S4-5

Recent trends on the interconnection between power storage facilities and real systems in Japan and the United States.

18th May 2017

Japan Electric Power Information Center (JEPIC)

Kawano Joji

Introduction

Advantages of renewable energy introduction to the grid

- Environment-friendly
- Low running costs

- Renewable energy introduction is expected to increase to realize a low-carbon society.

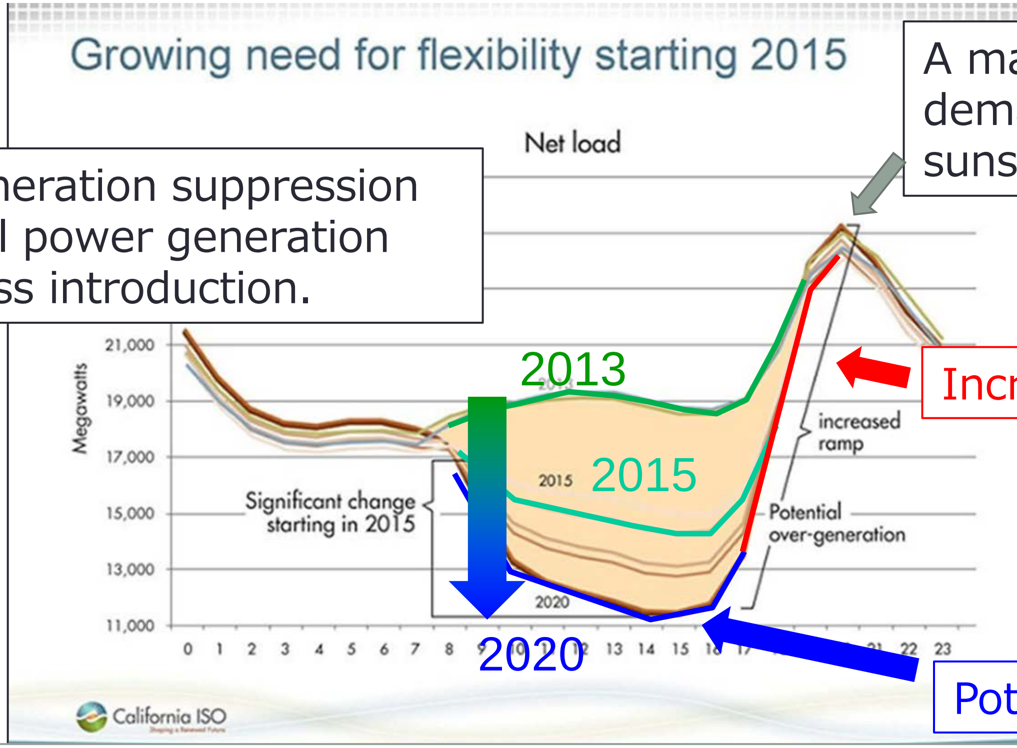
Problems of renewable energy introduction to the grid

- <u>Intermittent power generation (Strongly depends on the weather conditions)</u>
- <u>Reducing reliability of the grid</u>

- <u>A solution is needed to increase renewable energy introduction to the grid.</u>

Introduction

Example of reduced reliability of the grid #1



Power generation suppression of thermal power generation by PV mass introduction.

A maximum (peak) volume of demand is observed around sunset.

Increased ramp up.

Potential of over-generation.

(Comment)

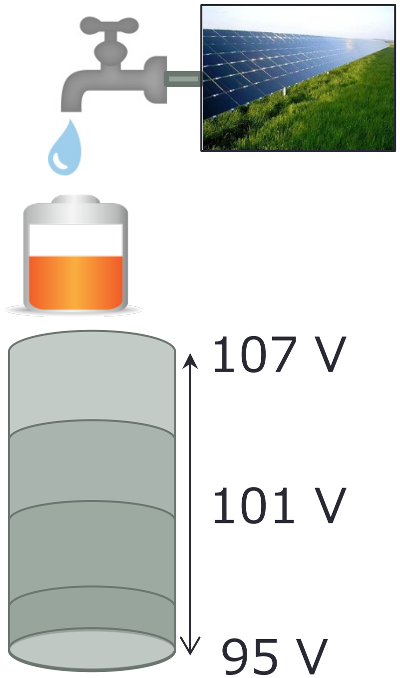
- The results listed above cause a reduction in the value of the base load generation.
- A sudden increase of demand will be observed around dusk.

(Solution)

- Expansion of pumped Hydro.
- Reduction in the volume of interconnectivity.

Introduction

Example of reduced reliability of the grid #2



(Comment)

- Voltage fluctuation in a transformer bank increases with the introduction of massive PV current.
- Massive PV current increases the risk of deviating from the standard range of voltage.

(Conventional solution)

- Installation of additional transformers.
- Reduction in the volume of interconnectivity.

"Fluctuations" are caused by the attribute of electricity, therefore a new solution is needed to increase renewable energy development.

And one of the solutions is "energy storage batteries" that make it possible to store electricity. We will introduce Japan and U.S. initiatives in energy storage batteries as case examples.

Purposes of interconnected energy storages

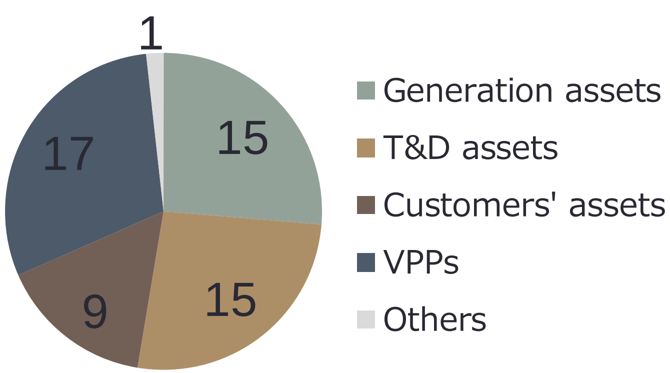
Interconnecting batteries to the grid has the following advantages.

- Batteries can be used for two purposes.
  ･･･Charging and discharging are possible whenever you like.
- Less loss and more environmentally-friendly while charging and discharging.
  ･･･Compared to other energy storage systems, the batteries have a small environmental load at charge and discharge.
- Added uses can be developed.
  ･･･ In addition to the use described above, batteries have other uses such as in virtual power plants which improves the performance and reliability of the grid.

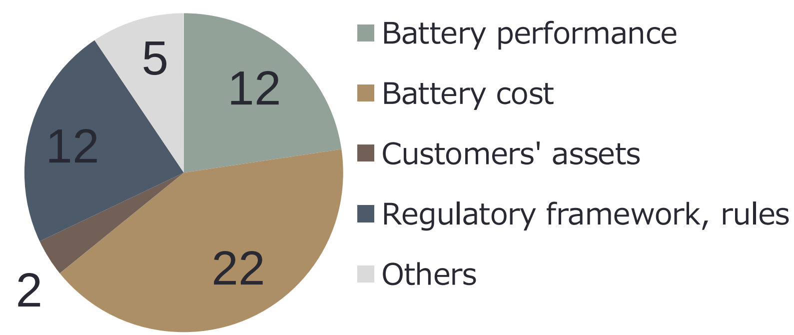
Survey results

Electric power suppliers' interests and concerns in Japan were surveyed by JEPIC.

Suppliers' interests



Suppliers' concerns

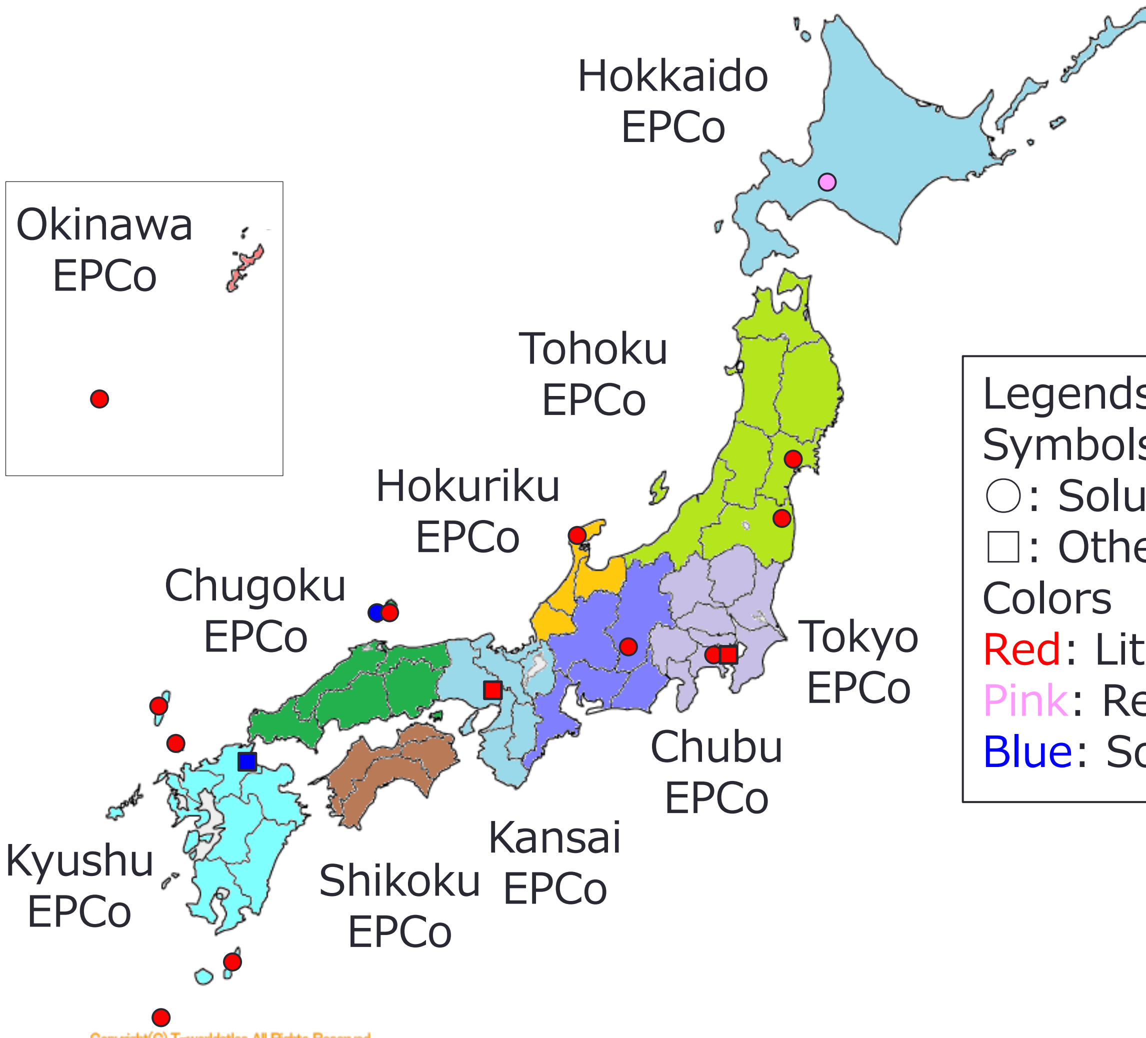


(N=28, multiple answers allowed)

- We surveyed participants' interests on application of energy storage systems.
- They have interests in each application.
- They need various types of information about how to apply energy storage.
- We surveyed participant's concerns when installing energy storage systems.
- We think performance and the cost of battery systems are in everyone's interest.

These results indicate that suppliers have a strong interest in energy storage systems, and therefore we have reported recent trends on the interconnection between power storage batteries and real systems in Japan and the United States.

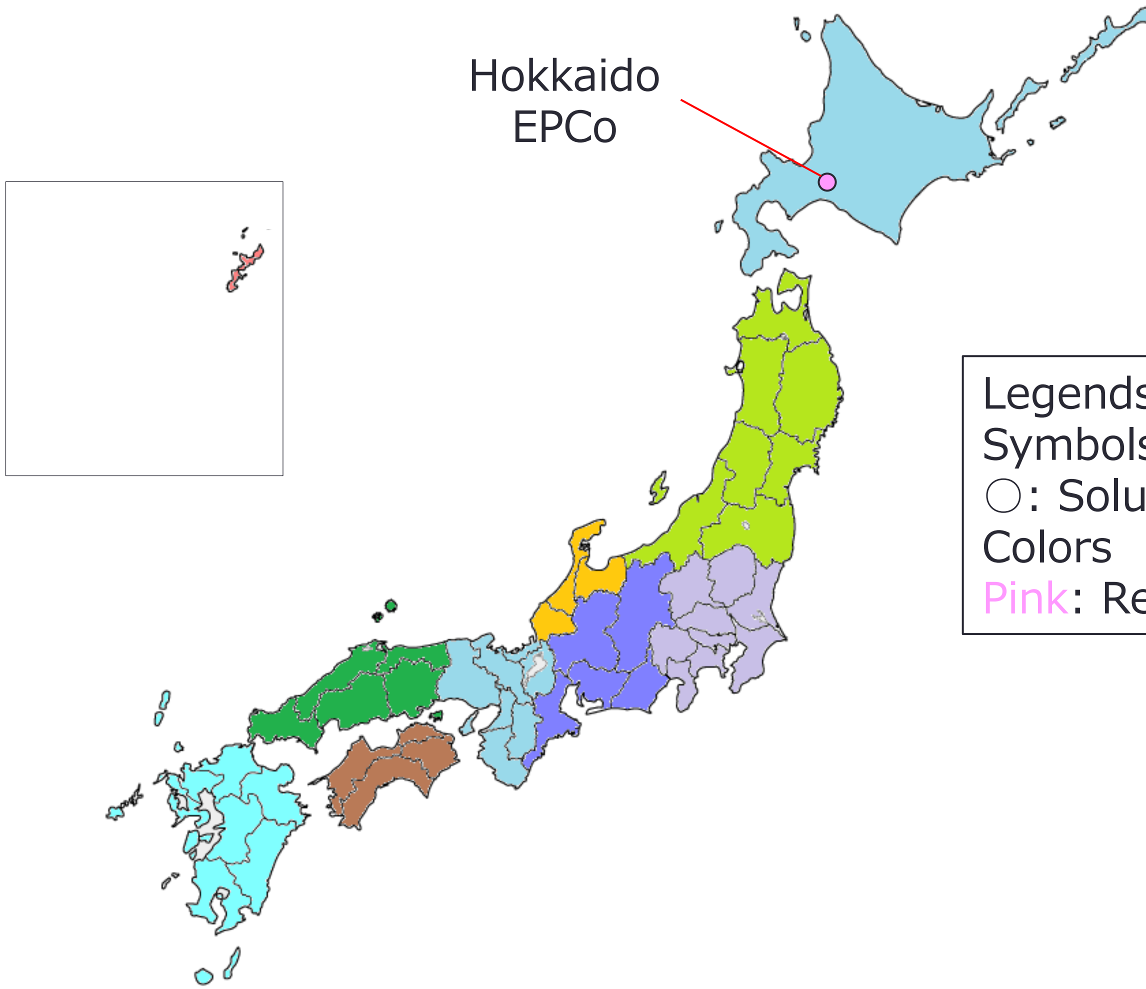
Recent demonstrations in Japan



Legends
Symbols
○: Solution for Renewable Energies
□: Others
Colors
Red: Lithium-ion
Pink: Redox-Flow
Blue: Sodium-Sulfur (NAS)

Source: Japanese electric power companies' web sites

Recent demonstrations in Japan



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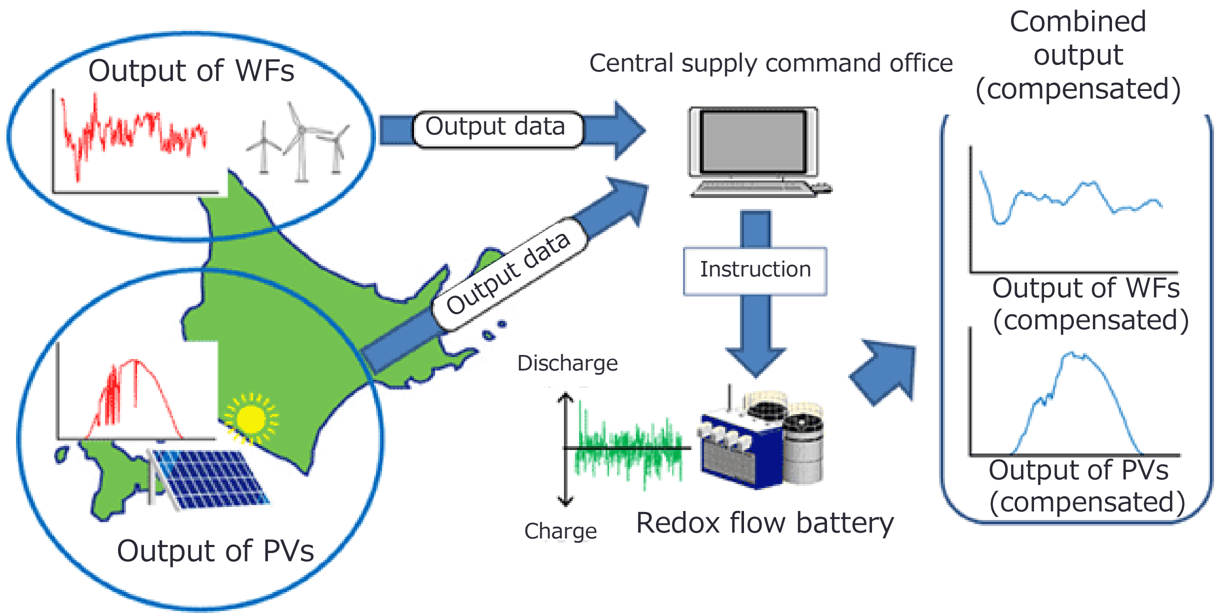
Recent demonstration by Hokkaido EPCo.

Minami-Hayakita Substation Large-Scale Storage Battery System Project



Project profile

- 60 MW of redox flow batteries has been installed in the Minami Hayakita substation.
- Development of the frequency control method by using BESS as a power supply for frequency adjustment
- Development of operational techniques against surplus electric power
- Performance evaluation of the redox-flow battery, etc.
- Test period FY 2013-2018.
  Construction: FY2013-2015
  Demonstration: FY2015-FY2019
- Supported by METI

Hokkaido Electric Power Co., Inc. ANNUAL REPORT 2015
http://www.hepco.co.jp/corporate/ir/ir_lib/pdf/annual2015.pdf

Recent demonstration by Hokkaido EPCo.

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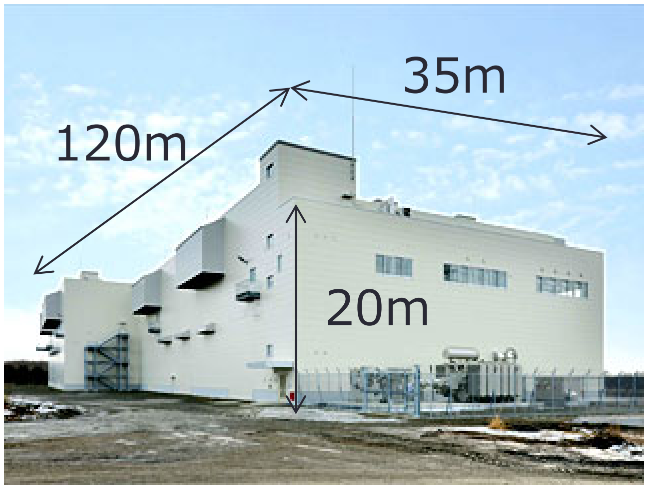
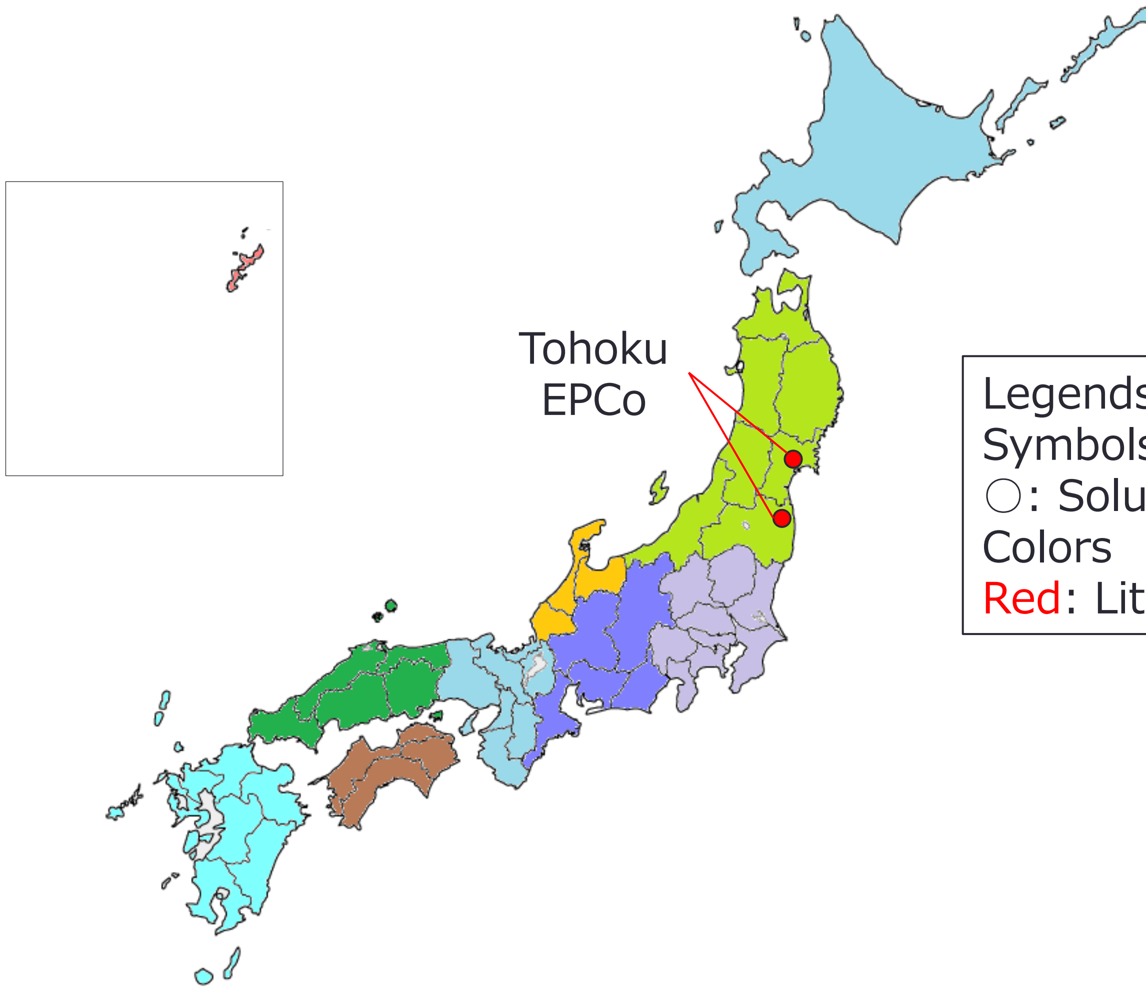


Overview of energy storage facility

- Tanks of electrolyte solutions are stored on the 1st floor.
- Cell stacks, and heat exchanger are stored on the 2nd floor.

  Footprint: 5,000 m^2
  Output: 15 MW
  Capacity: 60 MWh

Recent demonstrations in Japan



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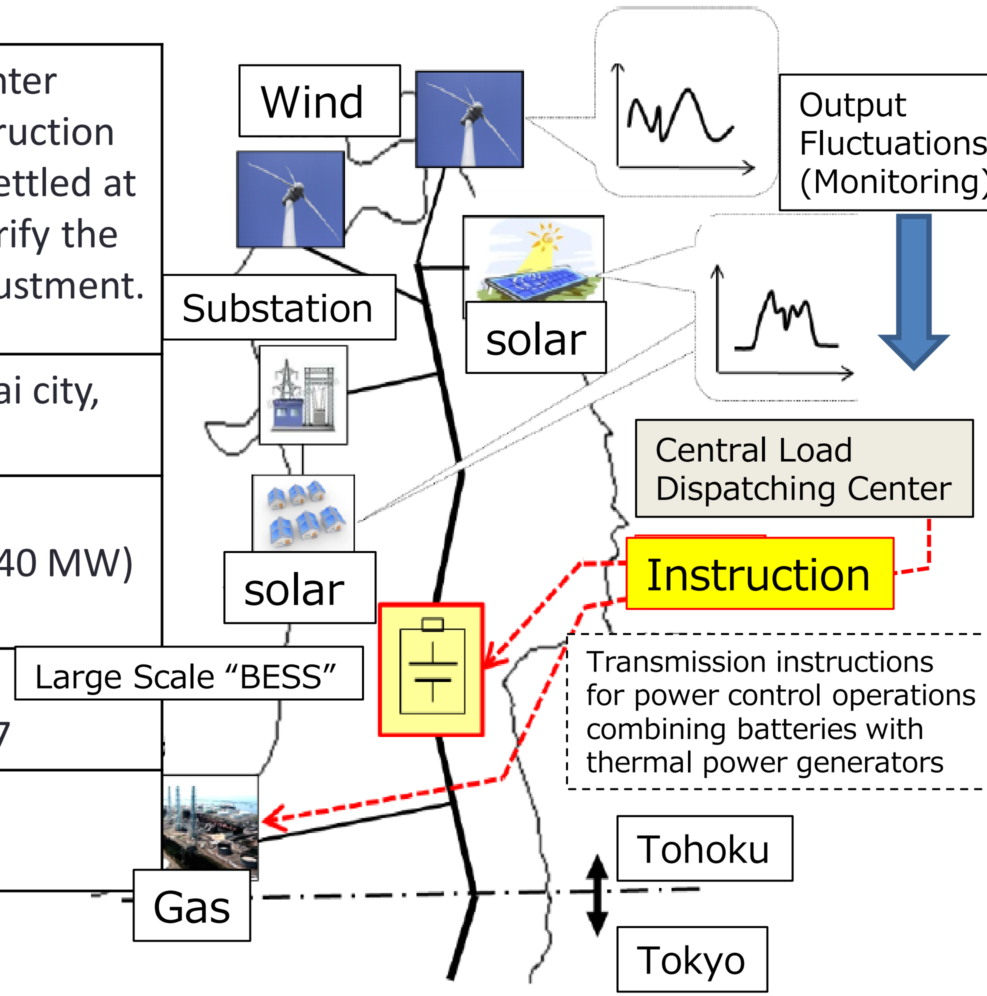
Recent demonstration by Tohoku EPCo. #1

Nishisendai Battery Storage Verification Project

Objectives		The power system central center controls by power adjust instruction sent to the large scale BESS settled at the substation, in order to verify the BESS effect for frequency adjustment.
Details	Location	Nishisendai Substation (Sendai city, Miyagi Prefecture)
	Specifi-cations	Lithium-ion battery Output: 20 MW (short term: 40 MW) Capacity: 20 MWh
	Test period	Construction: FY 2013-2014 Demonstration: FY 2014-2017
	Support	Associations

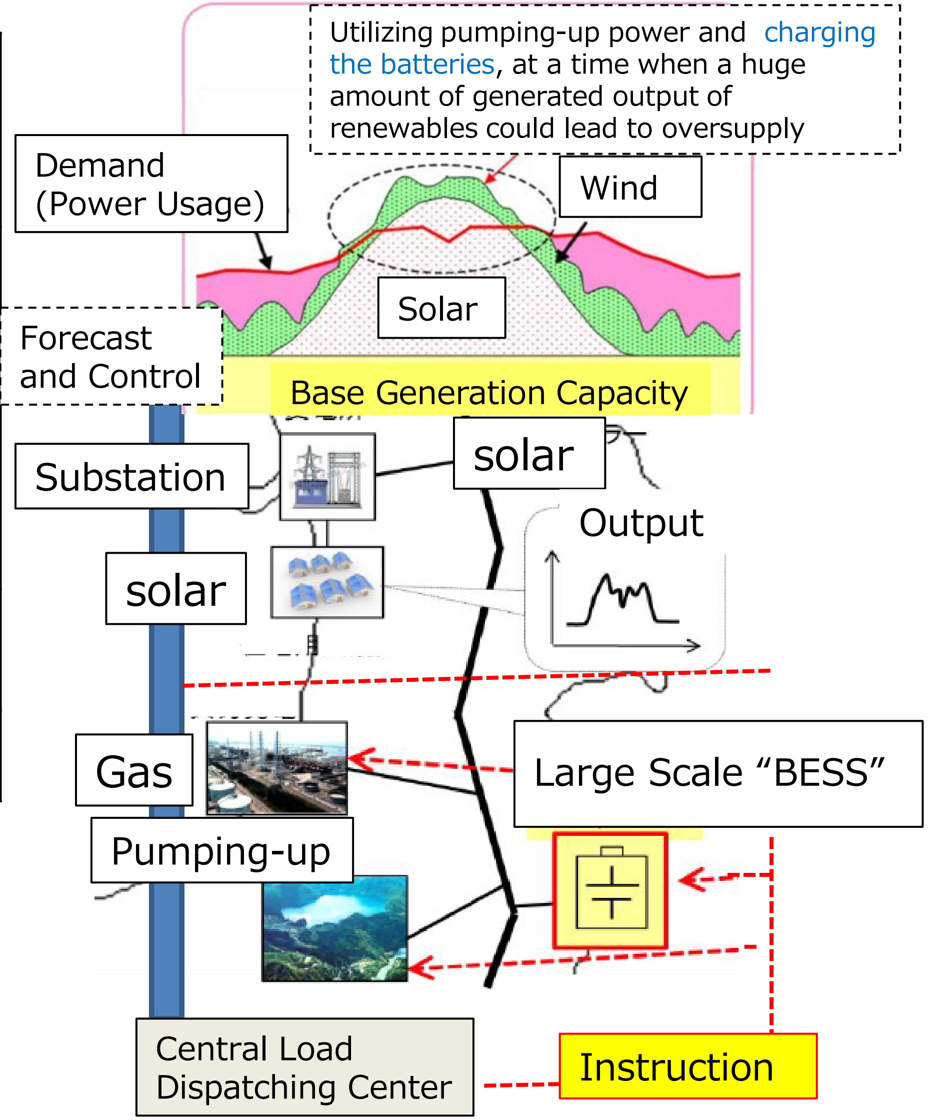


Tohoku Electric Power Co., Inc. ANNUAL REPORT 2016
http://www.tohoku-epco.co.jp/ir/report/annual_report/pdf/ar2016.pdf

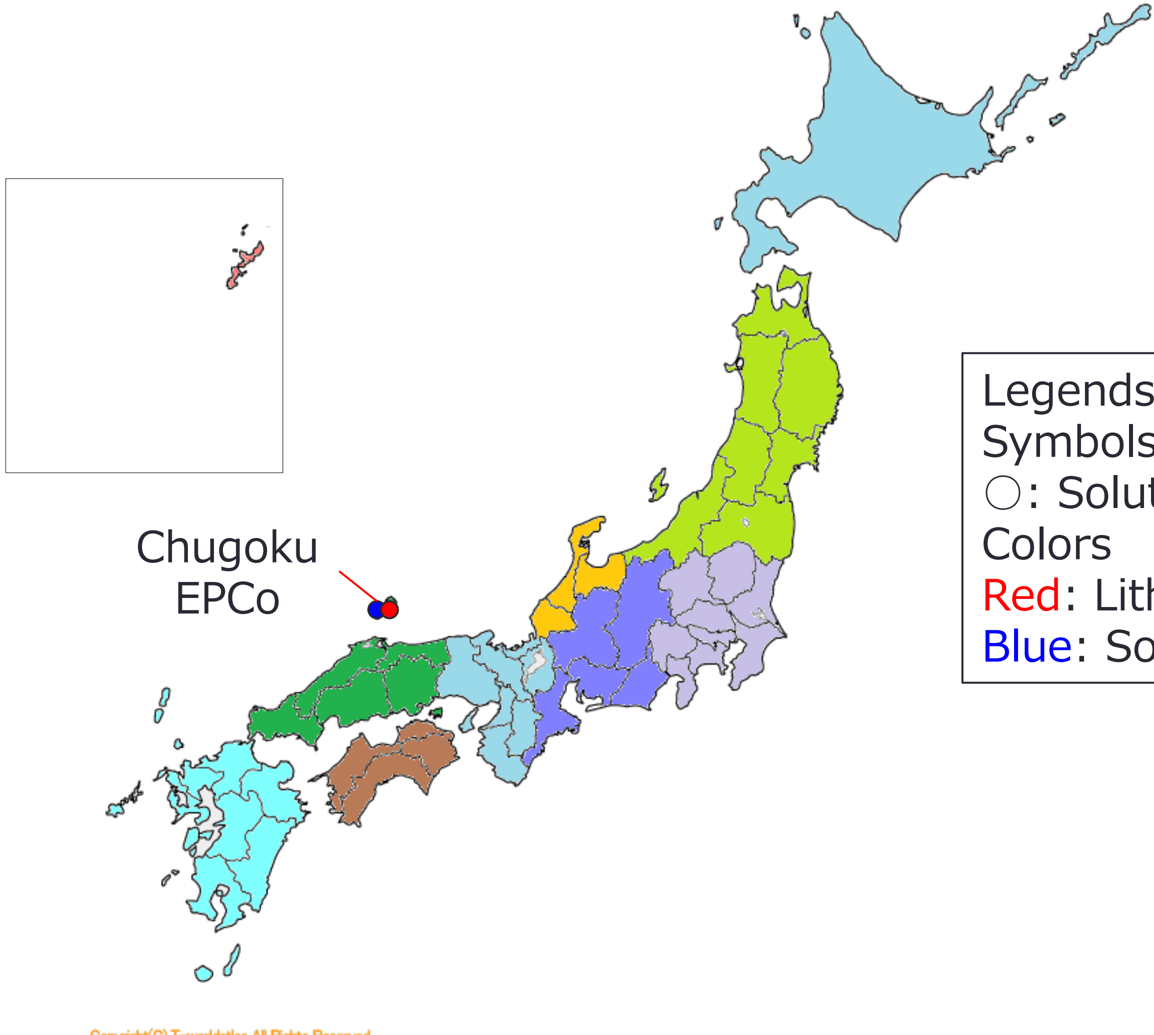
Recent demonstration by Tohoku EPCo. #2

Minamisoma Battery Storage Verification Project

Objectives		Improvement of balance of demand and power supply with large scale battery.
Details	Location	Minamisoma Substation (Minamisoma city, Fukushima Prefecture)
	Specifi-cations	Lithium-ion battery Output: 40 MW Capacity: 40 MWh
	Test period	FY 2016-2017
	Support	Associations



Recent demonstrations in Japan



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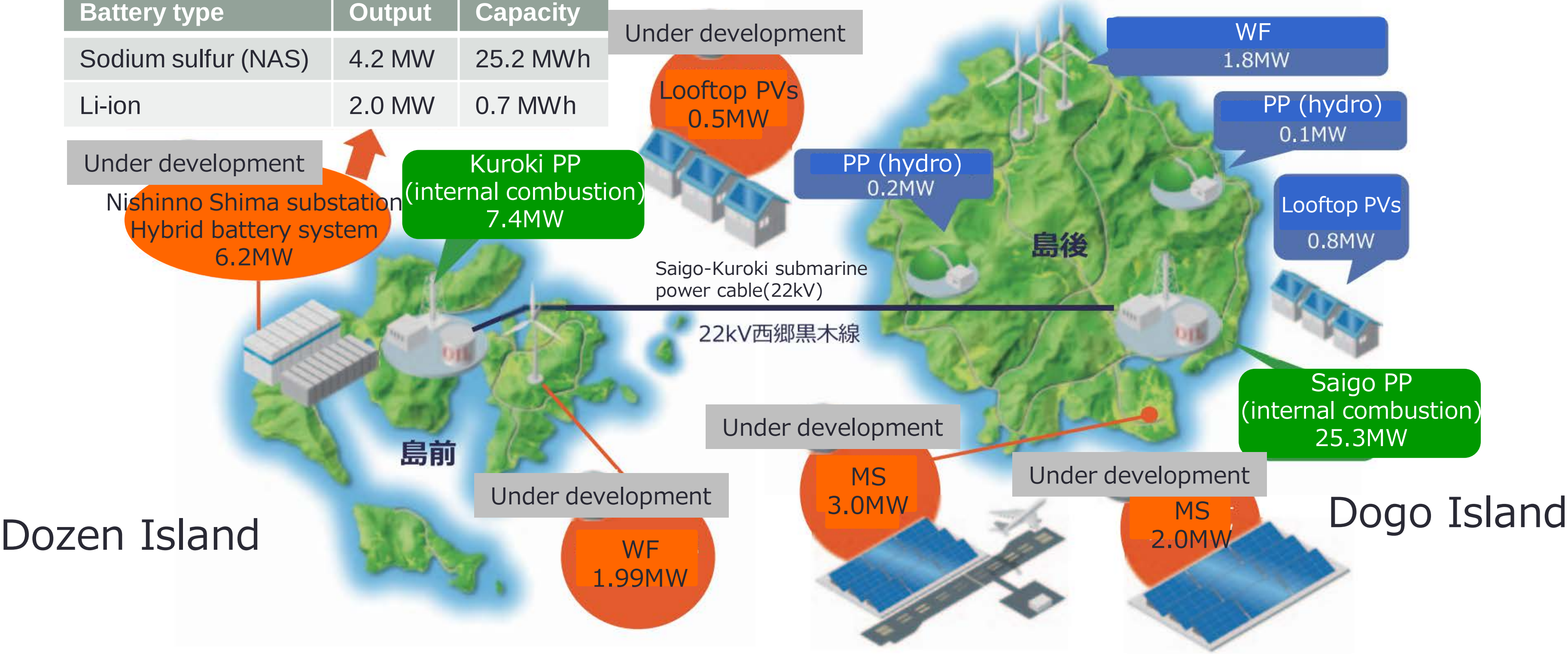
Source: Japanese electric power companies' web sites

Recent demonstration by Chugoku EPCo.

Demonstration Project utilizing Hybrid Storage Battery System on the Oki Islands

Specifications of hybrid battery

Battery type	Output	Capacity
Sodium sulfur (NAS)	4.2 MW	25.2 MWh
Li-ion	2.0 MW	0.7 MWh



Project profile

- ✓ In order to maximize renewable energy, a hybrid battery system will be installed, constructed with two types of batteries which have different characteristics.
- ✓ Charge-discharge management and control technology will be tested in the field.

EnerGia ANNUAL REPORT 2016
http://www.energia.co.jp/e/ir/report/pdf/ar16/ar16.pdf

Recent demonstration by Chugoku EPCo.

Demonstration Project utilizing Hybrid Storage Battery System in the Oki Islands

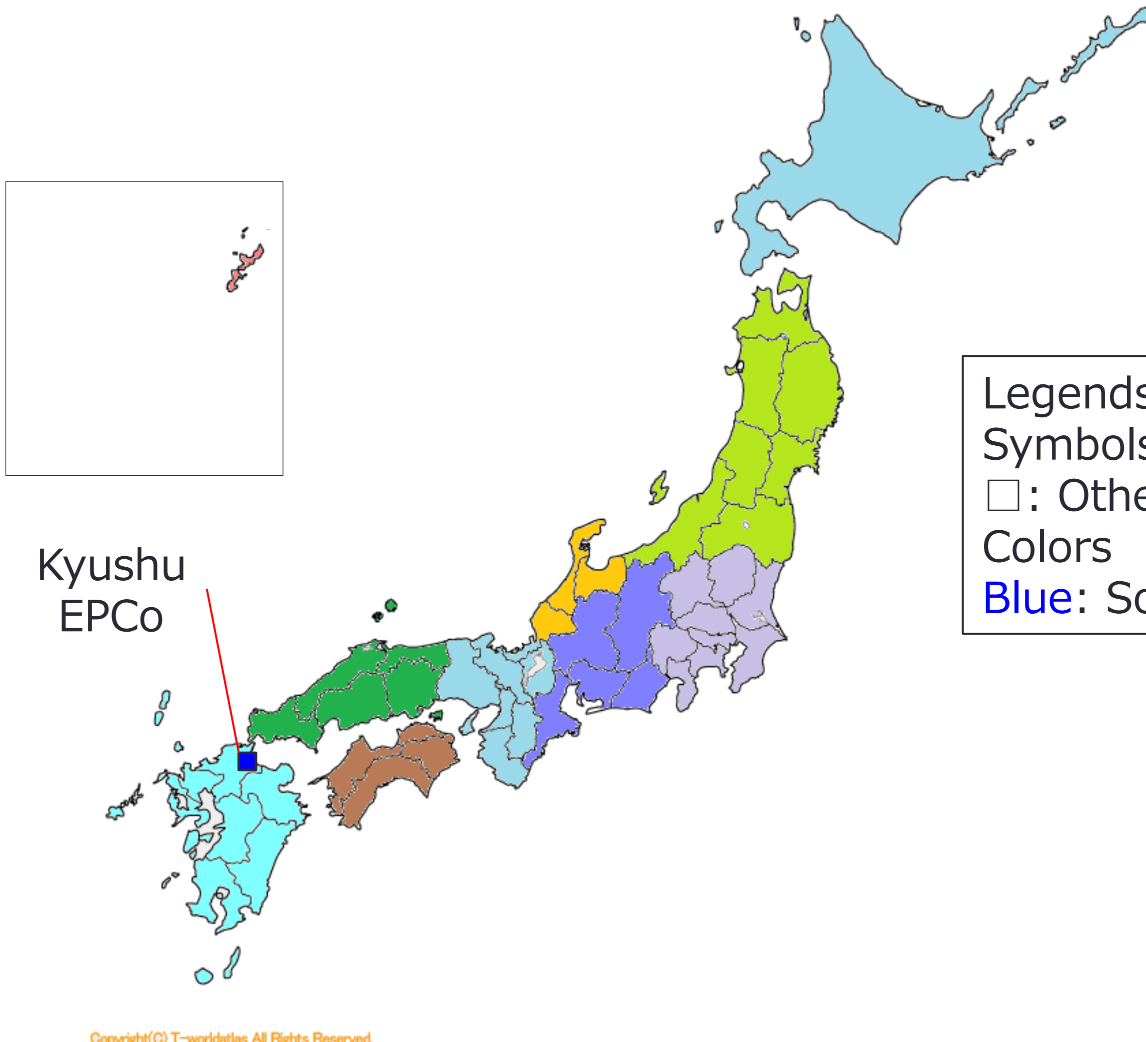
1. Overview of the energy storage facility
 (1) Location
  Oki Islands (at the Nishino Shima substation)

 (2) Battery System (Hybrid System)
  Sodium sulfur battery: 4.2 MW (25.2 MWh)
  Lithium-ion battery: 2.0 MW (0.7 MWh)

2. Test period
 Construction: FY2014-2015
 Demonstration: FY2015-FY2018

3. Supported by MOE

Recent demonstrations in Japan



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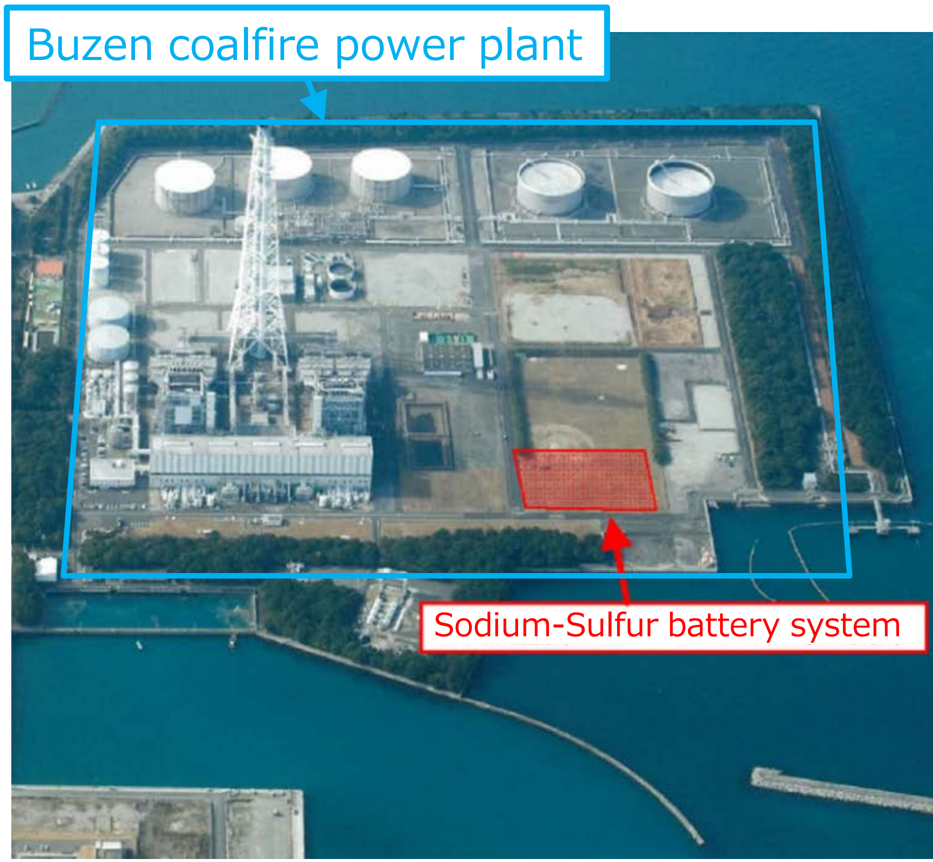
Source: Japanese electric power companies' web sites

Recent demonstration by Kyushu EPCo.

Demonstration at Buzen Battery Substation



Project profile

1. Location
   Buzen coalfire power plant
   (Buzen city, Fukuoka Prefecture)

2. Objectives
   - ✓ To improve the balance of supply & demand
   - ✓ To control grid voltage/frequency
   - ✓ To evaluate the battery system

3. Battery specification
   Sodium-Sulfur battery
   Output: 50 MW
   Capacity: 300 MWh
   Footprint: 14,000 m^2

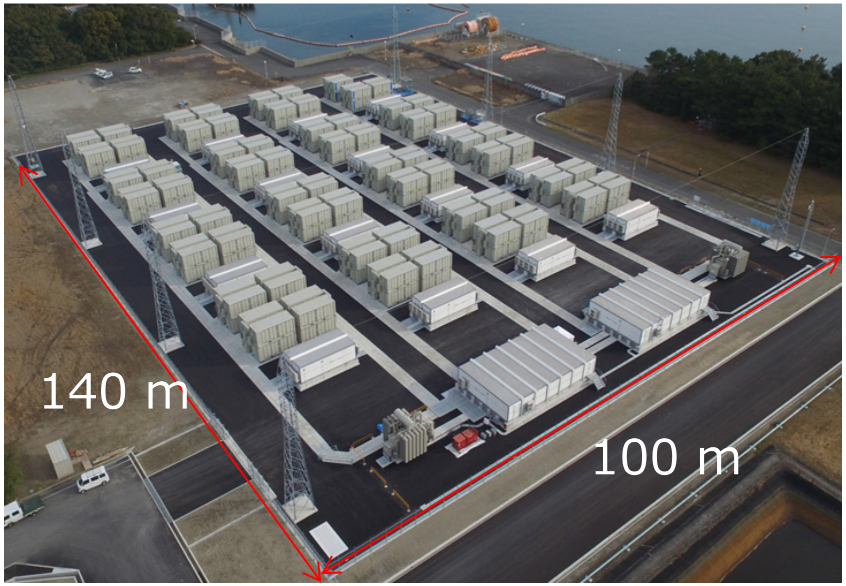
4. Test period
   FY 2015-2017

5. Supported by METI

Kyushu Electric Power Group Medium-term Management Policy
http://www.kyuden.co.jp/var/rev0/0053/7385/ji06d57xm764dh7.pdf
MITSUBISHI ELECTRIC Co. Press Release
http://www.mitsubishielectric.com/news/2016/pdf/0303-b.pdf

Recent demonstration by Kyushu EPCo.

Demonstration at Buzen Battery Substation



Features of the battery system

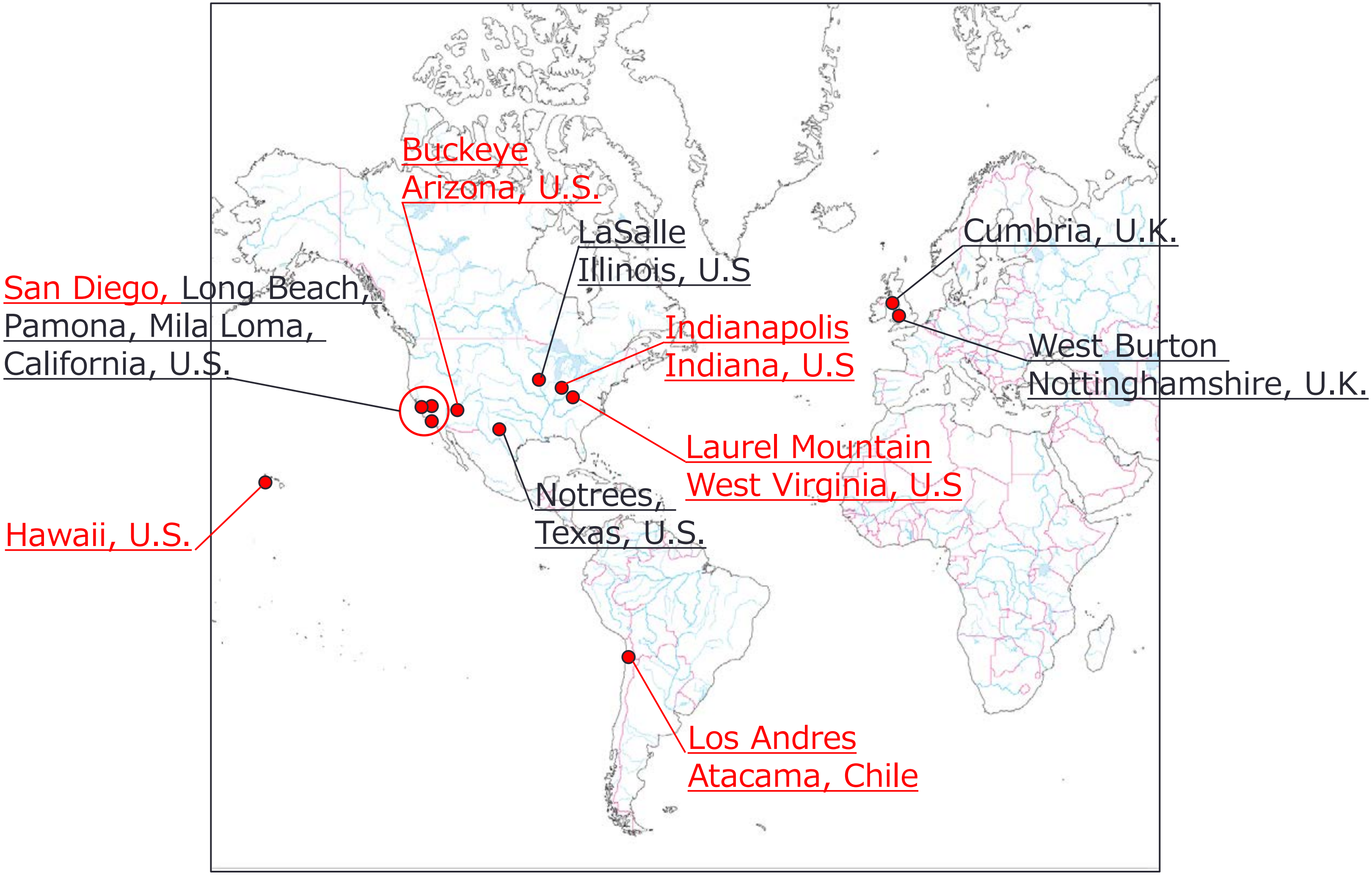
1. The facility offers energy-storage capabilities similar to those of pumped hydro facilities while helping to improve the balance of supply and demand when renewable energy sources are used.
2. The energy storage system achieves effective overall control and improved operational efficiency through the use of battery systems to monitor and control modules in a multiple module system.
3. Containerized, compact (double stacked) battery modules help to reduce the facility footprint, installation time and construction costs.

(Summary) Recent demonstrations in Japan

Company	Project	Battery(Output,Capacity)	Note（Targets of the project, etc)
Hokkaido	Minami-Hayakita	Redox flow (15 MW,60 MWh)	Renewables (demand/supply balancing)
Tohoku	Minami-Soma	Lithium-ion (40 MW,40 MWh)	Renewables (demand/supply balancing)
	Nishi-Sendai	Lithium-ion (40 MW,20 MWh)	Renewables (frequency control)
Tokyo	Yokohama Smart City	Lithium-ion (300 kW,100 kWh)	Renewables (frequency control, spinning reserve)
	Virtual Power Plant (VPP)	Unconfirmed (10 kWhx18)	Demand/supply balancing (normal times) Emergency power supply (disaster times)
Chubu	Simose	Lithium-ion (25 kWh)	Renewables (voltage control)
Hokuriku	Shika	Lithium-ion (50 kWhx2)	Renewables (overall performance test)
Kansai	Amagasaki	Lithium-ion (100 kW,300 kWh)	Overall performance test
Chugoku	Oki Islands	Lithium-ion (2 MW,0.7 MWh) Sodium-Sulfur (4.2 MW,25.2 MWh)	Renewables (demand/supply balancing), Island
Kyushu	Buzen	Sodium-Sulfur (50 MW,300 MWh)	Demand/supply balancing
	Isolated islands*	Lithium-ion (2~4 MW, 774 k~1.6 MWh)	*4 islands; Iki-shima, Tsu-shima, Tanega-shima, and Amami-ooshima
Okinawa	Miyakojima Islands	Lithium-ion + Sodium-Sulfur (100 kW,176 kWhx2)	Renewables (demand/supply balancing), islands

Source: Japanese electric power companies’ web sites

Recent installation examples in the Americas & Europe



Source: Power Distribution Utilities Retail web site
AES Energy Storage web site

Recent installation example in Chile.

Generation Alternative

Energy storage supplying critical spinning reserves.

Initial 2009 project leading to over 100MW of energy storage in Chile.

PURPOSES

- Primary & secondary reserves
- Contingency management

IMPACT

- ✓ Avoided load shedding and contingency curtailment
- ✓ Increased energy production and reduced costs
- ✓ Increased system security
- ✓ Inertia-like performance

12 MW Los Andes
Atacama, Chile
In operation (2009)

I thank AES for permission to use their articles.

Recent installation example in United States. #1

Generation Alternative

Energy storage frequency regulation from a wind farm since 2011

Serving US PJM Interconnection; integrated with eight power systems

PURPOSES

- Frequency Regulation
- Renewable ramp control

IMPACT

- ✓ Saving \$20m/year
- ✓ Competitive bid, wins every hour vs. traditional
- ✓ Reduces regulation by ~1.7x
- ✓ Saves 62,000t of CO2, 329t of SO2 & 97t of NOx / year

98 MW Laurel Mountain Wind Farm
with 32 MW Storage Resource
West Virginia, USA

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Recent installation example in United States. #2

Generation Alternative

Meeting critical local power capacity with world's largest battery

Two San Diego arrays of 37.5MW/150MWh installed in six months.

PURPOSES

- Capacity, local reliability
- Peak power mitigation
- Ramping/flexibility
- Ancillary services

IMPACT

✓ Rapid deployment
✓ Competitive & cost effective
✓ Meets flexibility (duck curve)

30MW Escondido Advancion Array
San Diego, California

✓ Battery storage devices were installed in the city that can not be installed with conventional thermal power generation facilities.

✓ Early operation was possible without strict environmental regulations being applied.

I thank AES for permission to use their articles.

Recent installation example in United States. #3

Transmission Alternative

Frequency control and capacity using 1 hour battery

20MW array is the first of its kind in the Midwestern US.

PURPOSES

- Frequency response
- Capacity
- Voltage control

IMPACT

- ✓ Meet control/reliability regulations
- ✓ Reduce cost of capacity
- ✓ Potential black start

20 MW Harding Street Array
Indianapolis, IN

I thank AES for permission to use their articles.

Recent installation example in United States. #4

Distribution Alternative

Embedding storage in the distribution network for reliability

Two Arizona arrays totaling 4MW/4MWh installed at substations for solar integration

PURPOSES

- Peak demand management
- Renewable integration

IMPACT

- ✓ Support rooftop solar growth
- ✓ Manage local feeder reliability
- ✓ Alternative to substation upgrades

2MW Buckeye Advancion Array
Buckeye, Arizona

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Recent installation example in United States. #5

Renewable Integration

Solving peaking demand through solar + storage on Hawaii

28MW PV with 20MW, 5 hour duration energy storage to take full advantage of renewable power

BRIEF

Hawaii co-op signs deal for solar+storage project at 11¢/kWh

Contains Forward Looking Statements | Confidential & Proprietary

✓ The state of Hawaii aims to make the ratio of renewable energy to the total power generation to 100% in the future.

✓ To compensate for the variability of renewable energy, the power storage system is necessary to achieve the target.

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(Summary) Recent installation examples in the Americas & Europe

Country	City (State)	Battery (Output, Capacity)	Note（Targets of the project, etc)
Chile	Los Andes (Atacama)	Lithium-ion (12 MW)	Primary & secondary reserves Independent grid
United States	Laurel Mountain (WV)	Lithium-ion (32 MW)	Renewables (frequency regulation)
	San Diego (CA)	Lithium-ion (37.5 MW,150 MWh)	Renewables (capacity, local reliability) Installed in 6 months
	Buckeye (CA)	Lithium-ion (4 MW,4 MWh)	Renewables (peak demand management)
	Long Beach (CA)	Lithium-ion (100 MW,400 MWh)	Renewables
	Pomona (CA)	Lithium-ion (20 MW,80 MWh)	Construction of the system in less than 4 months
	Mira Loma (CA)	Lithium-ion (20 MW,80 MWh)	
	Notrees (TX)	Lithium-ion (36 MW,24 MWh)	Renewables
	Grand Ridge, LaSalle (IL)	Unconfirmed (68 MW)	Renewables
	Indianapolis (IN)	Lithium-ion (20 MW,100 MWh)	Renewables (grid and transmission reliability) Built in under 12 months from ground-breaking to commissioning.
	Hawaii	Lithium-ion (20 MW,100 MWh)	Renewables (peak demand management)
United Kingdom	West Burton (Nottinghamshire)	Unconfirmed (49 MW)	Renewables (frequency regulation)
	Barrow-in-Furness (Cumbria)	Lithium-ion (49 MW)	Capacity

Source: Power Distribution Utilities Retail web site
AES Energy Storage web site

Conclusion

Recent demonstrations of grid batteries in Japan

- The projects in Japan are mainly implemented in collaboration with the central or local governments.
- Usually, multiple goals are set for each project.
- There are some other projects that municipalities, companies and other entities have implemented.

Recent installation examples in the Americas & Europe

- In the U.S., there are several examples of installing batteries in real systems.
- Usually, the limited goal is set for each installation.
- Especially in urban areas, it is difficult to start operating conventional power plants in a short period of time. Therefore applying storage battery systems has a great advantage in this respect.

List of batteries

Battery type	Lead-acid	Nickel-metal Hydride	Lithium-ion	Sodium-Sulfur	Redox-flow	Molten-salt
Compact (Energy Density : Wh/kg)	X 35	△ 60	◎ 200	○ 130	× 10	◎ 290
Cost (JPY/kWh)	50,000	100,000	200,000	40,000	Evaluating	Evaluating
Capacity Enlargement	○ - MW Class	○ - MW Class	○ - MW Class	◎ Over MW Class	◎ Over MW Class	Evaluating
Measurement Accuracy of State of Charge	△	△	△	△	◎	△
Safety	○	○	△	△	◎	◎
Material Resource	○	△	○	◎	△	◎
Heat-up during Operation	Not Need	Not Need	Not Need	Need (> 300℃)	Not Need	Need (> 50℃)
Life time (Charge-discharge Cycle)	17 Yrs. 3,150 Cyc.	5 - 7 Yrs. 2,000 Cyc.	6 - 10 Yrs. 3,500 Cyc.	15 Yrs. 4,500 Cyc.	6 - 10 Yrs. Non-limit	Evaluating

Source : METI(2012)