Japanese Power Market Regulation – Large Scale Battery Storage as a Solution for Challenges in Ancillary Services

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Outline

- Demonstration Projects with LARGE Batteries in JAPAN

- Demonstration Projects with SMALL Batteries in JAPAN
  - Overview
  - MIYAKO Island
  - OKI Island
  - Ni-i-jima Island

DEMONSTRATION PROJECTS WITH LARGE BATTERIES IN JAPAN

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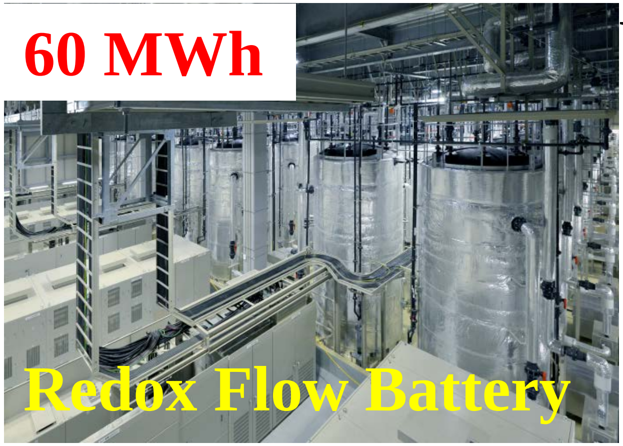
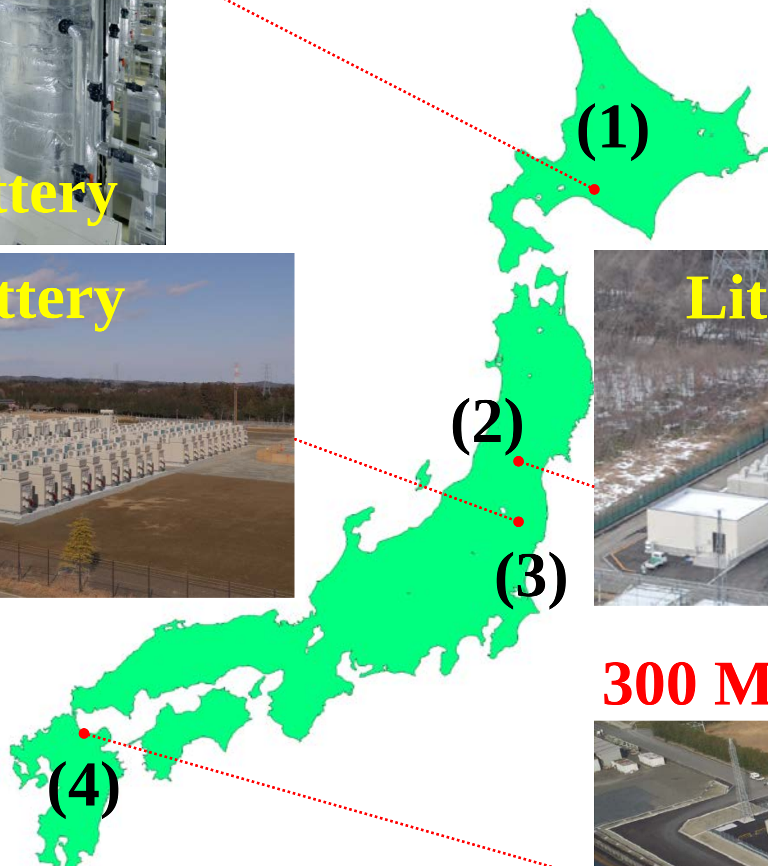
ほくでん

Hokkaido Electric Power Co., Inc.

KYUSHU ELECTRIC POWER CO., INC.

Overview of Demonstration Projects with Large Batteries in Japan





Large **Batteries for Integrating More Renewables**

Source: CIGRE 2016 Paris Session C4 Contribution

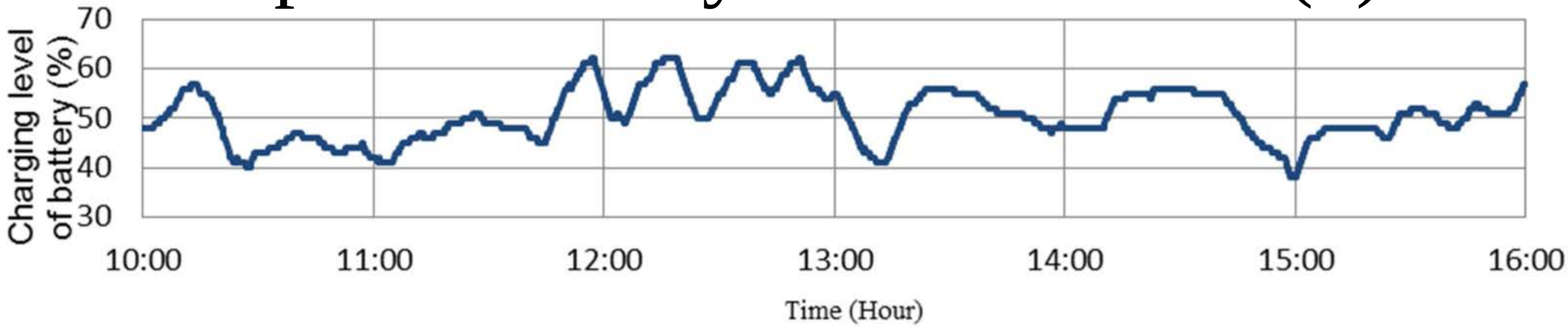
Studies of Demonstration Projects with Large Batteries in Japan

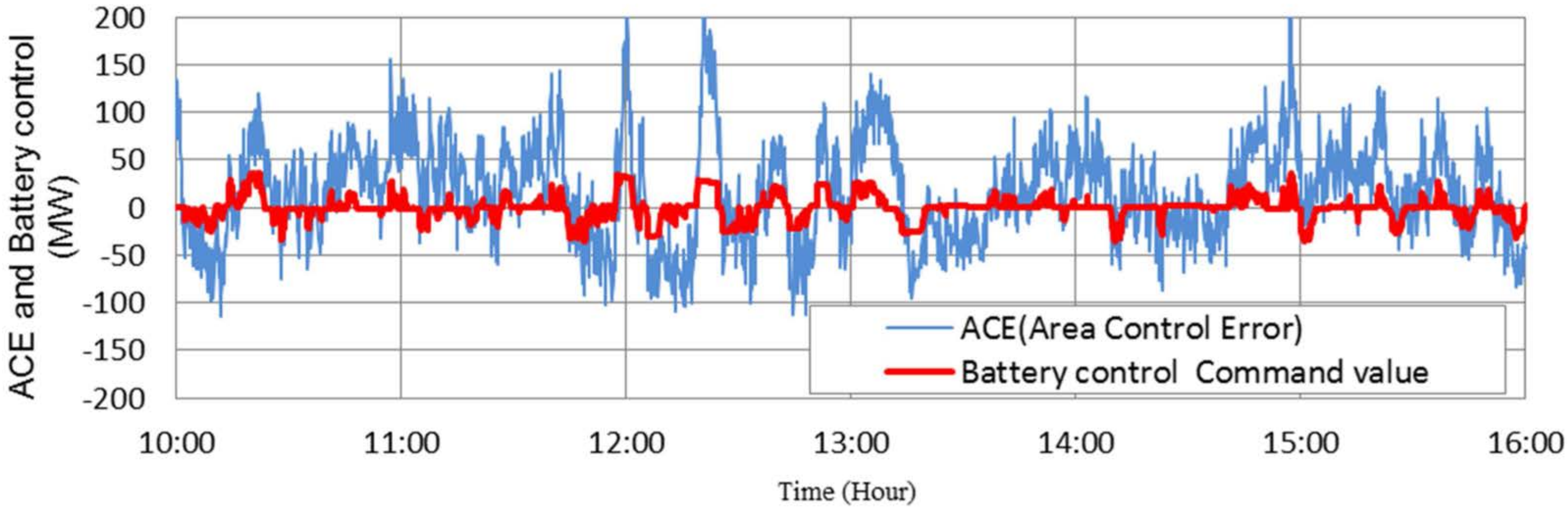
No.	Period of Demonstration	Primary Frequency Control /Reserve	Secondary Frequency Control/Reserve	Counter-measure for Over-generation	Voltage Control
1	2015.12-2018.12	X	X	X	
2	2015.02-2018.01		X		
3	2016.02-2017.02			X	X
4	2016.02-2017.03		X	X	X

Cover wide variety of *controls* and *countermeasures* to mitigate deterioration of power quality caused by renewables in steady state.

Source: CIGRE 2016 Paris Session C4 Contribution

Example System Performance of Proposed Battery Control at Site (2)





Battery can contribute increase in secondary frequency control capability.
[Ref] S. Yamamoto, et al, "*Countermeasures in substation for large renewable energy adoption in Japan,*" B3-204, CIGRE 2016

Source: CIGRE 2016 Paris Session C4 Contribution

DEMONSTRATION PROJECTS WITH SMALL BATTERIES IN JAPAN

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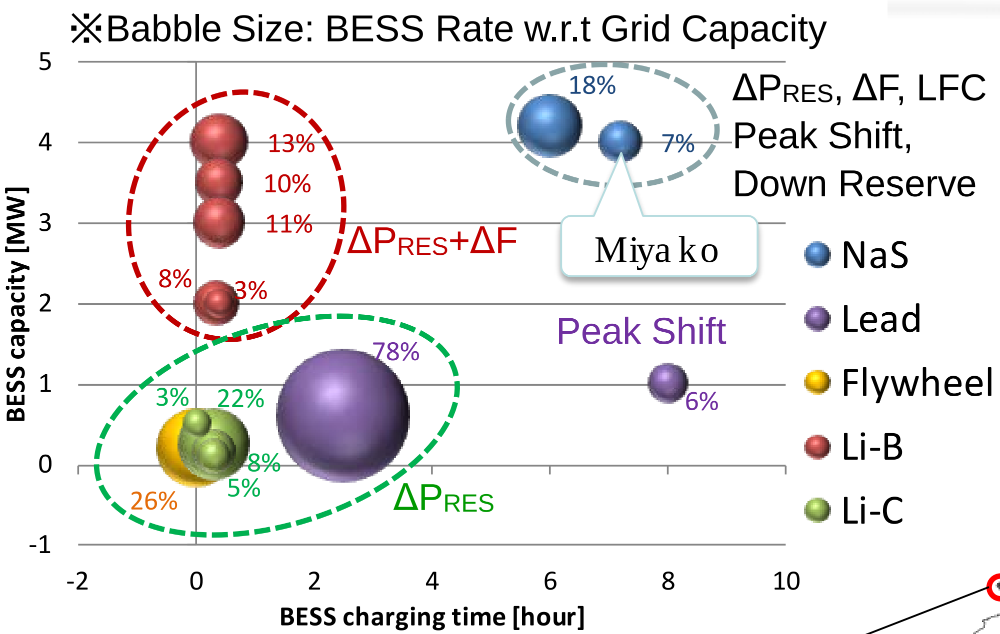
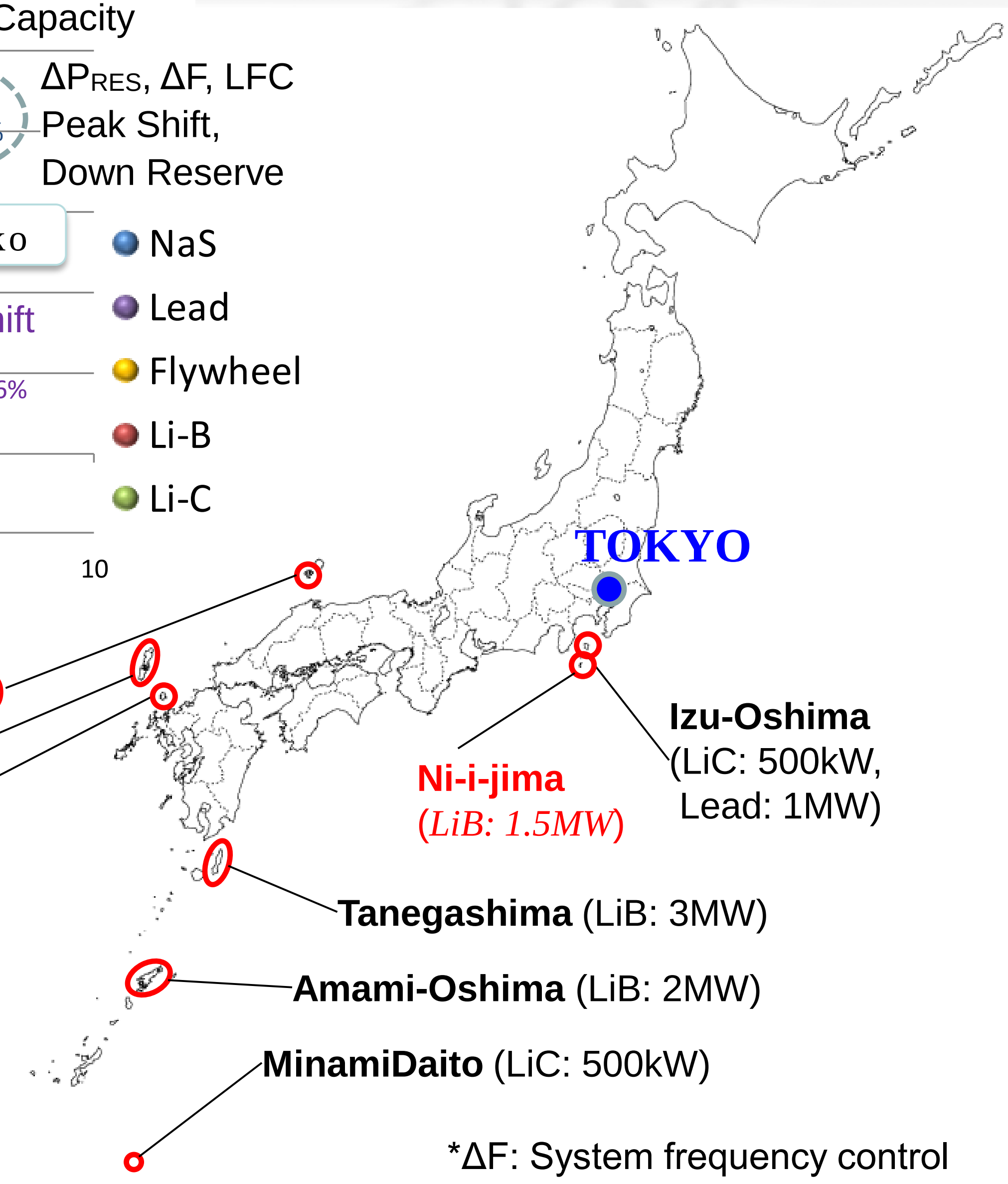
TEPCO

BESS PROJECTS FOR ISLAND GRID IN JP





*ΔF: System frequency control
ΔP_{RES}: Smoothing control for RES

Source: CIGRE 2016 Paris Session C2 Contribution

BESS PROJECTS FOR ISLAND GRID IN JP

as of Mar 2016

Island	BESS					System		RES	
	Type	kW	hour	kWh	Control mode	kW	BESS rate	kW	BESS rate
Miyako	NaS	4000	7.2	28800	ΔF, ΔP, Absb, Peak, RsvDn	55000	7%	24000	17%
Oki-Islands	NaS	4200	6	25200	Absb	24000	18%	6300	67%
Oki-Islands	Li-B	2000	0.35	700	ΔP	24000	8%	6300	32%
Ikinoshima	Li-B	4000	0.4	1600	ΔP+ΔF	30000	13%	9300	43%
Tsushima	Li-B	3500	0.4	1400	ΔP+ΔF	36000	10%	9000	39%
Tanegashima	Li-B	3000	0.4	1200	ΔP+ΔF	27000	11%	11900	25%
AmamiOshima	Li-B	2000	0.4	800	ΔP+ΔF	62000	3%	9300	22%
Tarama	Li-C	250	0.31	78	ΔP	1160	22%	250	100%
Yonaguni	Li-C	150	0.31	47	ΔP	1930	8%	150	100%
MinamiDaito	Li-C	100	0.31	31	ΔP	2083	5%	100	100%
IzuOshima	Li-C	500	0.03	15	ΔF	15400	3%	1200	42%
IzuOshima	Lead	1000	8	8000	ΔP, Peak	15400	6%	1200	83%
Hateruma	Lead	600	2.5	1500	ΔP	768	78%	500	120%
~~Hateruma~~	~~Flywheel~~	~~200~~	~~0.01~~	~~2~~	~~ΔF, ΔP, ΔV~~	~~768~~	~~26%~~	~~500~~	~~40%~~

【 Role of BESS 】

ΔF: System Frequency Control
ΔP: RES Variation Mitigation Control
ΔV: Voltage control

Absb: Absorb of RES surplus power
Peak: Peak load supply
RsvDn: Downward reserve

Source: CIGRE 2016 Paris Session C2 Contribution

DEMONSTRATION PROJECTS WITH SMALL BATTERIES IN JAPAN ~*MIYAKO ISLAND*~

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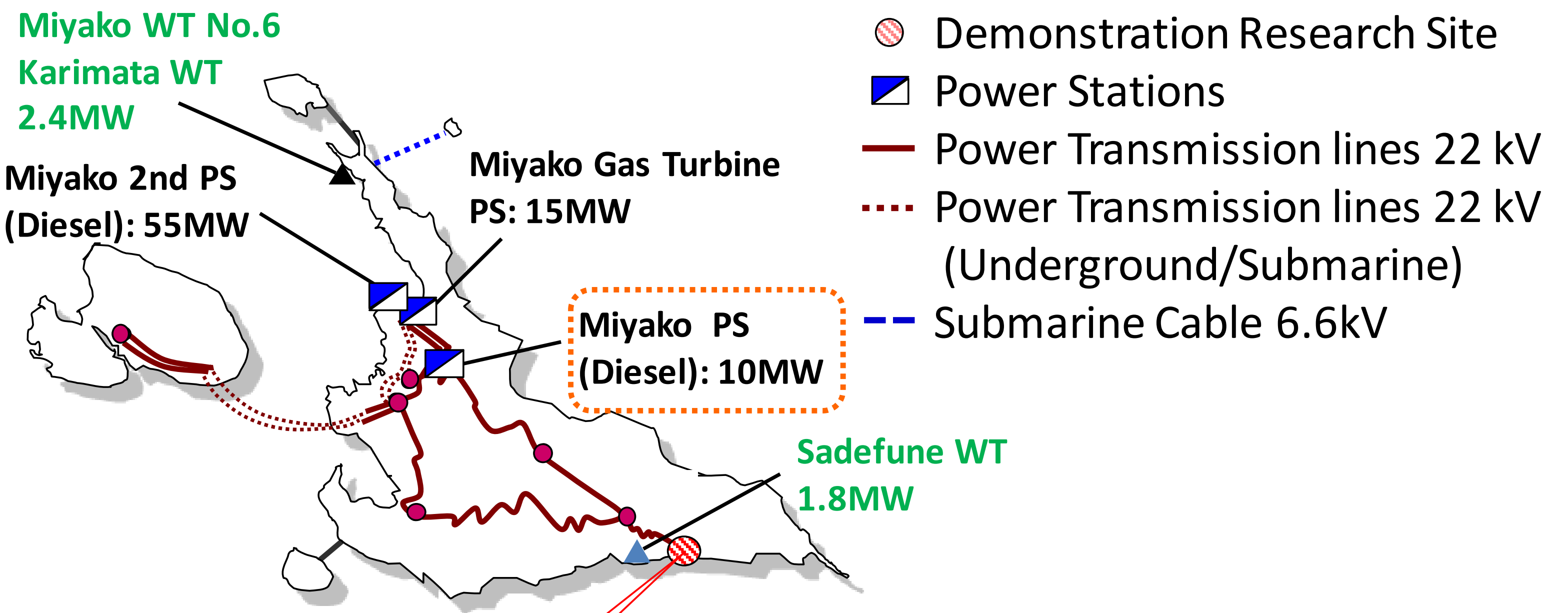
POWER SYSTEM OF MIYAKO ISLAND

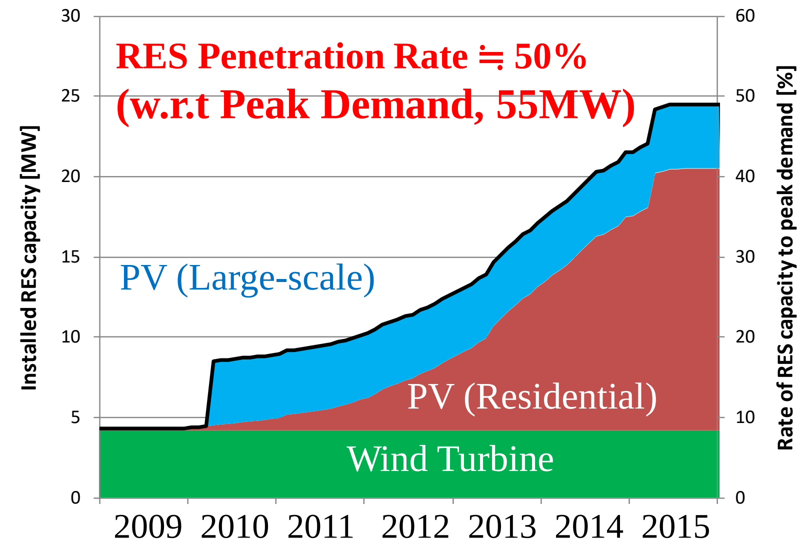


Miyako Island Demonstration Research Facility

PV Plants : 4MW

NaS Batteries : 4MW (28.8MWh)

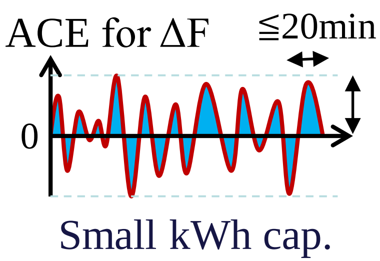
Excessive capacity was intentionally selected for test purpose.

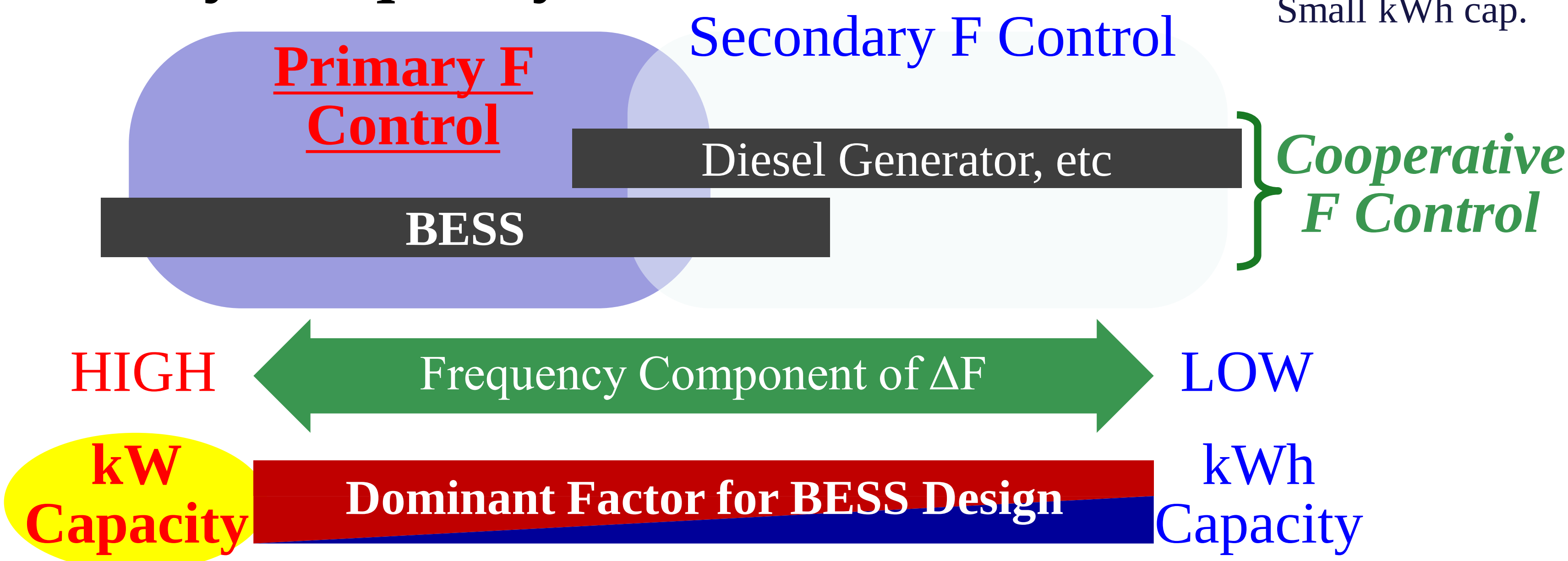


Source: CIGRE 2016 Paris Session C2 Contribution

BESS CAPACITY DESIGN FOR UTILITIES

- BESS Capacity Design:
  - **kW Capacity** and **kWh Capacity**
- BESS Utilization for Frequency Control:
  - Dominant RES Issue in ΔF: **Fluctuation**
  - Major Intended Frequency Control: **Primary Frequency Control**

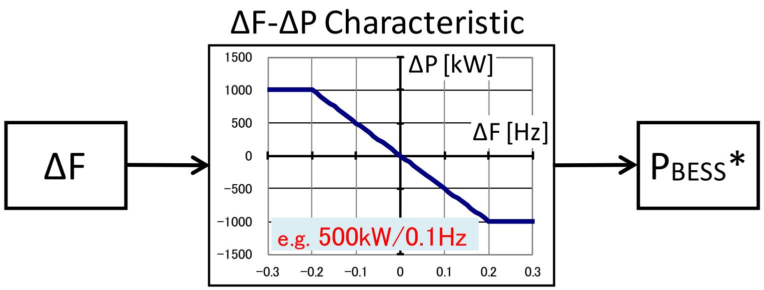




Source: CIGRE 2016 Paris Session C2 Contribution

METHODOLOGY FOR ESTIMATING MINIMUM NECESSARY BESS CAPACITY

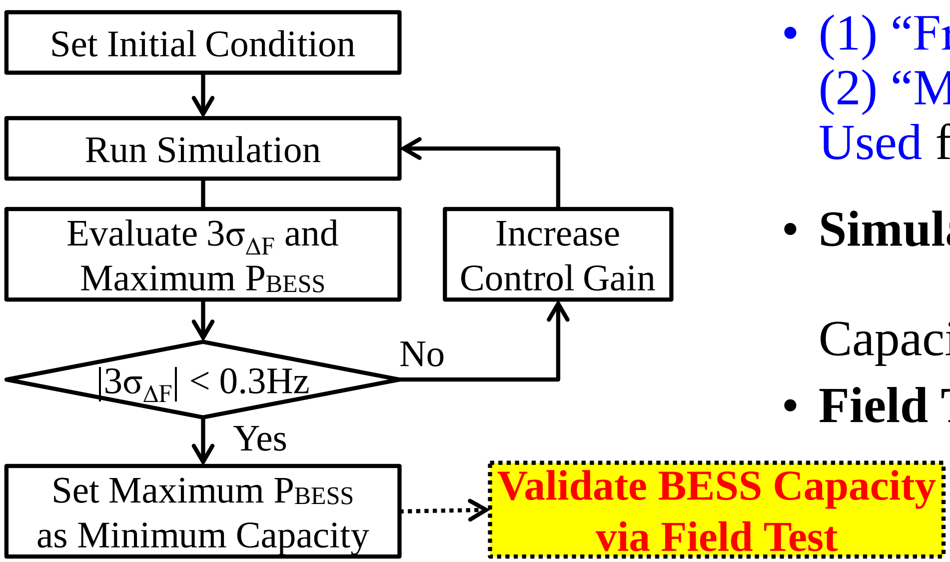
【Primary Frequency Control by BESS】



ΔF Input Controller for BESS

- Permissible Frequency Deviation (ΔF): No Larger than 0.3Hz
- BESS Controller: ΔF Input Control
- Larger control gain, $\Delta F/\ \Delta P_{BESS}$
  ⇒ Larger Primary F Control Capability
  ⇒ Smaller Frequency Deviation

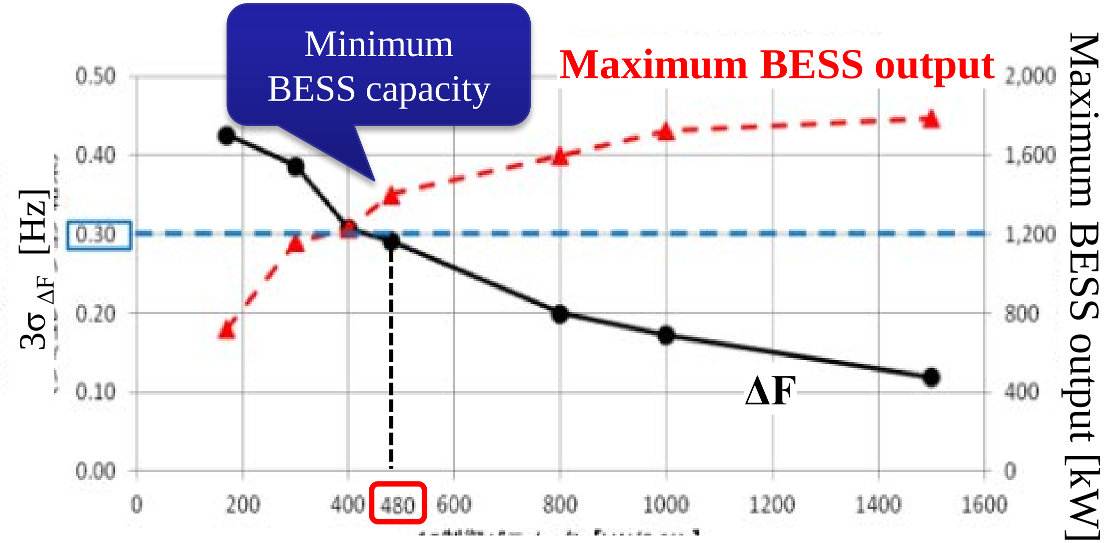
【Flowchart for Estimating Required BESS Capacity】



- (1) "Frequency Deviation (ΔF)" and (2) "Maximum BESS Output (P_{BESS})": Used for Estimation
- **Simulation**: Derivation of Minimum Necessary BESS Capacity
- **Field Test**: Validation of Derived BESS Capacity

Source: CIGRE 2016 Paris Session C2 Contribution

ESTIMATED MINIMUM BESS CAPACITY (201



① Select Control Gain of 480 kW/0.1 Hz with Minimum BESS capacity:

(=Maximum BESS output)

□ Estimate Minimum BESS Capacity: **About 1400 kW (5% of RES)**.

③ Validate Derived BESS Capacity Using Field Test.

- **Maximum BESS output: About 1200 kW** (with Control Gain of 480kW/0.1Hz)
- Frequency Deviation $3\sigma_{\Delta F}$: No greater than 0.3Hz.

Note: (1) Minimum BESS Capacity from Compensation of Short-term RES Variation Perspective: About 1100 kW

(2) Minimum BESS Capacity from AGC Perspective: About 900 kW

(This BESS-AGC compensates only high-frequency component (T < 1min) of ACE.)

Source: CIGRE 2018 Paris Session C2 Contribution

DEMONSTRATION PROJECTS WITH SMALL BATTERIES IN JAPAN
~OKI ISLAND~

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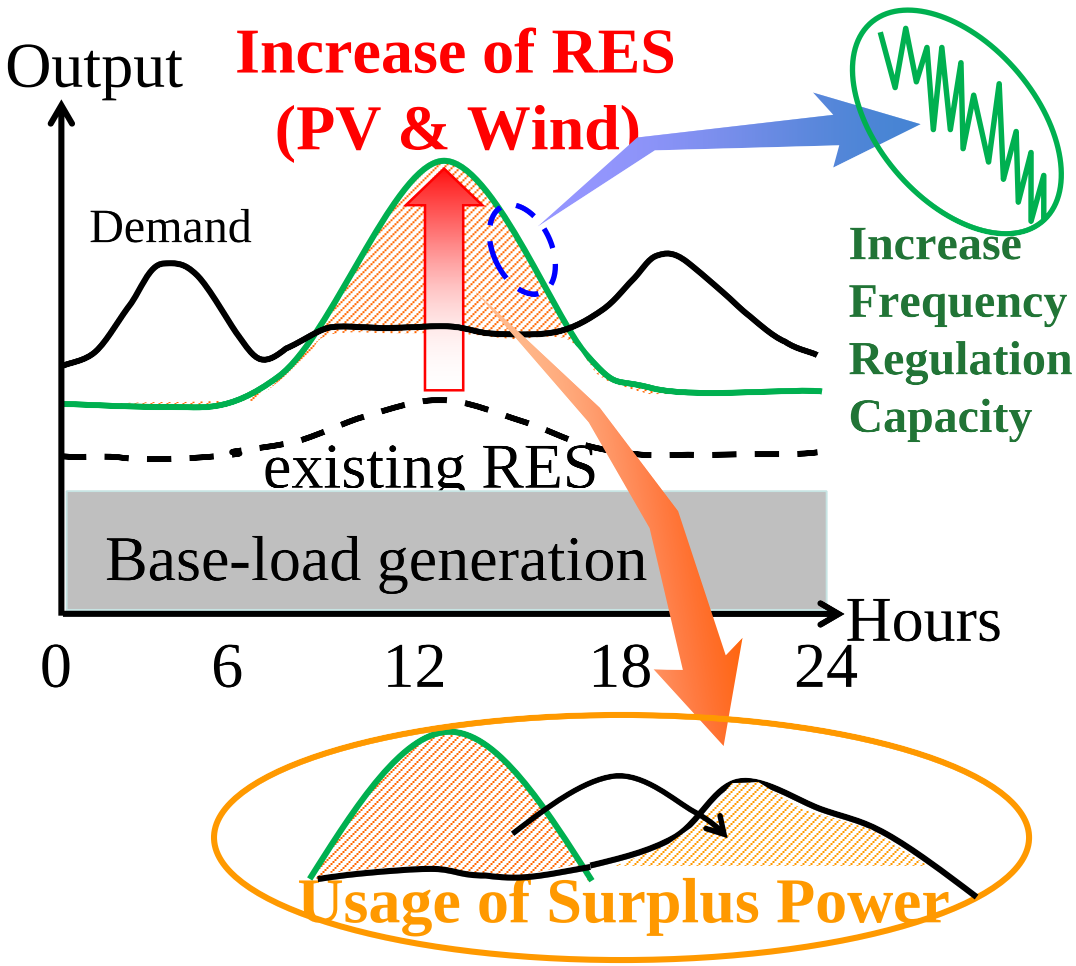
MITSUBISHI ELECTRIC
Changes for the Better

Concept of Hybrid BESS

Daily Demand Curve



Measures for
Short term fluctuation
↓
Li-ion battery
Small capacity, high-power (kW)

Coordinated Control

Measures for
Long term fluctuation
↓
NaS battery
Large capacity (kWh)

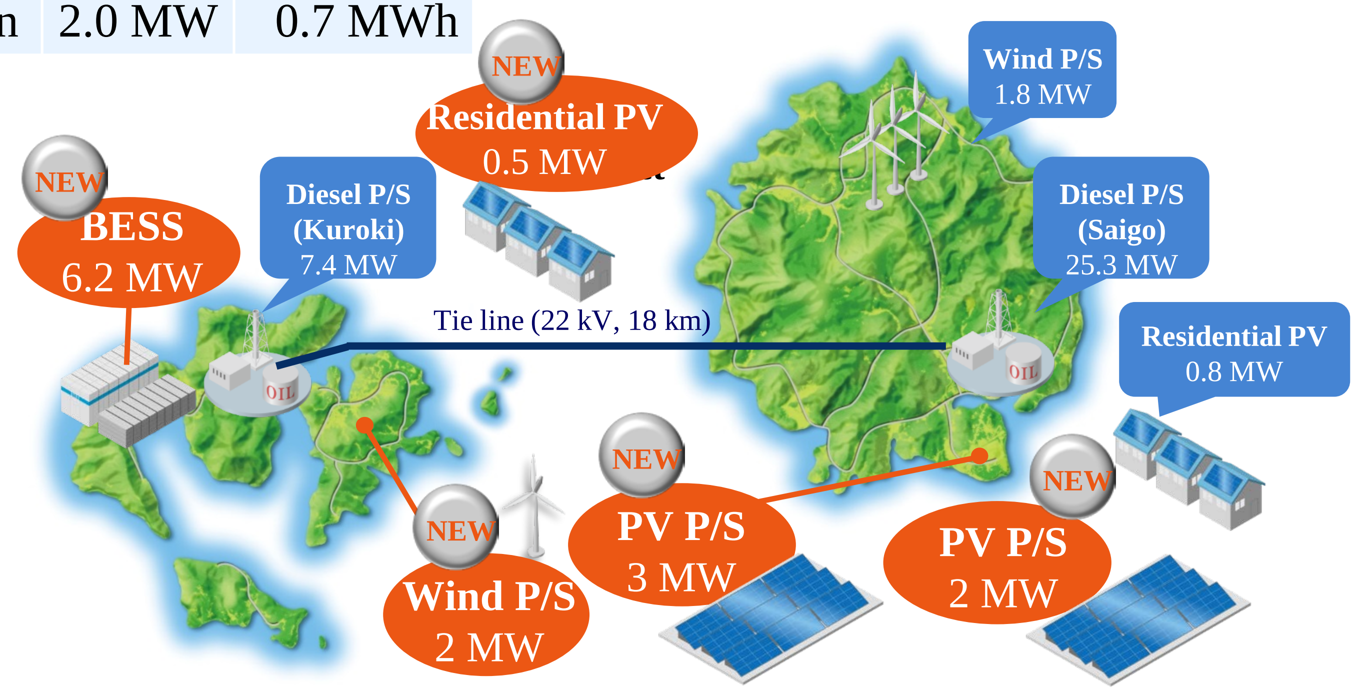
Source: CIGRE 2017 Symposium

Outline of the Demonstration Project

- Period : From Sep. 2015 to Mar. 2019 (3.5 years)
- **Coordinated control** between **existing Diesel generators** and the **Hybrid BESS**
- Efficient charge-discharge management and control methods of BESS

Type	Output	Capacity
NaS	4.2 MW	25.2 MWh
Li-ion	2.0 MW	0.7 MWh

[Demand]
Max. 24MW
Min. 10MW



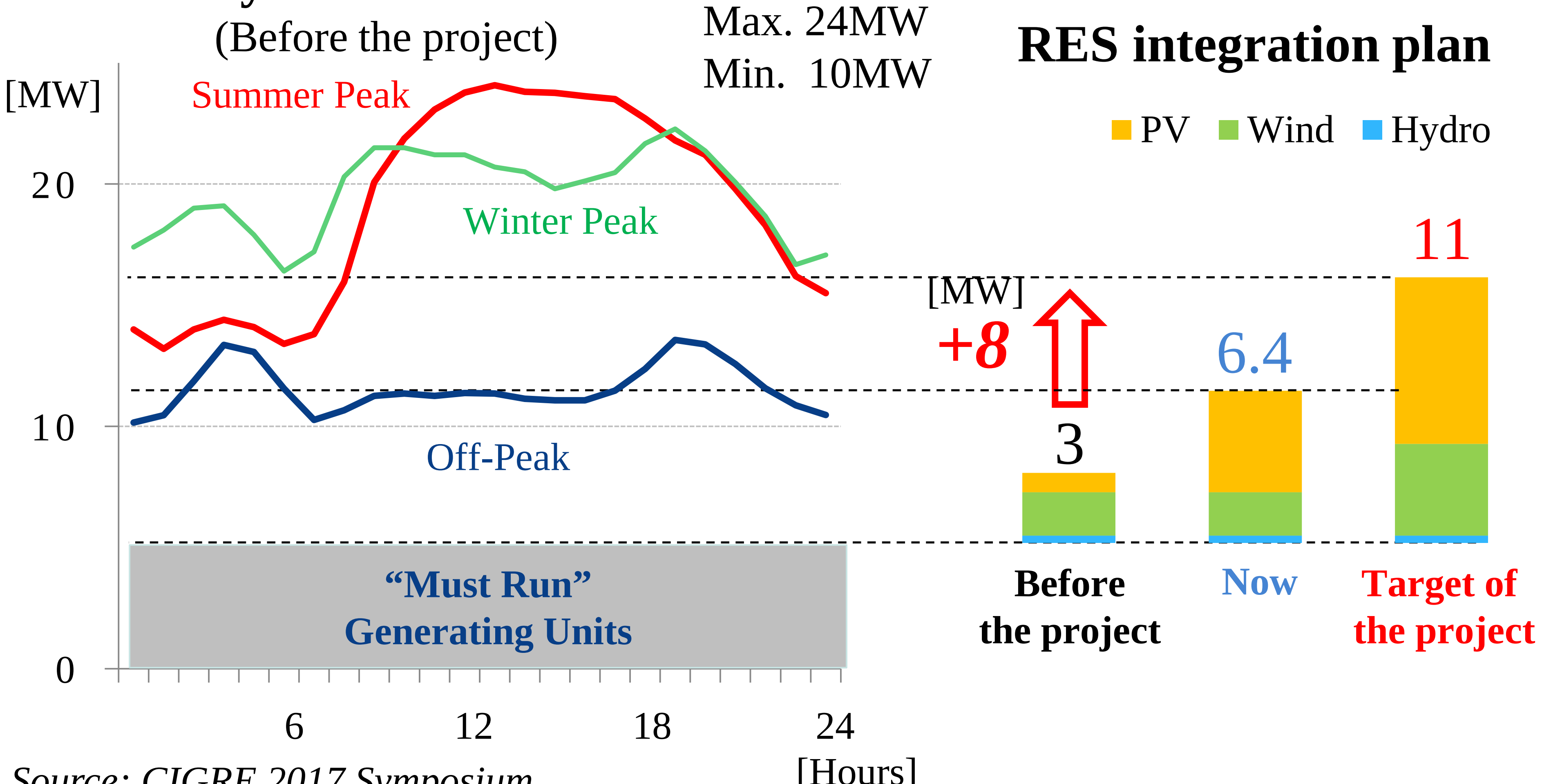
Source: CIGRE 2017 Symposium

Note: subsidized by the Ministry of the Environment.

RES introduction plan of the project

- **Aiming to introduce about 11 MW of RES in total, by newly introducing 8 MW in addition to existing 3 MW of RES, which exceeds the minimum demand (about 10 MW).**

Daily Demand Curve



Source: CIGRE 2017 Symposium

Benefits of Hybrid BESS

- Compared with single BESS (NaS only), benefits of Hybrid BESS are as follows.

Operational Range of NaS Expansion

Due to combining with Li-ion, SOC of NaS needs to be reset *more* frequently.
Besides, NaS is not required to absorb short term fluctuation.

By reducing margin, operational range of NaS can be expanded.

Heating-Loss of NaS Reduction

NaS needs heating in operation.

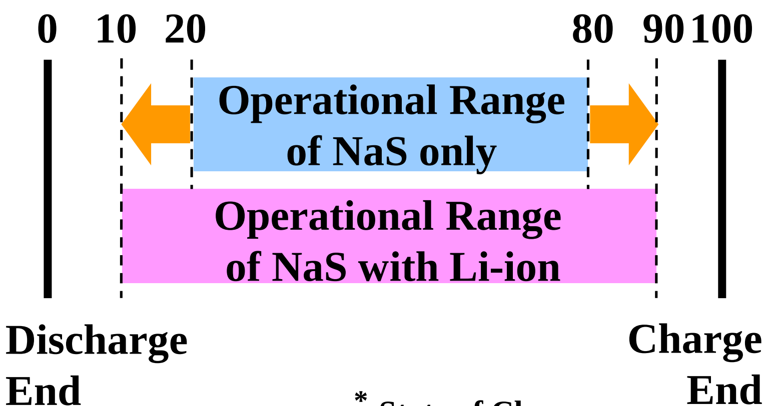
By reducing capacity of NaS, auxiliary power consumption can be decreased by about 30%.

Introduction Cost Reduction

"Cost per kW of Li-ion" and "cost per kWh of NaS" are economical.

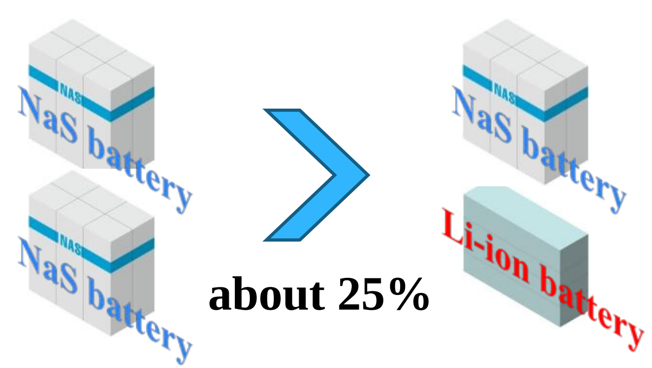
By reducing capacity of NaS, introduction cost can be decreased by about 25%.

SOC* of NaS [%]



* State of Charge

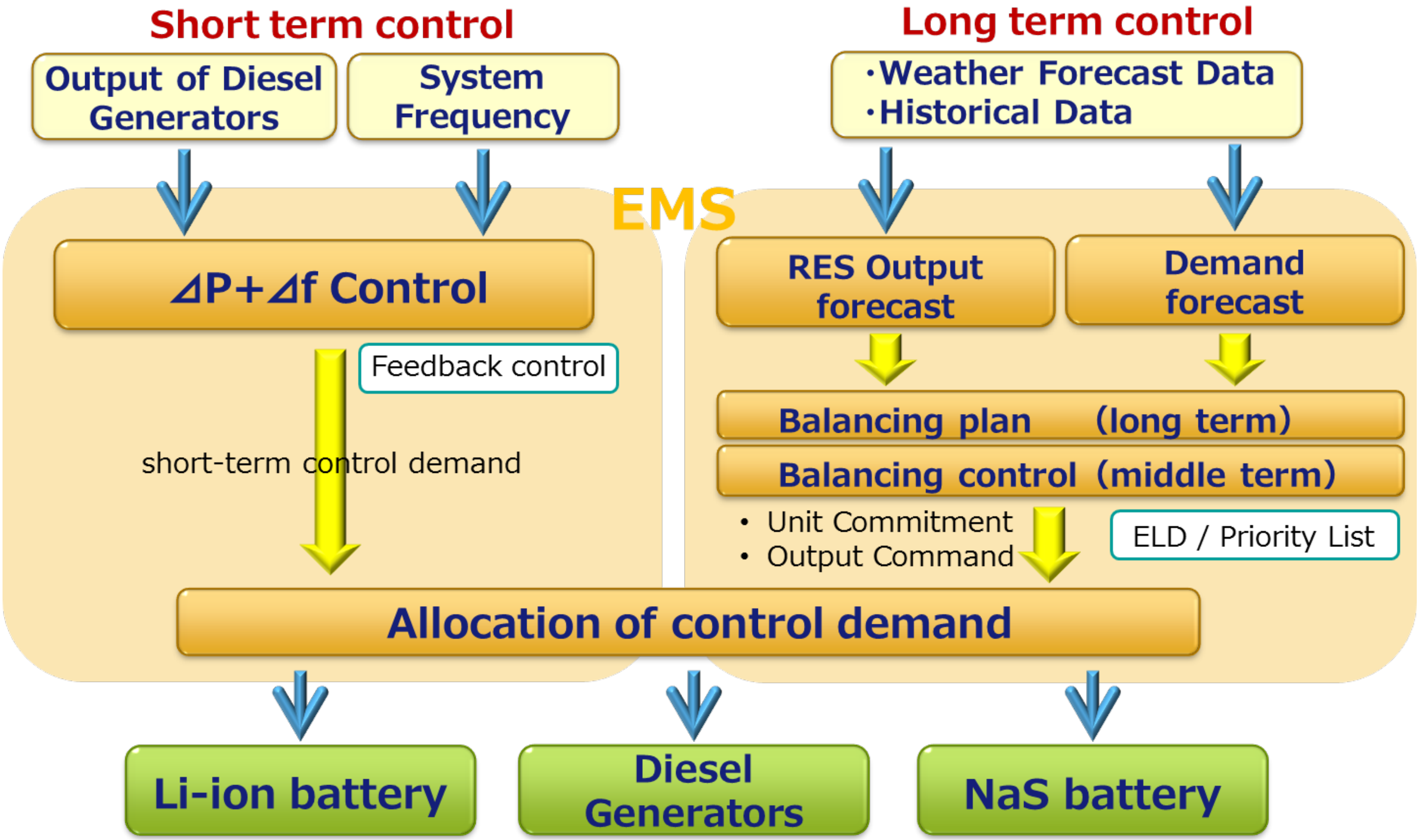
Cost Comparison(initial + running)



Source: *CIGRE 2017 Symposium*

Overview of Control Method

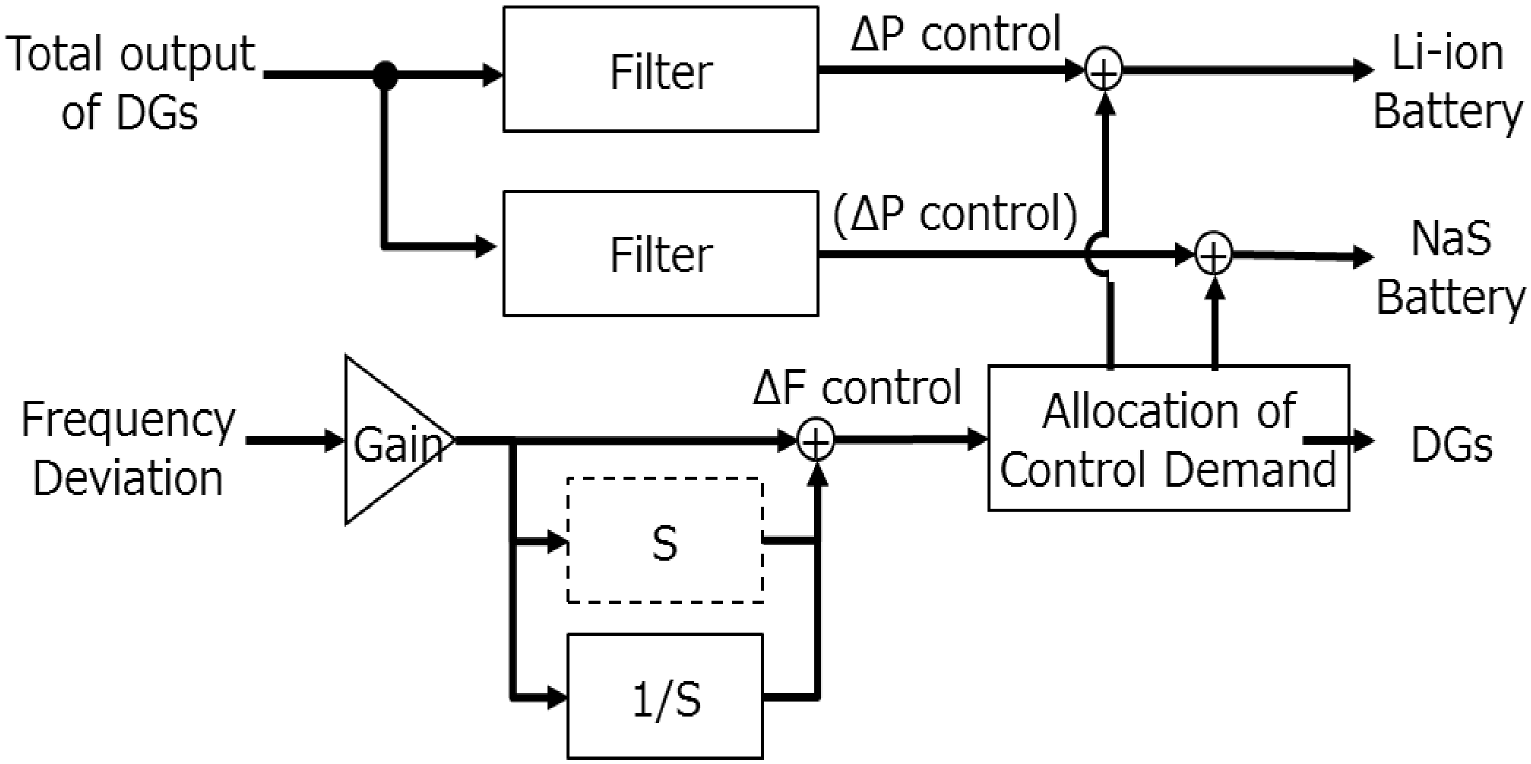
- To realize coordination control, an Energy Management System (EMS) has been developed, integrating the hybrid BESS, power stations and a control center via communication network.



Source: CIGRE 2017 Symposium

Overview of Control Method

- By means of unmanned automatic operation, coordinated control between BESS and diesel generators is executed.

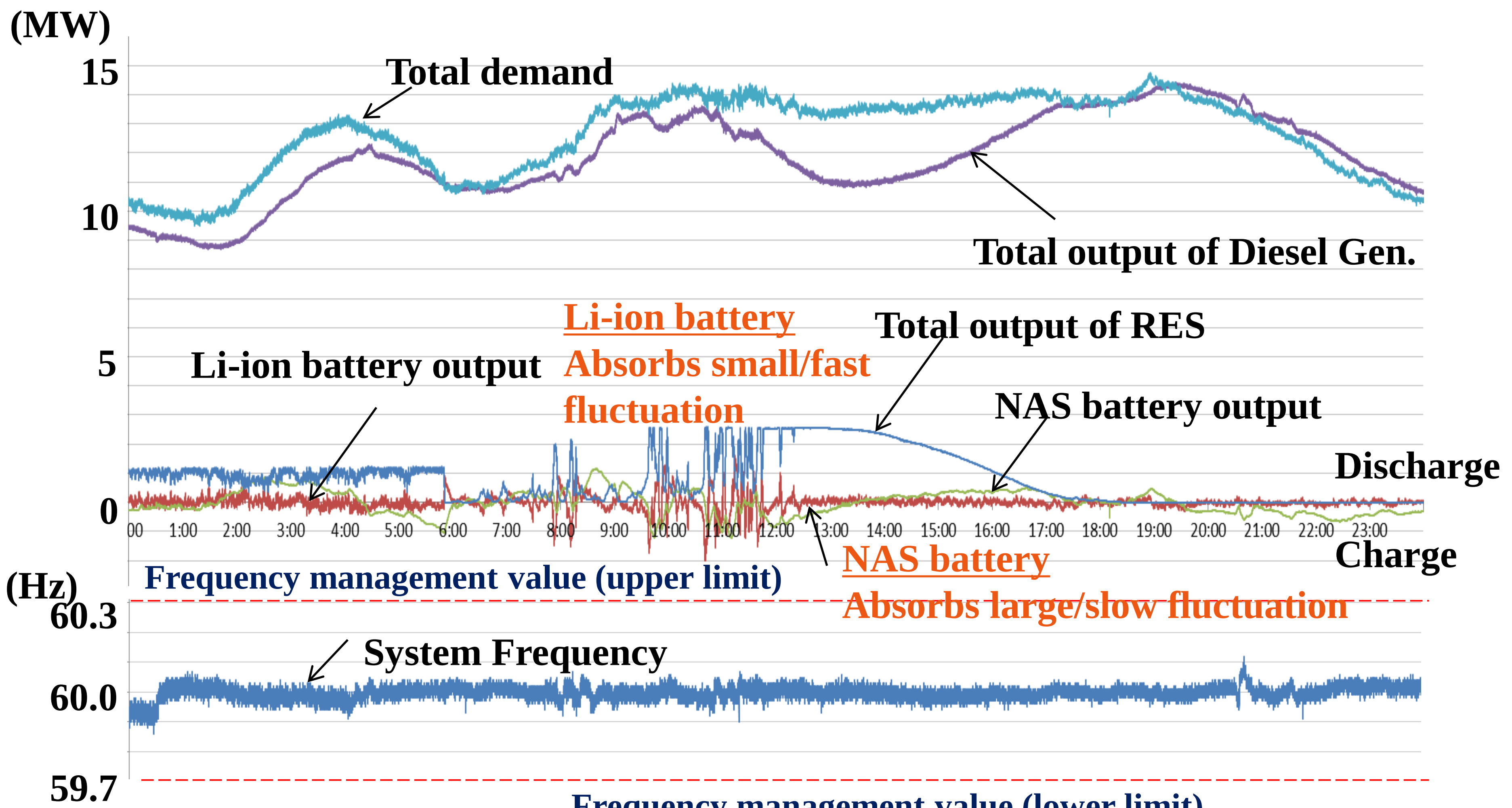


Short-term control block diagram

Source: CIGRE 2017 Symposium

Operational Performance of Hybrid BESS

- Up to the present time, the **total capacity of RES** integrated in the grid has reached 6.4MW, about **60 % of this project's target**, and **coordination control** has been **generally well-performed**.



Source: CIGRE 2017 Symposium

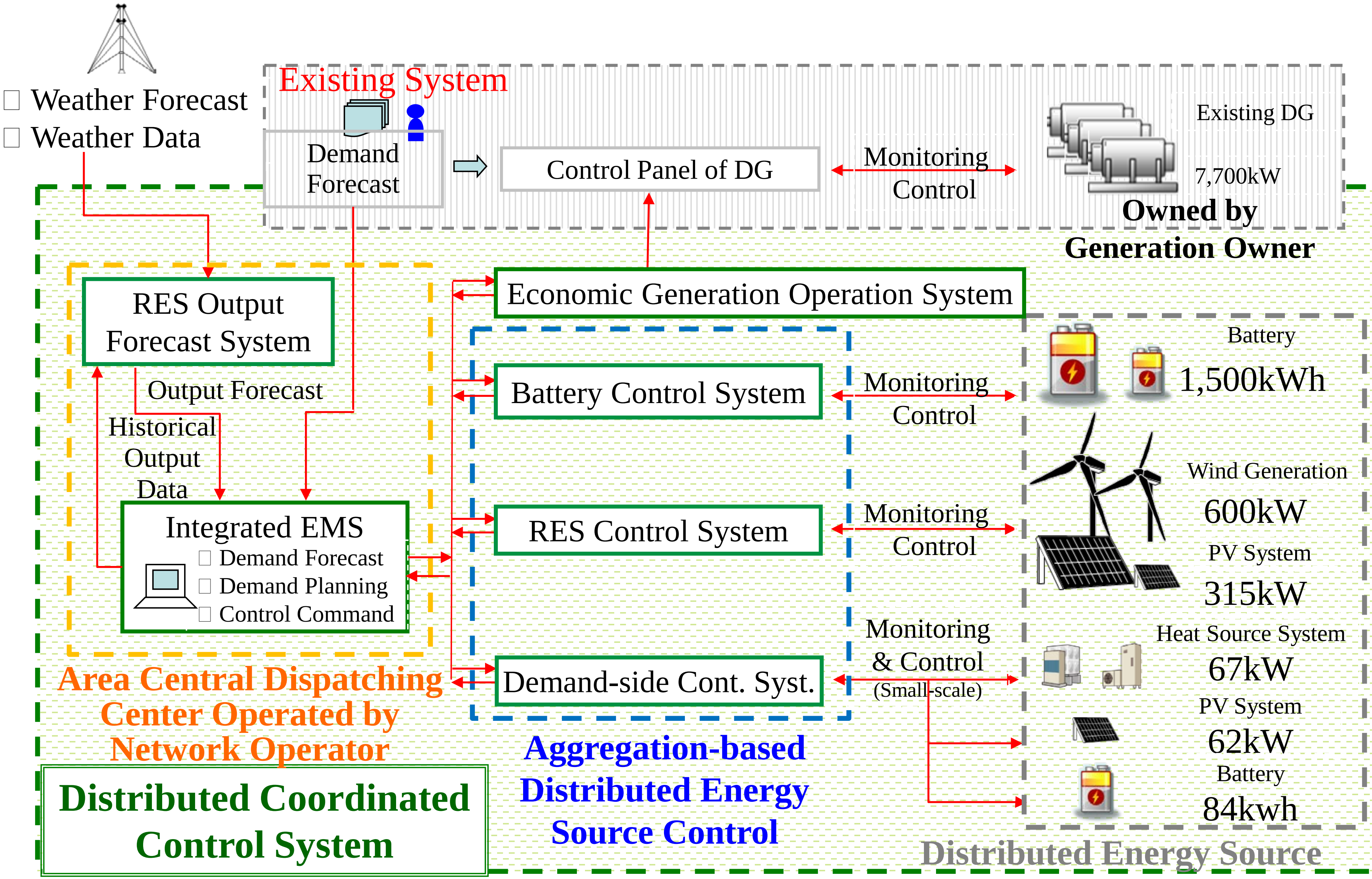
(Aug. 31, 2016)

DEMONSTRATION PROJECTS WITH SMALL BATTERIES IN JAPAN
~NI-I-JIMA ISLAND~

NEDO

3. Distributed Coordinated Control System

(1) Overview of Developed System



3. Distributed Coordinated Control System

(2) Overview of RES Control and Battery Control

Example Use Case of Controls

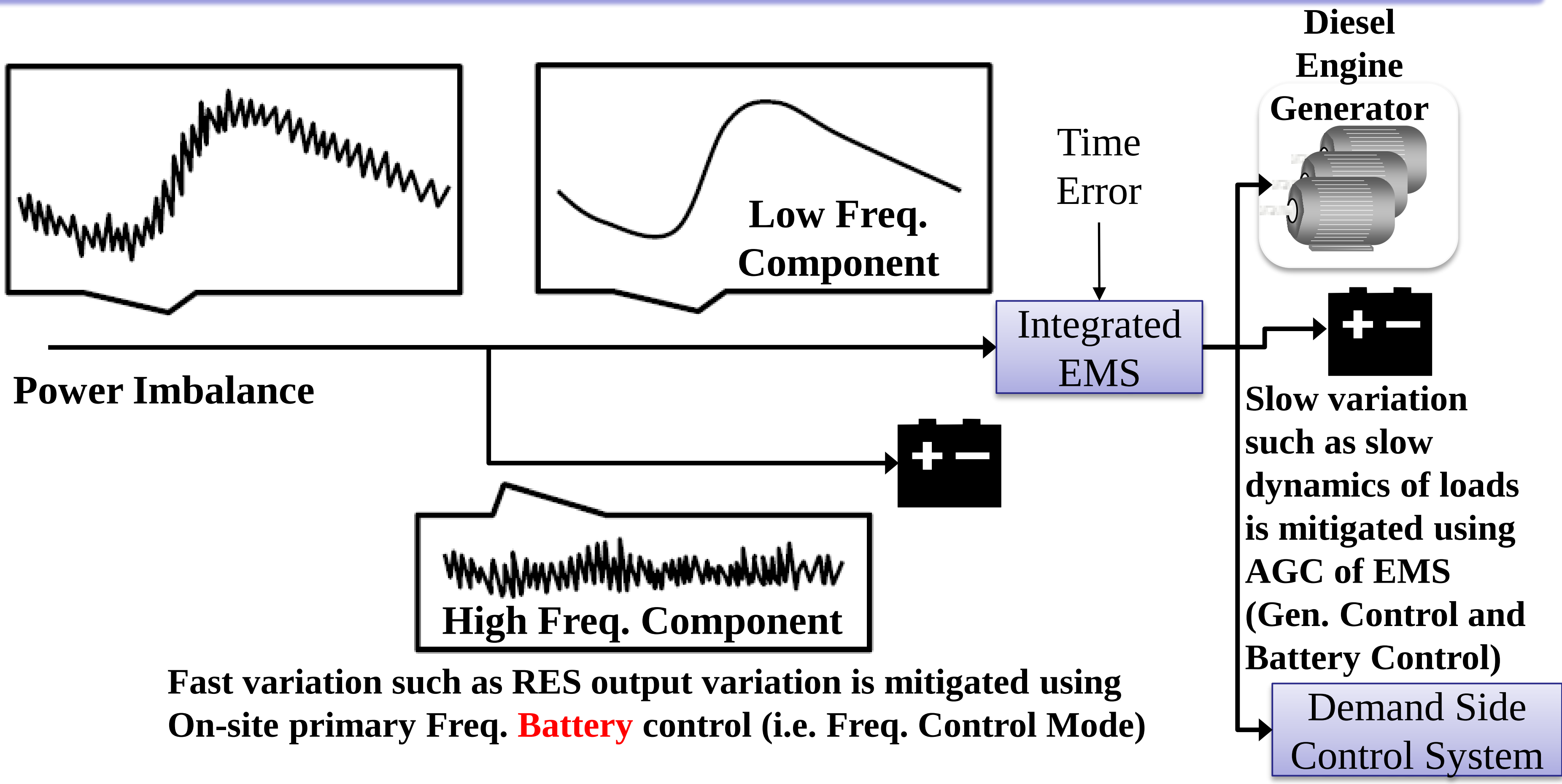
	Purpose	Control	Control Object
Overgeneration	EMS based Curtailment Control of RES and EMS based Direct Battery Control	Curtailment Control of RES Battery Control	Wind and PV Generation and Large-scale Battery Small-scale Battery
Overgeneration	Demand-Shift Control in case of Curtailment of RES	Curtailment Control of RES Battery Control	Wind and PV Generation and Large-scale Battery Heat Source System
RES Variation Mitigation	Mitigation of RES Output Variation At RES Site	Battery Control	Wind and PV Generation and Large-scale Battery
RES Variation Mitigation	Frequency Control Mitigating RES and Load Variations	Demand-side Control	Small-scale Battery Heat Source System
Planned UC	Compensation of Mismatch between Planned and Real Generation	Battery Control	Wind and PV Generation and Large-scale Battery

3. Distributed Coordinated Control System

Frequency Control: Two Frequency Controls depend on Frequency Component of RES Output Variation

- Primary Freq. Control: On-site control is preferred due to time-delay of controllers
- Secondary Freq. Control: Remote control is preferred from economic control perspectives*

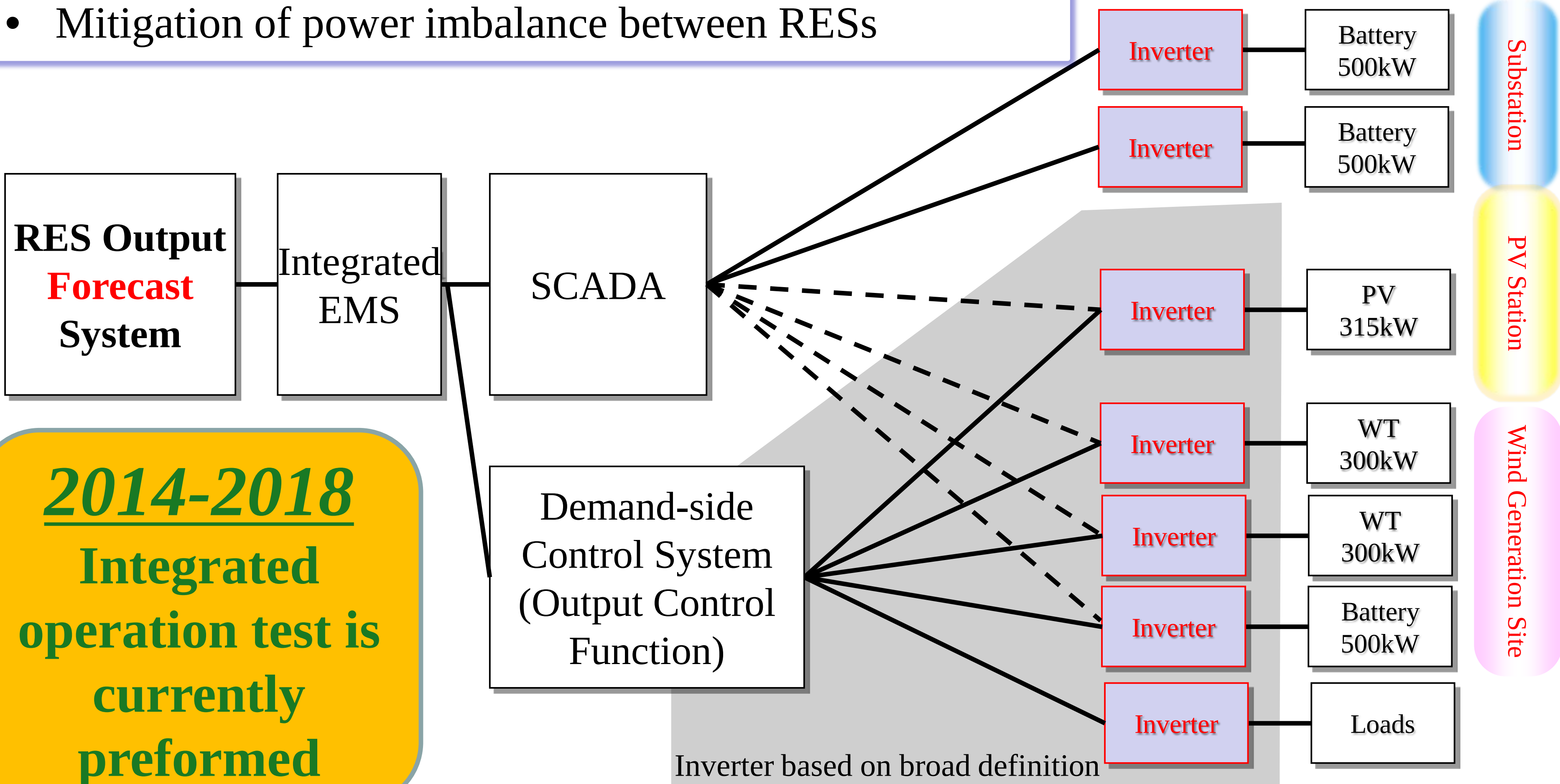
*On-site Control of RES owners is applied to Site-level Frequency Control



3. Distributed Coordinated Control System

(4) Structure of Developed Control

- Remote control of demand-side components using demand-side control system
- Curtailment of RES in case of overgeneration
- Mitigation of power imbalance between RESs



2014-2018

Integrated operation test is currently preformed

Conclusion

- Overview of Ongoing Demonstration Projects with LARGE and SMALL Batteries in JAPAN
- Introduction of Latest Research Study of Projects with SMALL Batteries in JAPAN
  - Coordinated Control Bet. Diesel and BESS
  - Coordinated Control Bet. Li BESS and NaS BESS
  - Coordinated Control Bet. EMS based BESS (including RES forecast data) and Local BESS

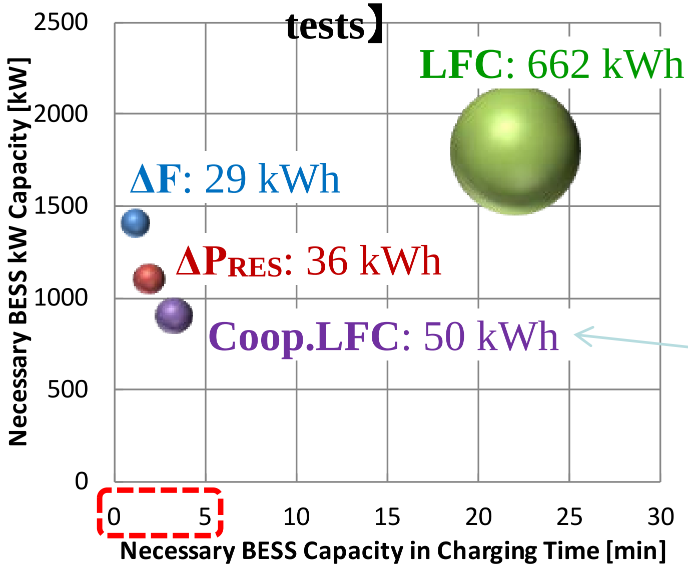
Other than how to coordinate control using BESS, …

- **Accumulating Operational Experience**
- **Examining Increase in Efficiency/Life Time of BESS**
- **Studying Potential Increase in Integration of RES using BESS**

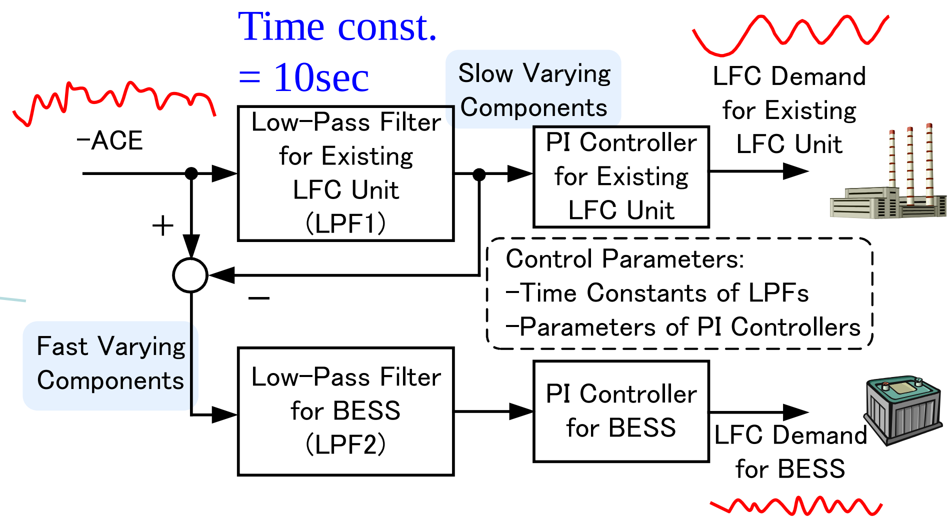
Thank you for your attention.

NECESSARY BESS KWH CAPACITY

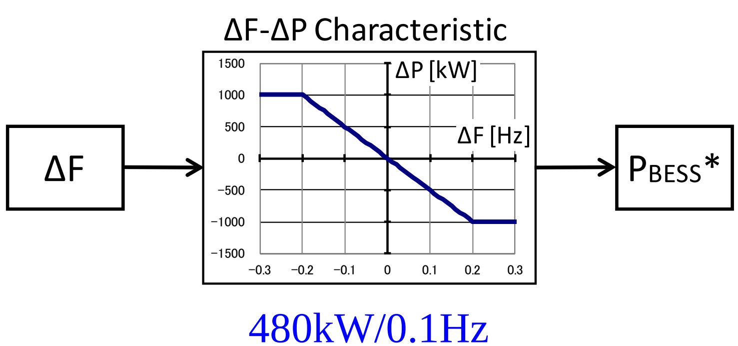
【BESS kWh needed during field tests】



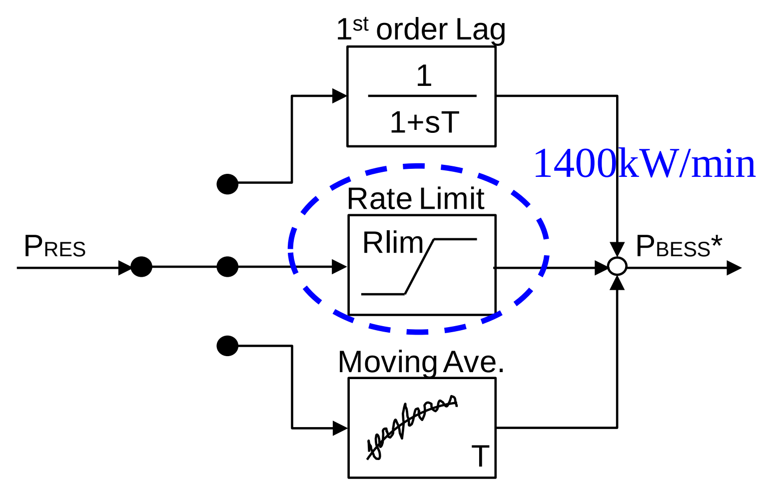
Cooperative LFC by Diesel & BESS



ΔF Controller for BESS

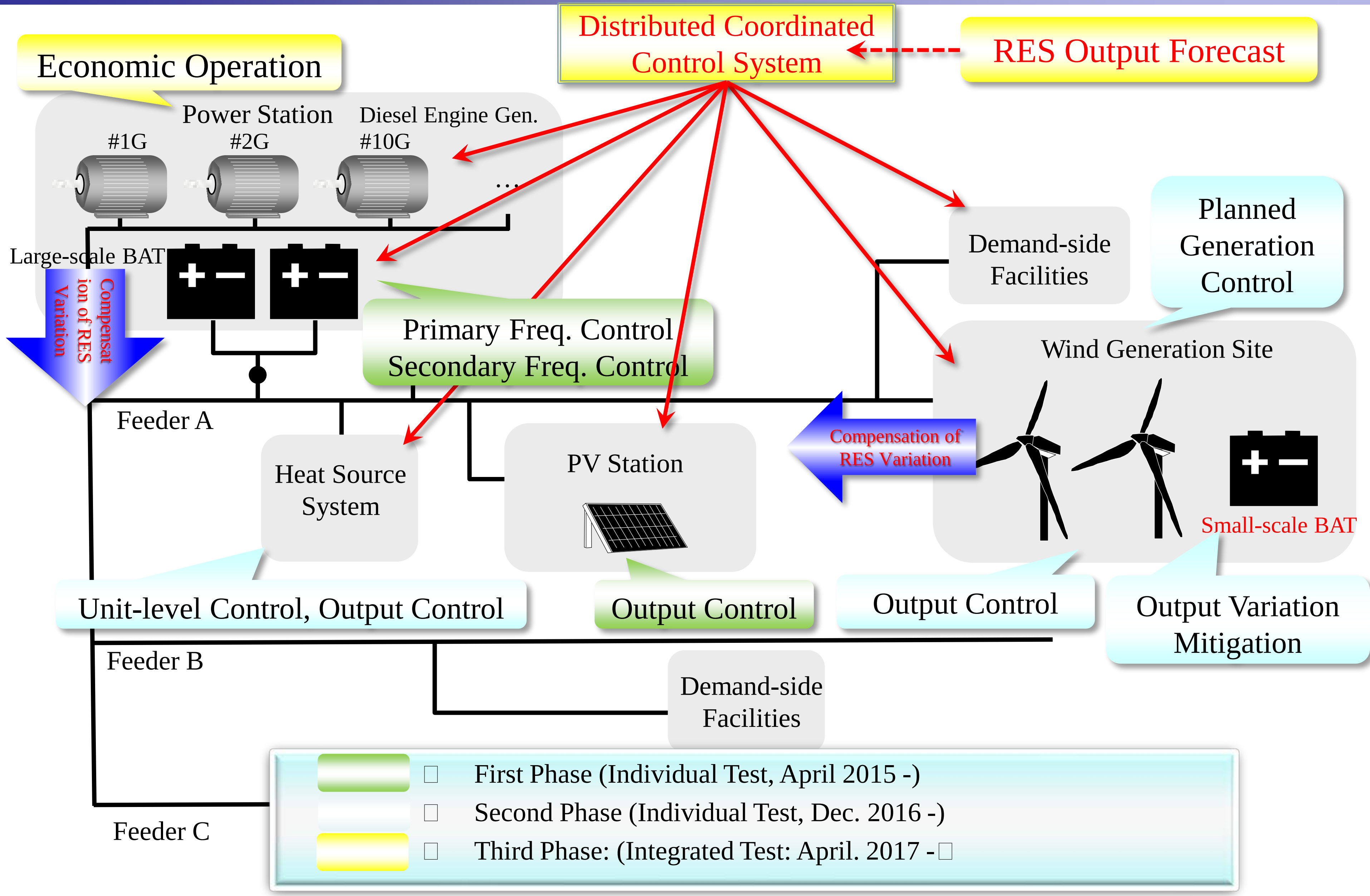


ΔPRES Controller for BESS



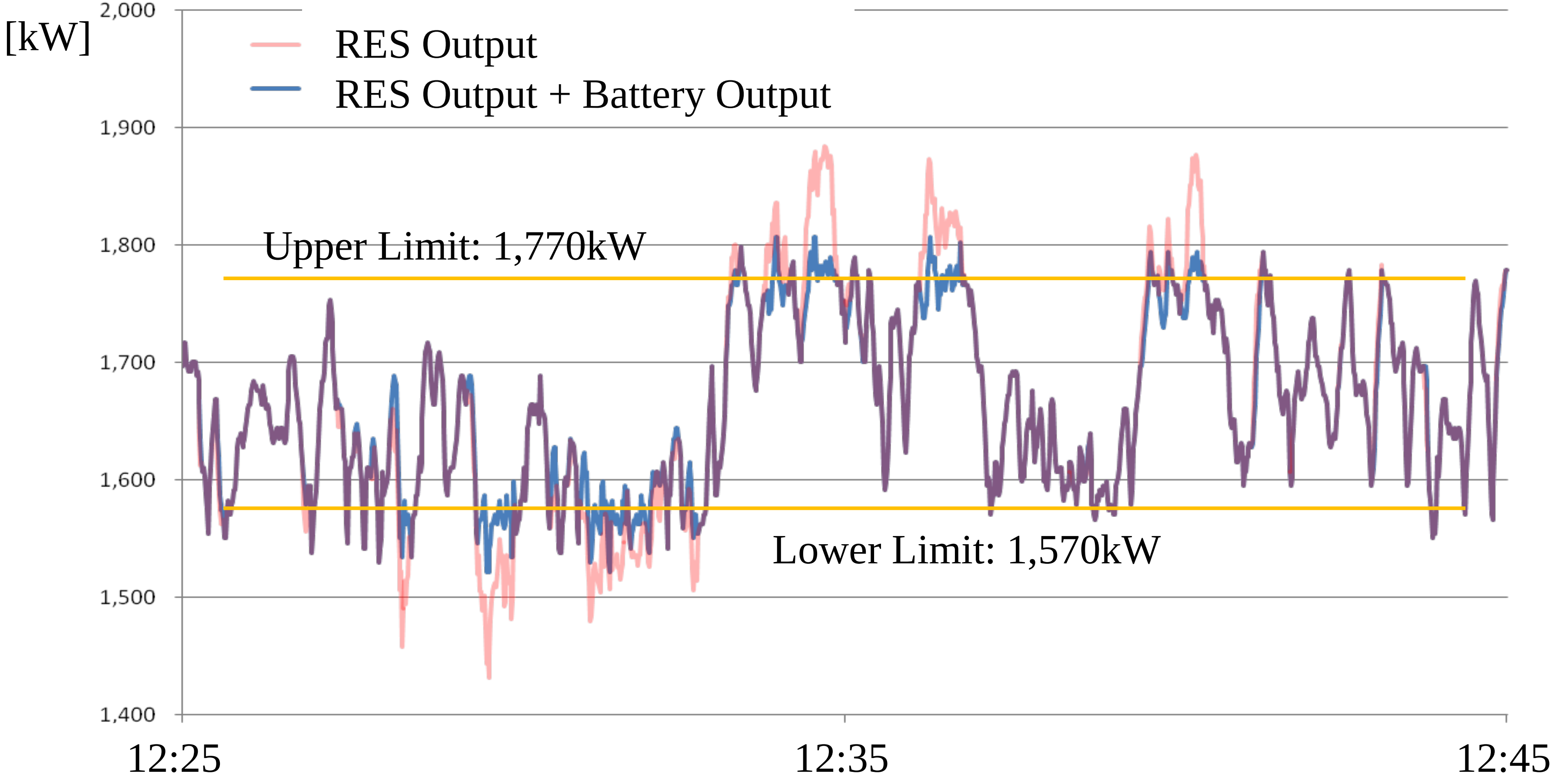
Source: CIGRE 2018 Paris Session C2 Contribution

6. Schedule of Demonstration Field Test



7. Example Result of Demonstration Field Test (Phase 1: Mitigation of RES Output Variation Using BAT)

(2) Battery Control for Mitigating RES Output Variation



Operational performance of Hybrid BESS

- **Up to the present time, the total capacity of RES integrated in the grid has reached 6.4MW, about 60 % of this project's target, and coordination control has been generally well-performed.**

Charge/discharge efficiency of each BESS
(from Oct 2015 to Sep 2016)

NaS	**84.6% ***
Li-ion	83.6% *

*** AC based value**

Source: CIGRE 2017 Symposium

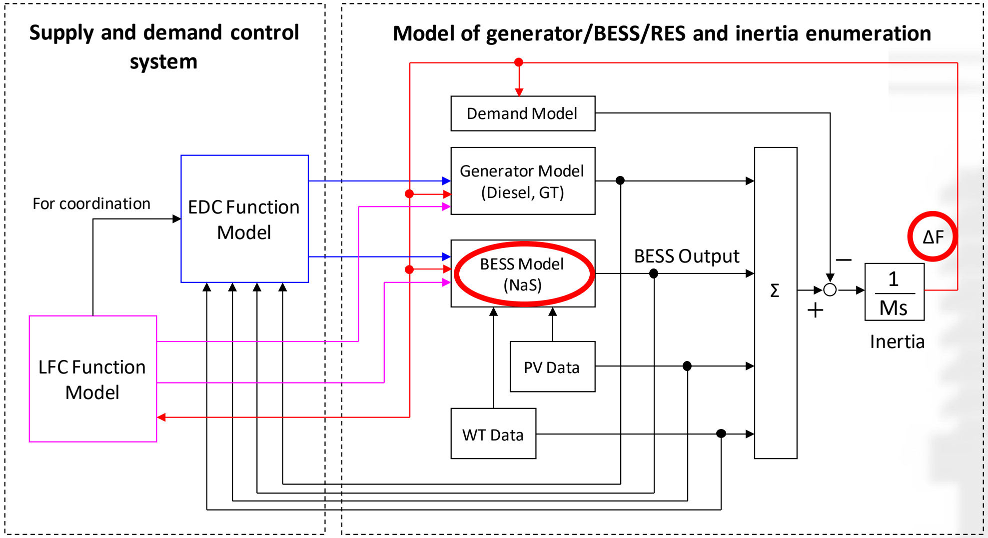
CONTENTS OF Q 1.4

Question 1.4: Papers C2-108, C2-109 and C2-112 discuss the use of BESS on secondary frequency control, mitigation of frequency deviation and as primary control reserve (PCR).

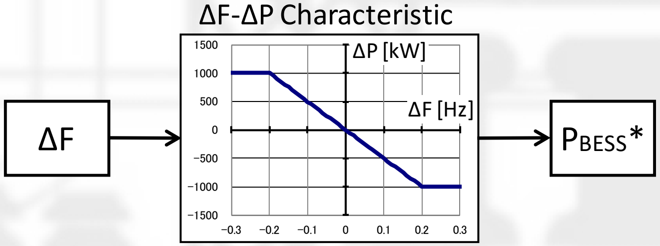
1. **How much BESS capacity is needed per installed MW of renewable energy source?**
2. Is it necessary to distribute the BESS installations along the power system?
3. What is the estimated batteries' service life, considering different operating profiles (Operational Reserve, Load Frequency Control (LFC), etc?
4. At the end of their service life, what is the disposal/recycling plan for the batteries?
5. What is the charging time after a long period of use?
6. Is the large scale use of BESS economically feasible?
7. How do regulatory issues affect this economical feasibility?
8. What is the payback for an investment on a BESS plant?

SIMULATION-BASED ESTIMATION OF BESS CAPACITY FOR SYSTEM FREQUENCY

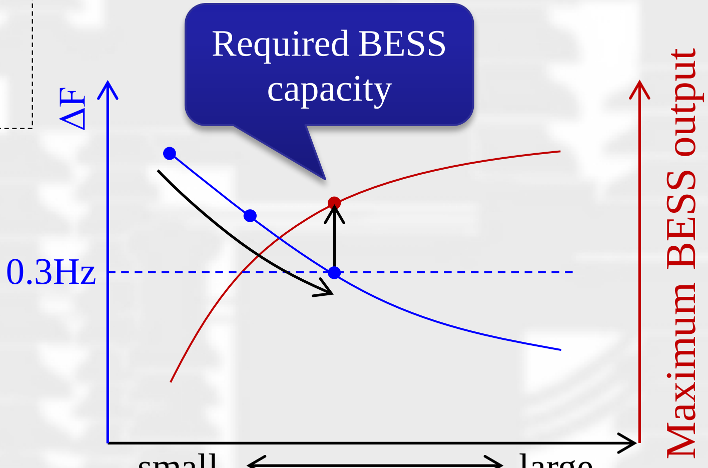
【System frequency control simulation】



【ΔF Controller for BESS】



ΔF control by BESS (primary frequency control)



Control gain of BESS (ΔP-ΔF sensitivity [kW/0.1Hz])

- Dynamic characteristics of generators, BESSs, etc, and inertia constant are identified by actual experiment data.
- System frequency and BESS output are evaluated for estimation of BESS capacity.