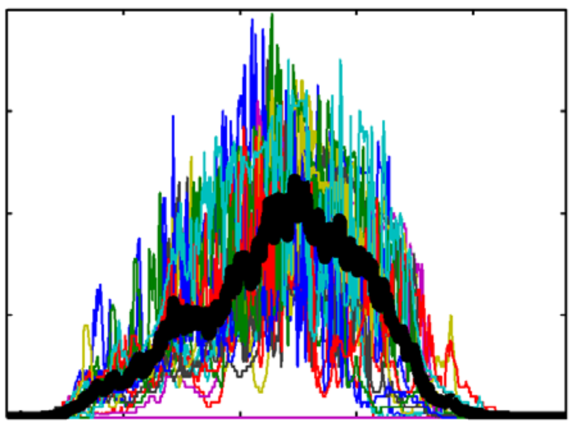
短周期変動への対応

- 負荷周波数制御領域より長周期の変動の影響懸念

⇩

- 変動の平滑化効果見極め
- 新しい調整力の確保：蓄電池　　　等





PV出力の平滑化効果(例)

苫前WF設置のレドックスフロー電池

[出典]NEDO：風力発電電力系統安定化等技術開発