Symposium on Microgrid in Newcastle, 2017

Microgrid systems for remote island

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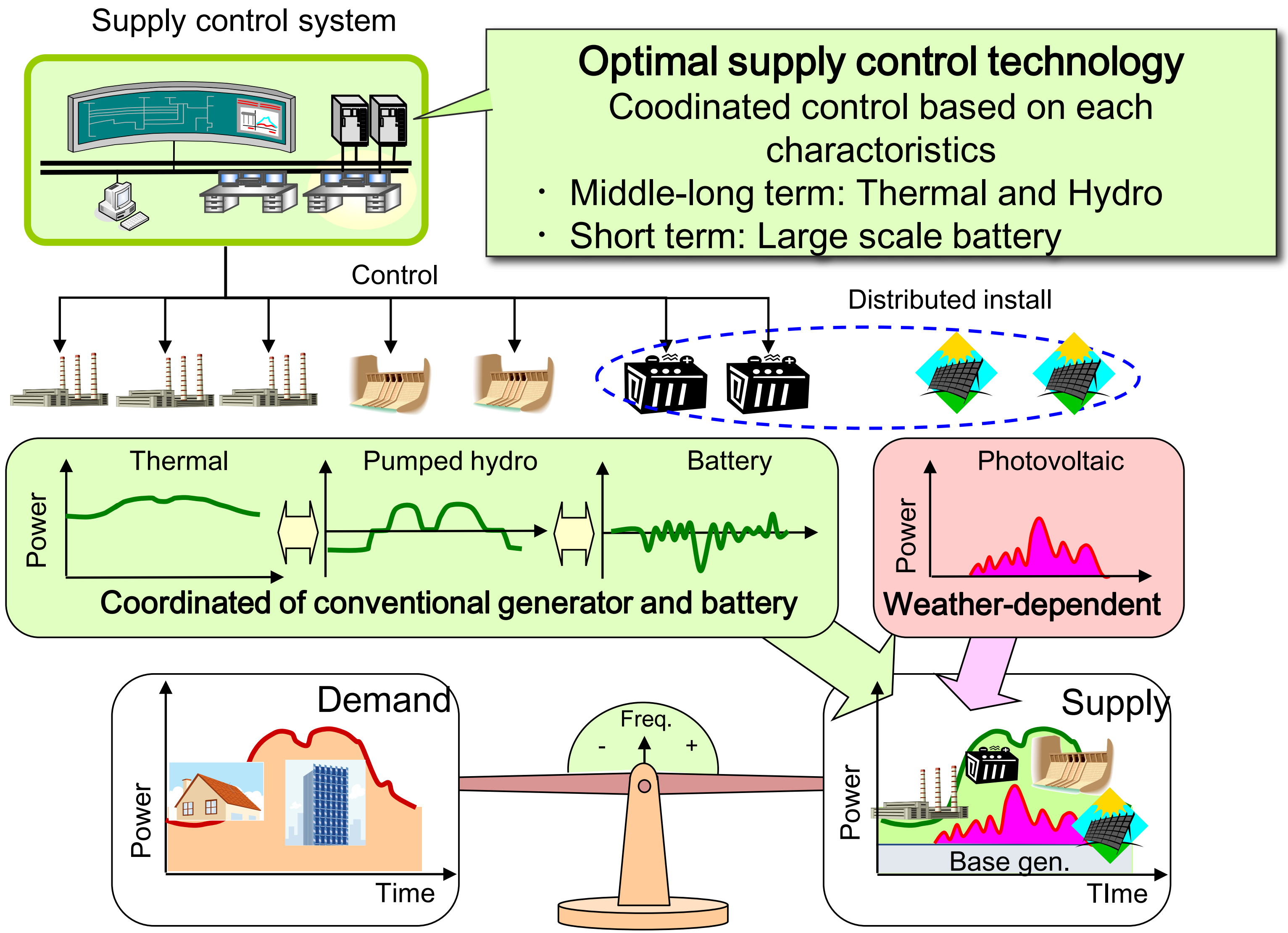
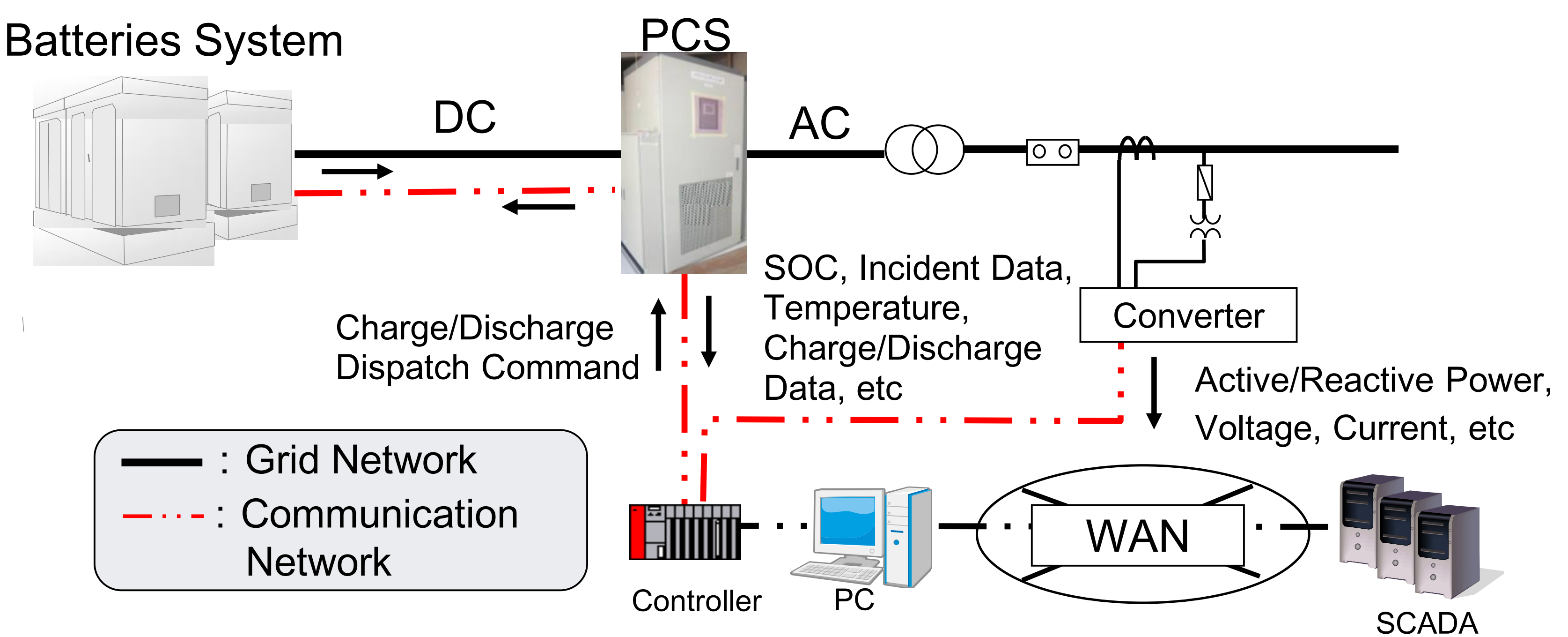
Demand and Supply control with Battery

- Demand and supply balance control with renewable energy
- Coordinated supply control considering various generators



MELCO Smart Battery Solution

- ■Control technology for power system quality
  - ・ Demand and supply control (short/long term, lower margin balancing)
  - ・ Voltage control
- ■Usage technology for different batteries*1
  - ・ Evaluate batteries in in-house Smart Grid facility (LiB, NAS, NiH)
- ■Battery system integration
  - ・ Total system design including power equipment and deterioration diagnosis, safety evaluation



*1 Currently, MELCO doesn't produce battery

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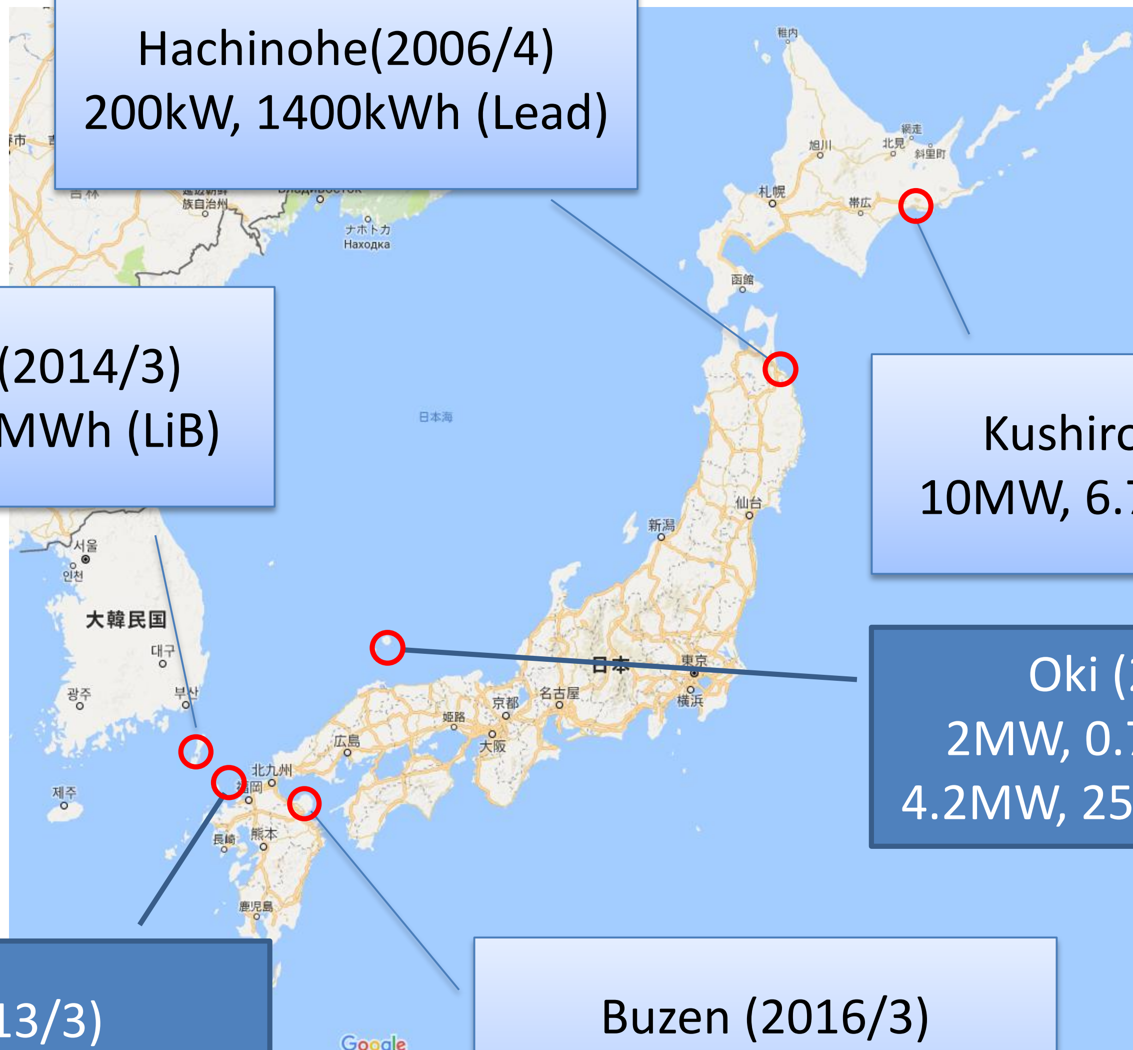
MELCO's Battery projects for renewable energy

No.	Area	Location	Purpose※	Battery type/capacity
1	Tohoku (2005-'08)	Hachinohe/Aomori (Microgrid)	Balancing Short term Long term	Lead acid 200kW 1,400kWh
2	Kyusyu (2013-)	Iki/Nagasaki (Island)	Balancing Short term	Lithium 4,000kW 1,600kWh
3	Kyusyu (2014-)	Tsushima/Nagasaki (Island)	Balancing Short term	Lithium 3,500kW 1,400kWh
4	Chugoku (2015-)	Oki/Shimane (Island)	Balancing Short term Long term	Lithium 2,000kW 700kWh Sodium-sulfur 4,200kW 25,200kWh
5	Kyushu (2016-)	Buzen/Fukuoka	Balancing Lower Margin	Sodium-sulfur 500,00kW 300,000kWh
6	Obayashi Corp. (2017-)	Kushiro/Hokkaido	Mitigate output fluctuation	Lithium 10,000kW 6,750kWh

※most battery system for balancing control support voltage stability

MELCO's Battery projects



Hachinohe(2006/4)
200kW, 1400kWh (Lead)

Tsushima (2014/3)
7.5MW, 1.4MWh (LiB)

Kushiro (2017/3)
10MW, 6.75MWh (LiB)

Oki (2015/9)
2MW, 0.7MWh (LiB)
4.2MW, 25.2MWh (NaS)

Iki (2013/3)
8 MW, 1.6MWh (LiB)

Buzen (2016/3)
50MW, 300MWh (NaS)

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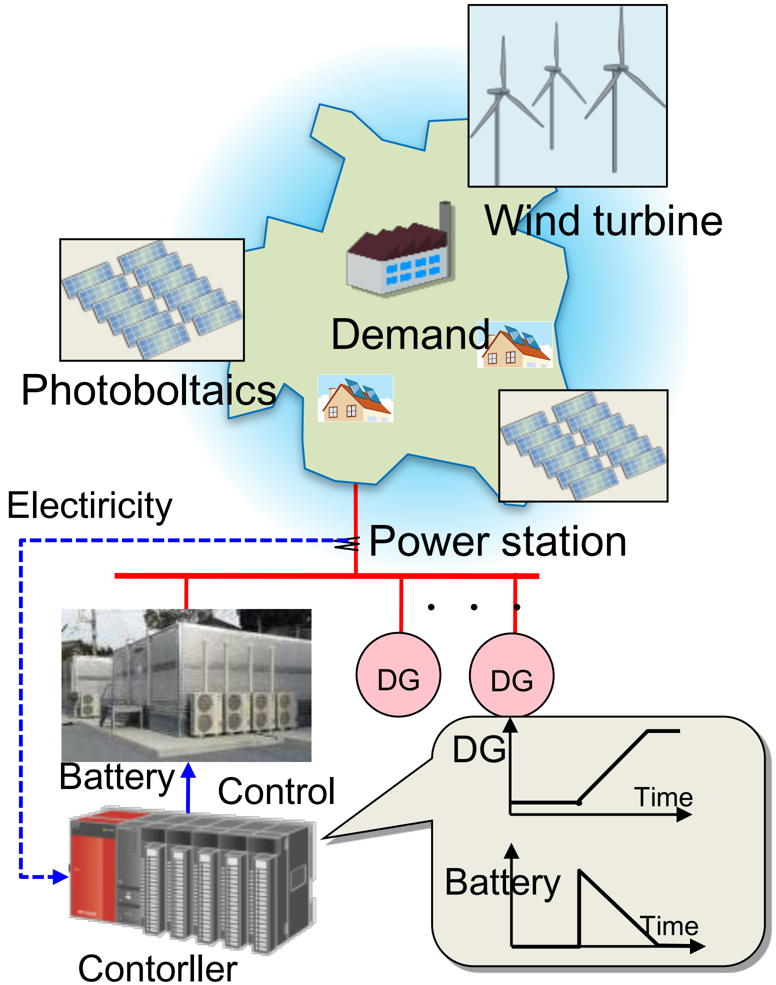
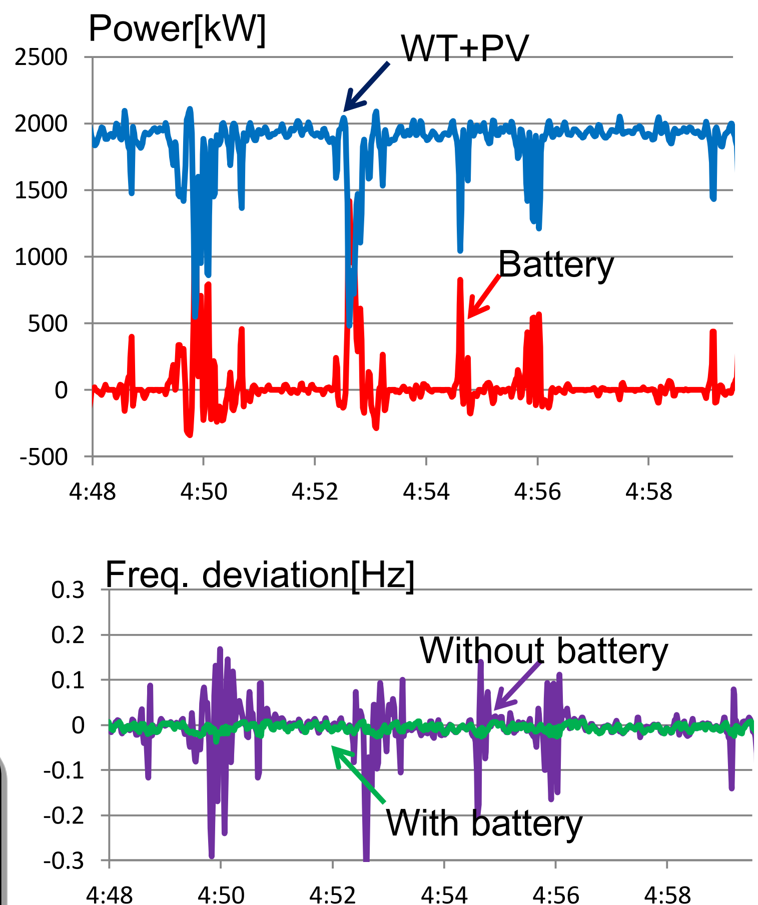
Short Term Balancing

- Battery Storage System for Island (Iki-island, Nagasaki, Kyusyu)

Issues behind Microgrid System in Island

- Penetration of renewable energy cause frequency problem, especially in island
- MELCO Smart Battery Solution supports stability of frequency
- Fast and accurate control without communication network are applied to island cases.





Simulation results

Short term control method

Control method using only local information

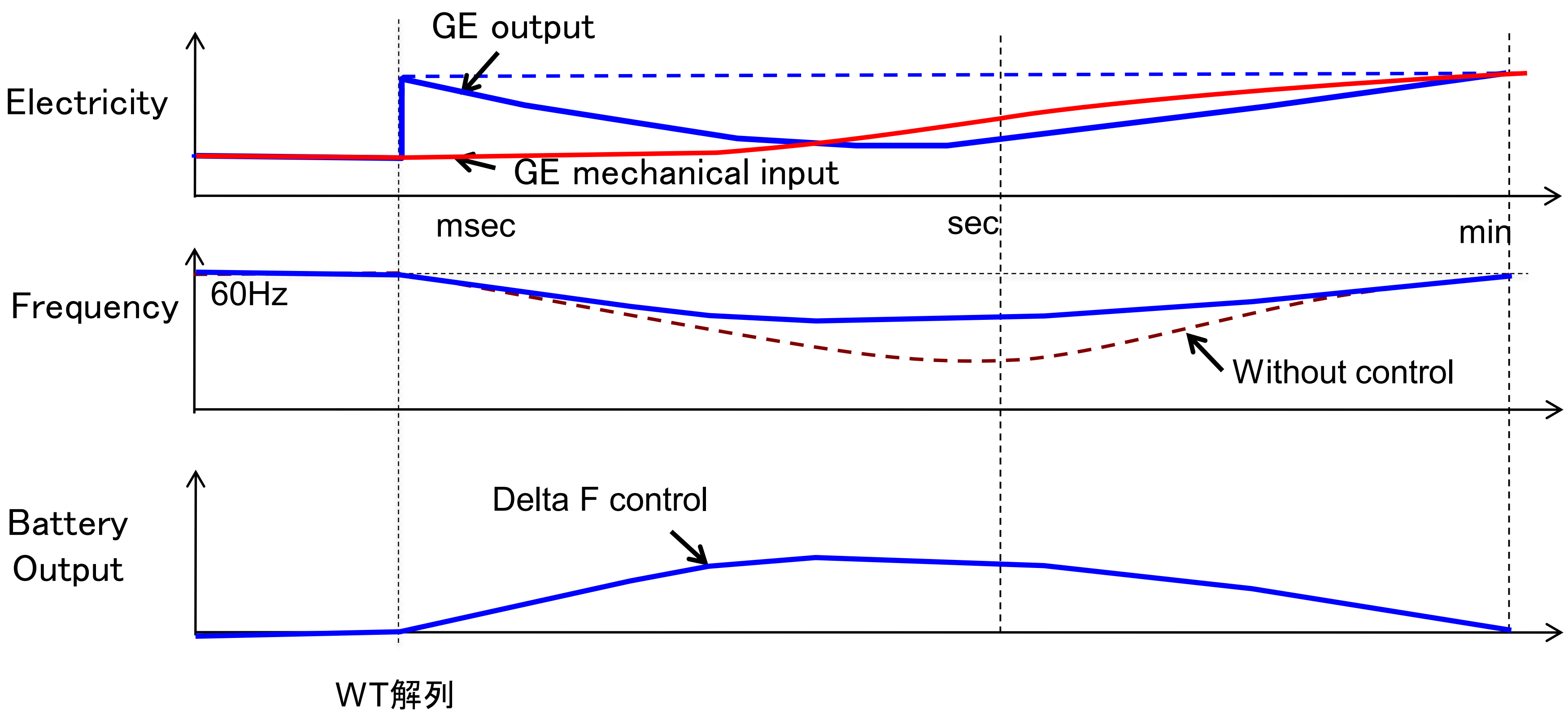
	Delta F	Delta P
Detection	Frequency fluctuation (Frequency deviation caused by Demand and supply unbalance)	Generator output fluctuation (Demand/supply balance)
Control	PI(D) calculation and feedback control based on frequency fluctuation	Fast feedforward control
Response	Not so fast (Control after frequency fluctuation)	Very fast (Control before frequency fluctuation)
Parameters	PID gain tuning (miss tuning cause oscillation)	No needs
Incorrect control	no	Depend on measurement point

We apply hybrid method

Delta F control

Delta F control

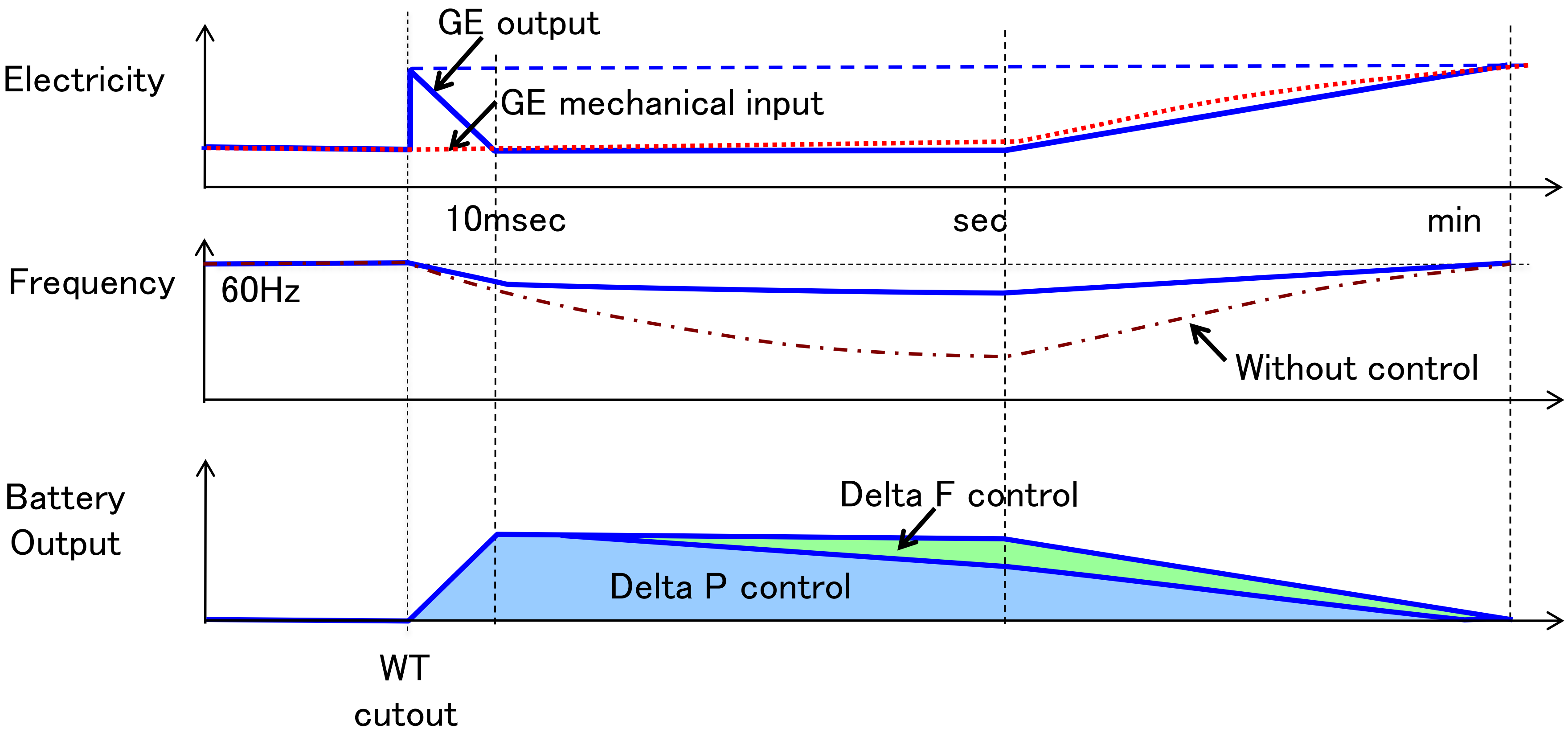
Detect frequency error and regulate frequency ***after deviation***.
Hachinohe Microgrid (2005) apply this control method using Lead battery.



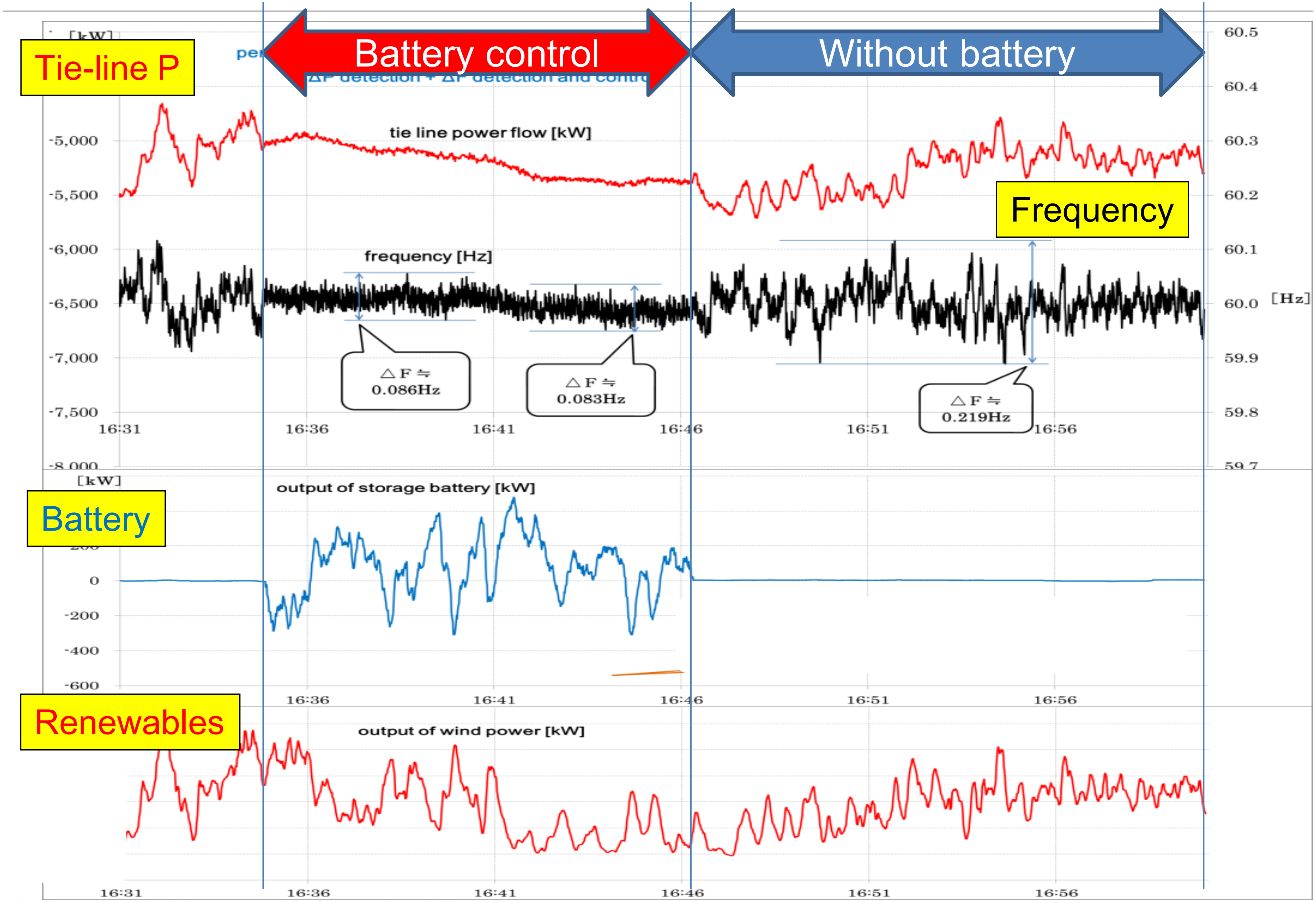
Delta P and Delta F control

Delta P+Delta F control

Detect and control demand/supply mismatch to ***prevent frequency deviation***.
Frequency error is regulated with delta F control. Used after Iki system (2013).



Control result of delta P +delta F control

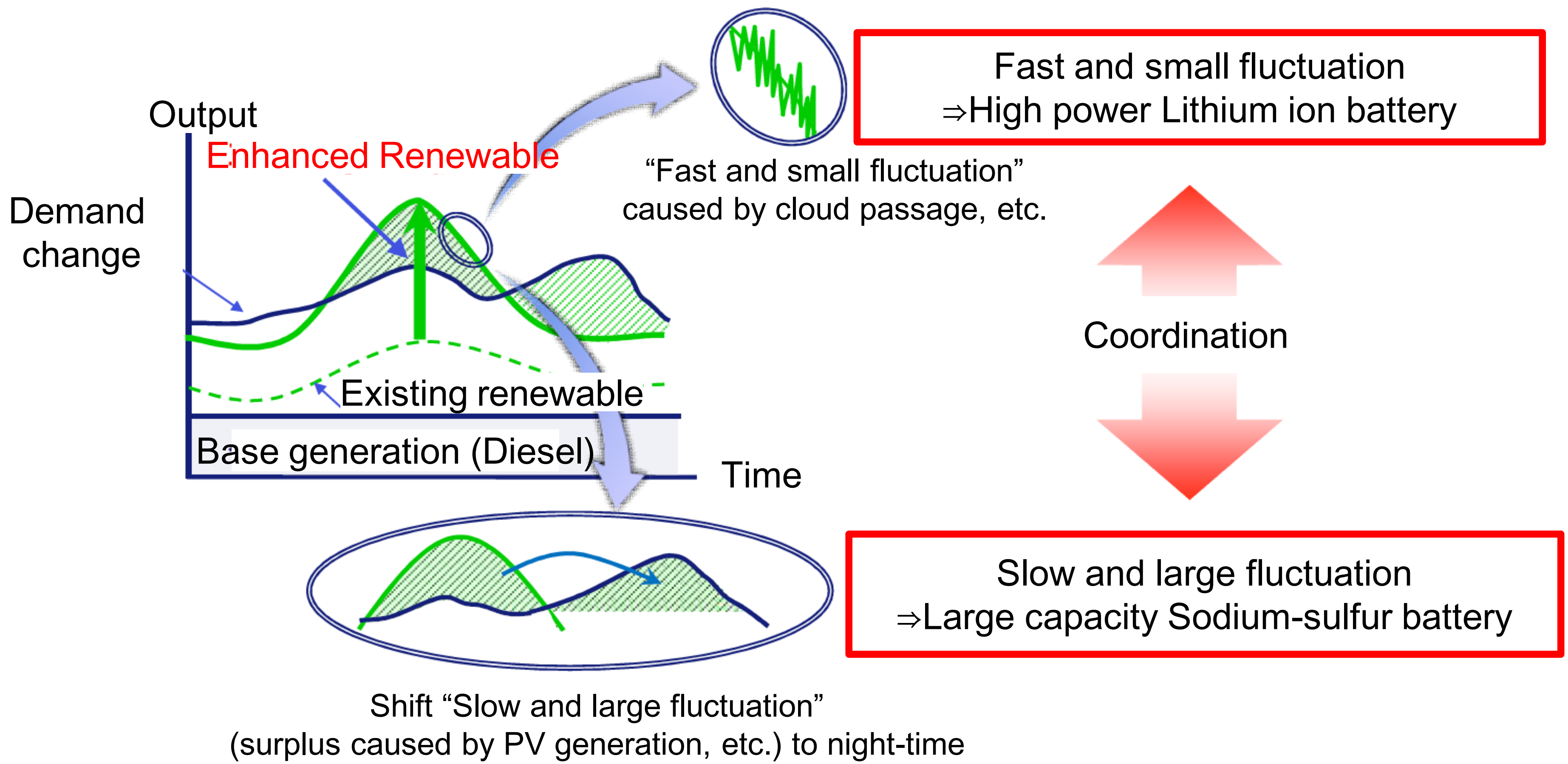


Short & Long Term Balancing

- Battery Storage System for Island
Oki-island, Shimane, Chugoku

Issues behind Microgrid System in Island

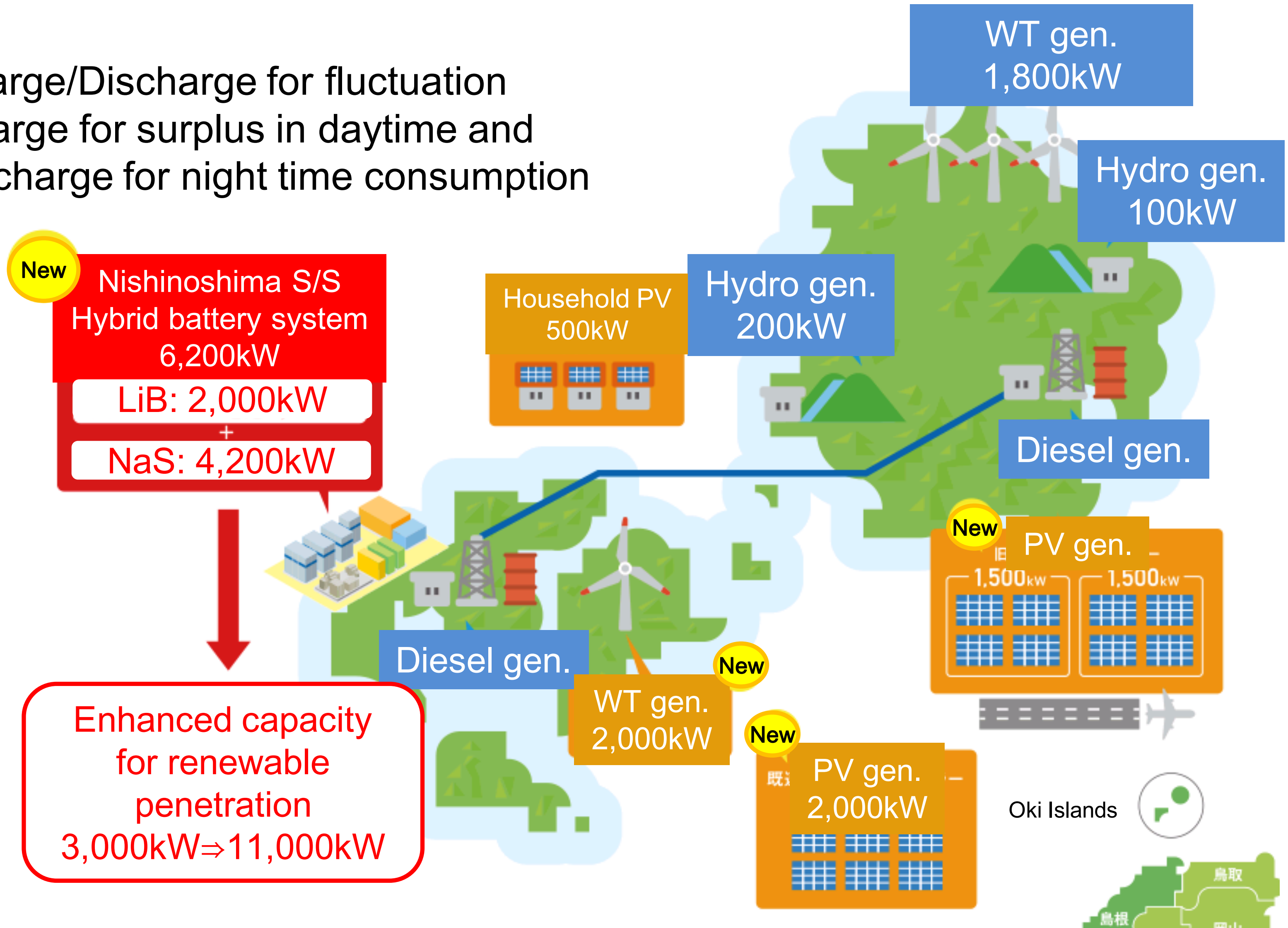
- In-addition to short term issue, evaluated possibility of shifting PV generation power for peak-time use (Long Term Issue).



Reference : The Chugoku Electric Power Co., Inc. press release (9/30/2015)

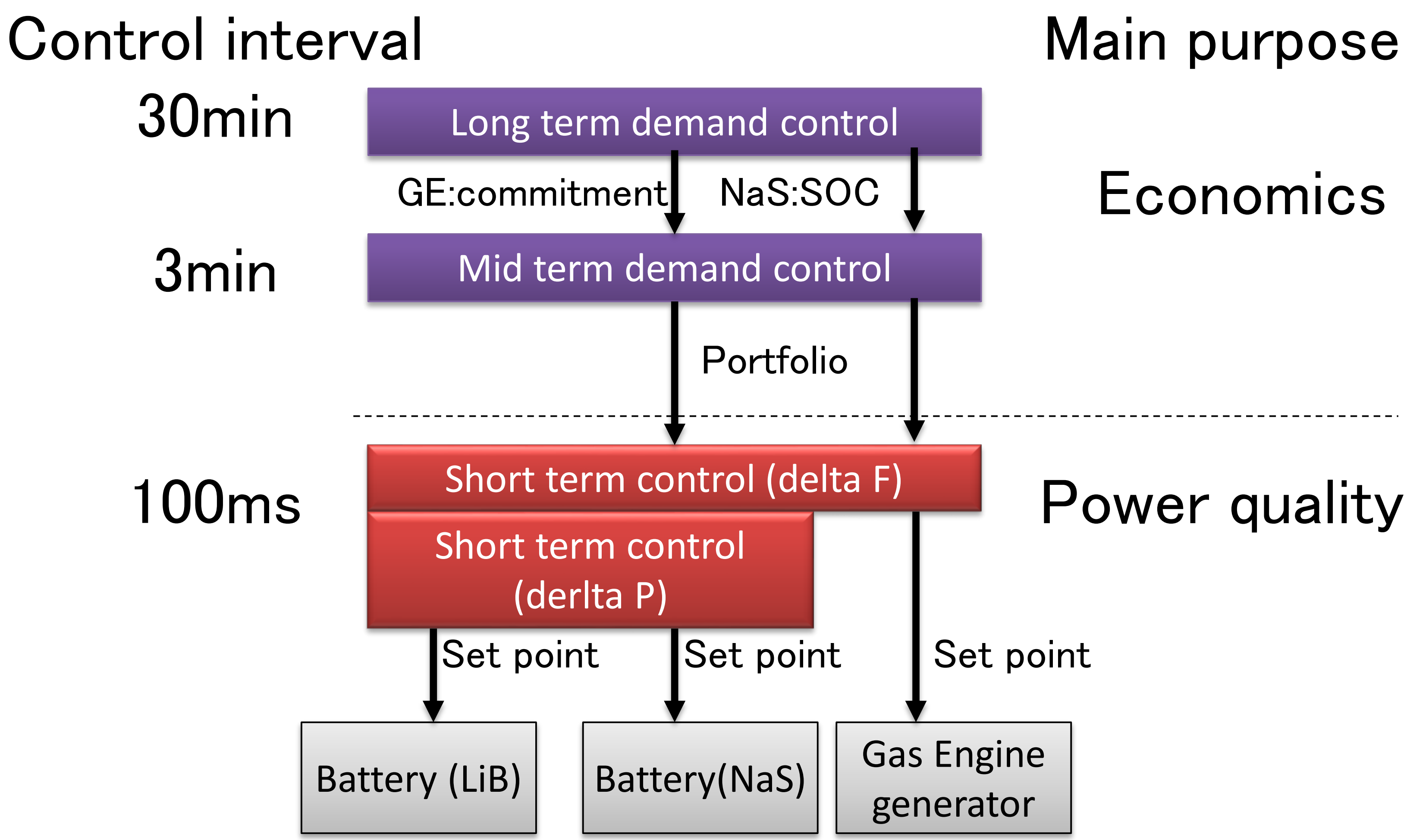
Short & Long Term Pilot System (Oki)

LiB: Charge/Discharge for fluctuation
NaS: Charge for surplus in daytime and discharge for night time consumption



Reference : The Chugoku Electric Power Co., Inc. home page
http://www.energia.co.jp/okihybrid/project

Concept of energy control (Long & short term)



Elemental tech. of Long term problem

Realtime and large scale optimization tech.

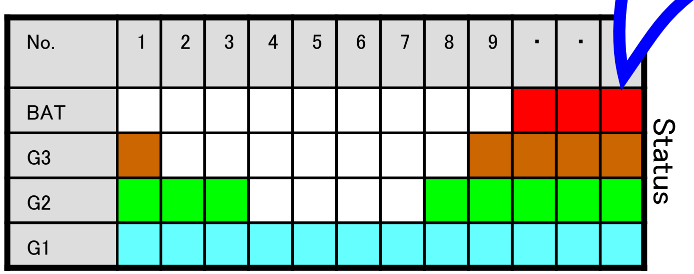
- Unit commitment problem nests output determination problem
- Fast and stable optimization method for discrete and continuous problem

Unit commitment

【Objective】
Fuel cost + constraint violation

【Constraint】
- Shortest operation/stop time
- Mimimum operation units, etc.

【Variables】
- Gereration status: $U_i(t)$



Determine generation status
(Discrete optimization)

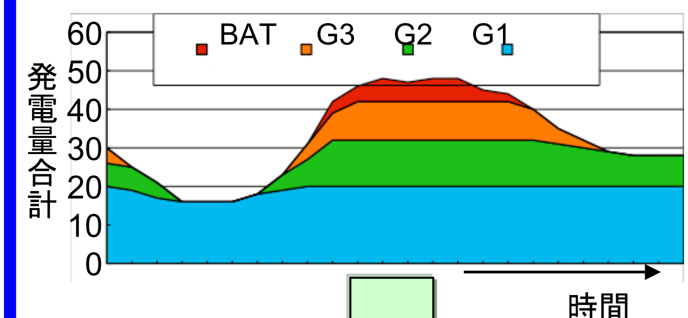
Loop

Output determination

【Objective】
Fuel cost

【Constraint】
- Demand and supply balance
- Upper/lower limits, etc.

【Variables】
- Output of thermal gen. : $P_i(t)$
- Charge/discharge of battery: $BAT(t)$



Determine generation outout
(Continuous optimization)

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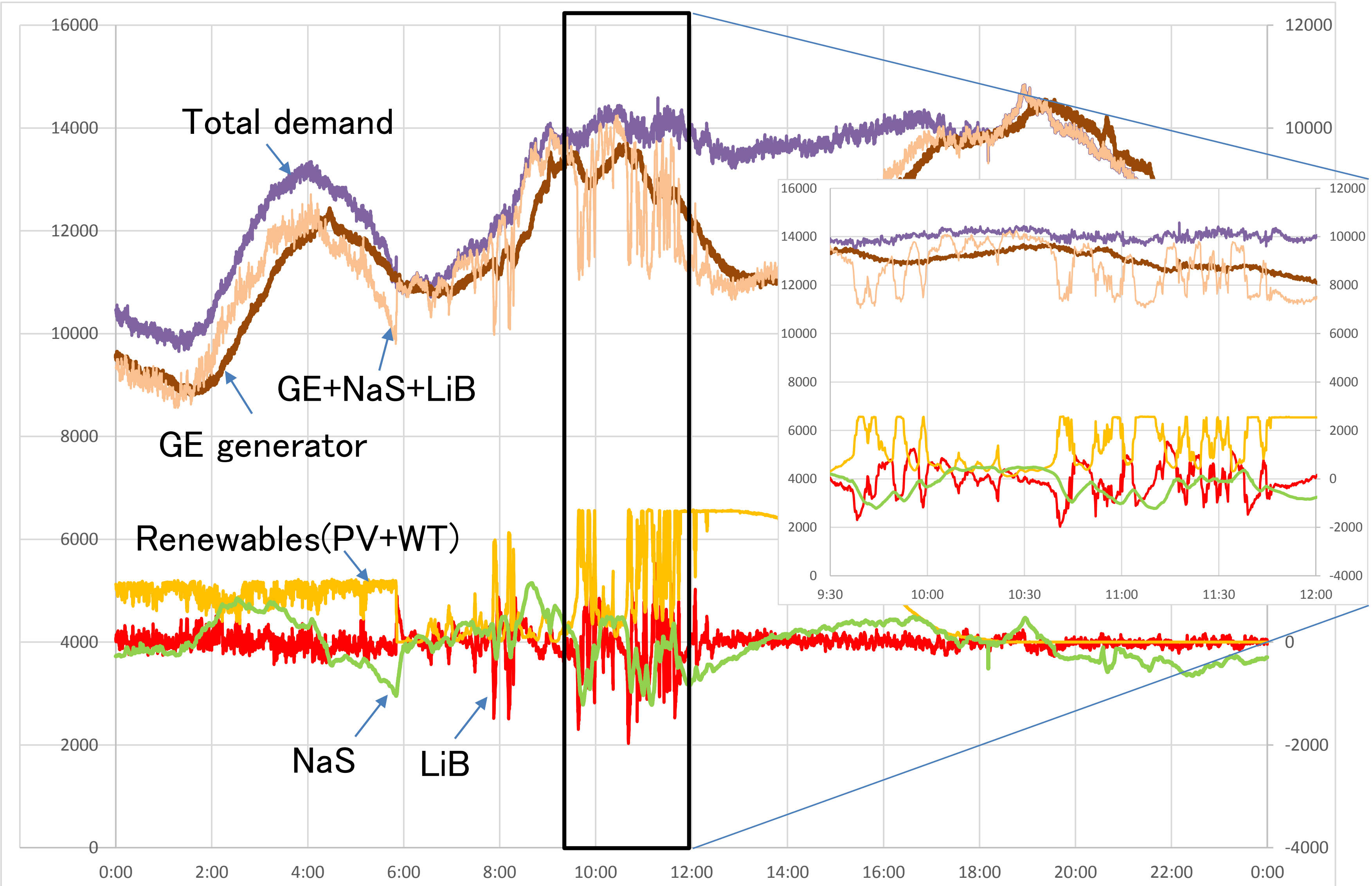
Example of control results



Nishino-shima S/S Site view (Oki-island)

Reference：The Chugoku Electric Power Co., Inc. press release (9/30/2015)

Battery container

＜NaS battery＞

＜Li-ion battery＞

Reference：The Chugoku Electric Power Co., Inc. press release (9/30/2015)

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