Operation Result of the Hachinohe Microgrid Demonstration Project

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1. Objective

2. System Overview

3. Control Concept

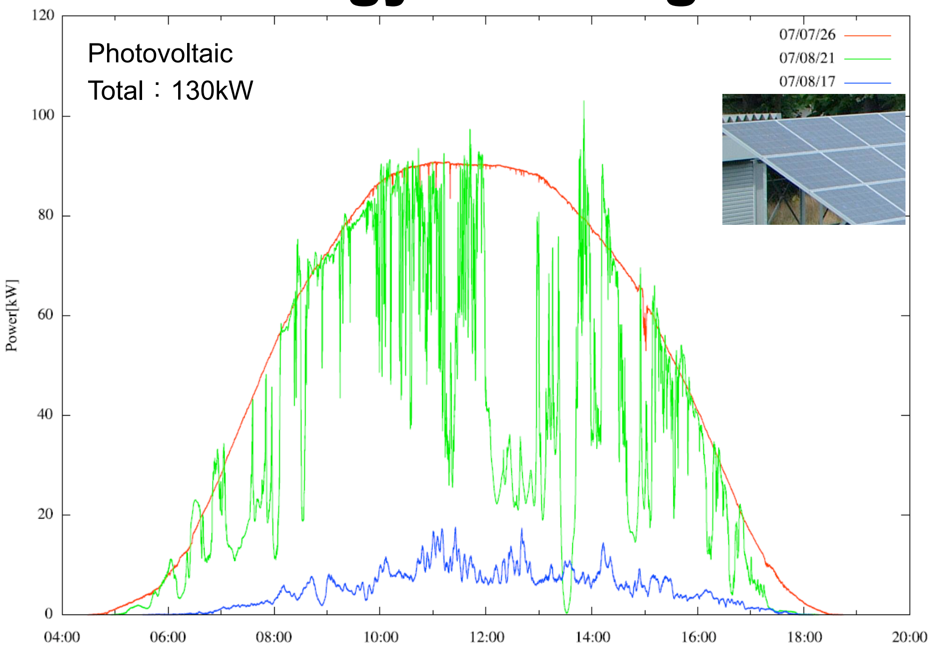
4. Operation Results

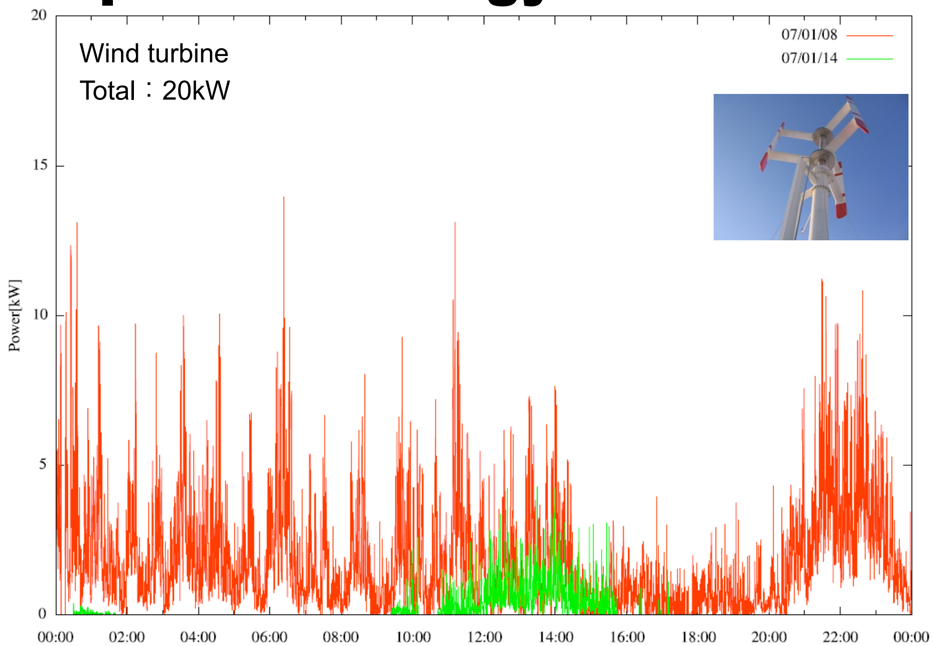
    1. Interconnected operation

    2. Islanding operation

1.Objective

- **Stabilization of weather-dependent energy is one of the main driving factor of Microgrid in Japan.**
- **Objectives of Microgrid Demonstration Project:**
  - **Demonstration of Microgrid system as a new way of introducing PVs, WTs, or other Renewable Energy Sources (RES).**
  - **Development, operation, and evaluation of Microgrid system with the ability to stabilize and control total energy including weather-dependent energy.**





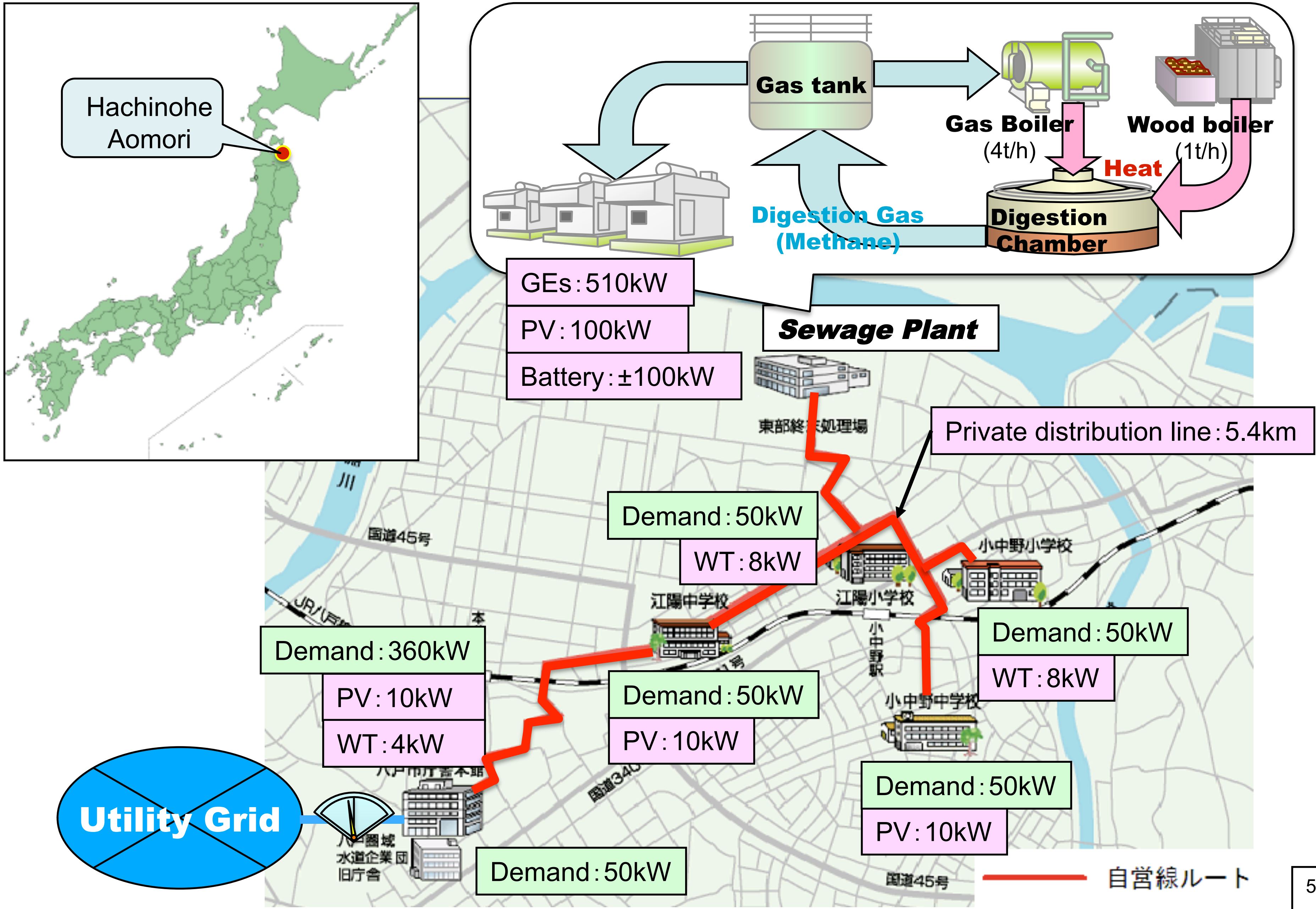
2. System overview

Hachinohe Project:

- Demand: Seven building facilities, sewage plant
  - ✓ Electricity: maximum 610kW at Hachinohe City hall, four schools and office building.
  - ✓ Heat: 10Gcal/day at Sewage plant
- Energy supply: Only RESs
  - ✓ Electricity: 510kW(170x3) biogas engines, 130kW PVs, 20kW WTs, 100kW lead-acid battery
  - ✓ Heat: 1.0t/h wood boiler and 4t/h gas boiler
- Energy management
  - ✓ 5.4km Private line (electricity & communication)
  - ✓ Interconnected with commercial grid at a single point.
  - ✓ Control error target: Within 3% every 6 minutes moving average

This project is jointly undertaken by Mitsubishi Research Institute, Mitsubishi Electric Corporation, and Hachinohe City with the support of the New Energy and Industrial Technology Development Organization(NEDO)

2. System overview



3. Control Concept

- **To satisfy both of economical (or environmental) optimization and electric power quality,**
  - ✓ **Control system consists of four functions to handle enormous dimensions of the problems.**
  - ✓ **Implement local control system considering islanding operation.**

Object	Function	Abstract	Interval	Time unit, Period
Optimization (Economical & Environmental)	Weekly Operation Planning(WOP)	Calculation of the optimal fuel supply, the storage plan of electricity and heat in a week timeframe.	1day	30-minute unit, 8 days
	Economic Dispatching Control(EDC)	Redispatch generation based on the difference between forecasted and actual data.	3min	3-minute unit, 2 hours
Quality (Tie-line flow and frequency)	Flat Tie-Line Control (Central Frequency Control)	Simply central P-I control for generation is installed to reduce the fluctuation of tie-line power flow.	1sec	-
	Local Frequency Control (Islanding mode)	High-speed compensation of battery output using local frequency observation is installed.	10msec	-

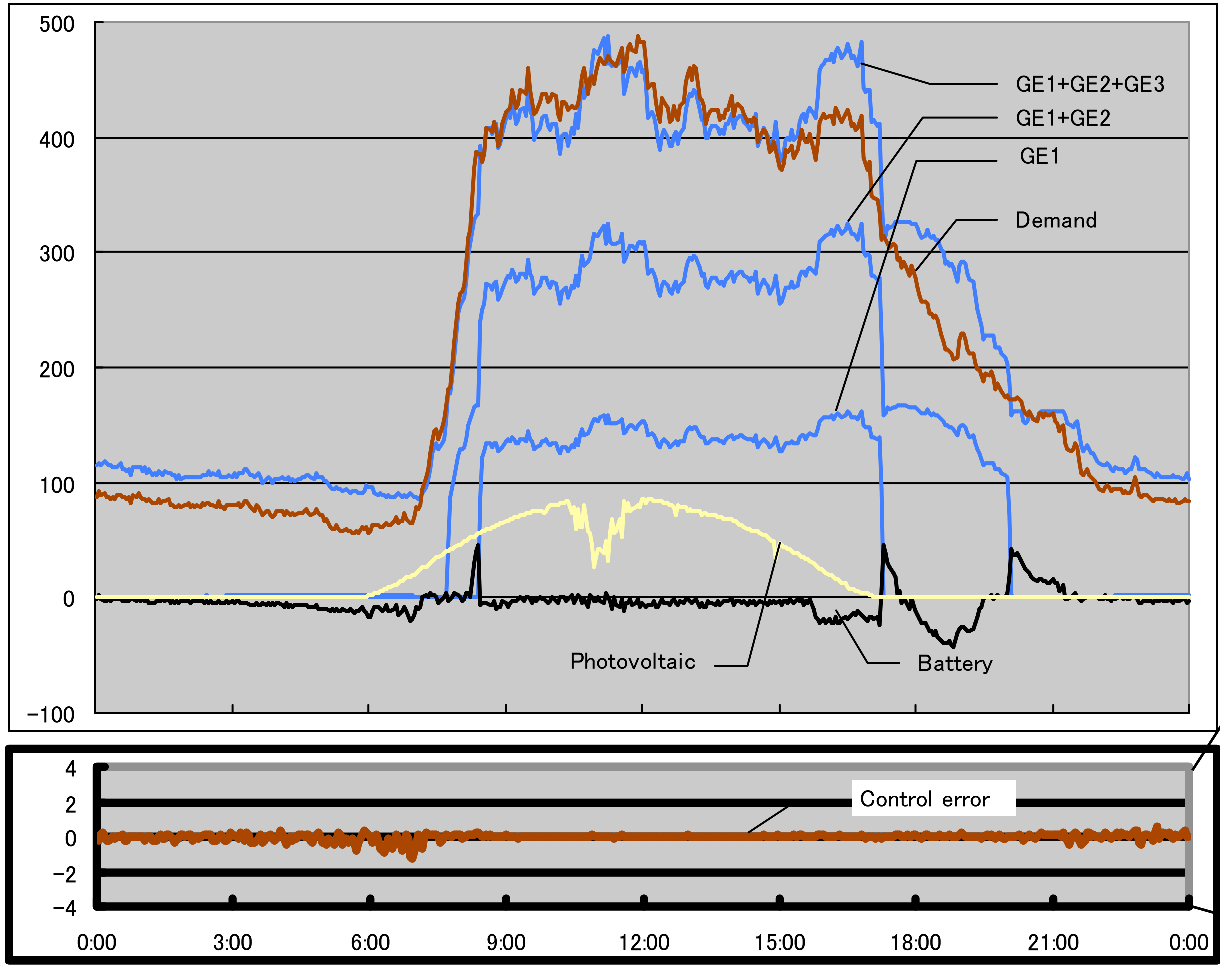
3. Control Concept

- **Coordination of gas engines and battery, local control and central control**

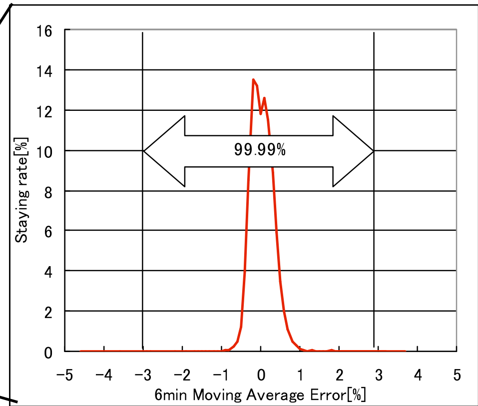
	Inter-connecting mode	Intentional islanding mode
Gas Engines (SYNC)	Set-point control (40sec lag) APFR (PF=1.0~0.95)	Set-point with droop (2Hz/100%) AVR (and CCC)
Battery (INV)	Set-point control (response in 10 millisecond) APFR (PF=1.0)	Set-point control APFR
Frequency control		High speed P and Q compensation using battery
Phase unbalance control		Negative sequency compensation using PV PCS
Central Control	･Economic Dispatching Control ･Flat Tie-line Control	･Economic Dispatching Control ･Frequency Control ･Phase unbalance control
Control Error	Tie-line power flow fluctuation	Frequency fluctuation

4.1 Interconnecting operation(1)

- **Example of Economic Dispatching Control and Flat Tie-line Control under inter-connecting operation**
- **Target precision:**
  - **Maintain six minutes moving average of tie-line power flow within 3% of scheduled value**



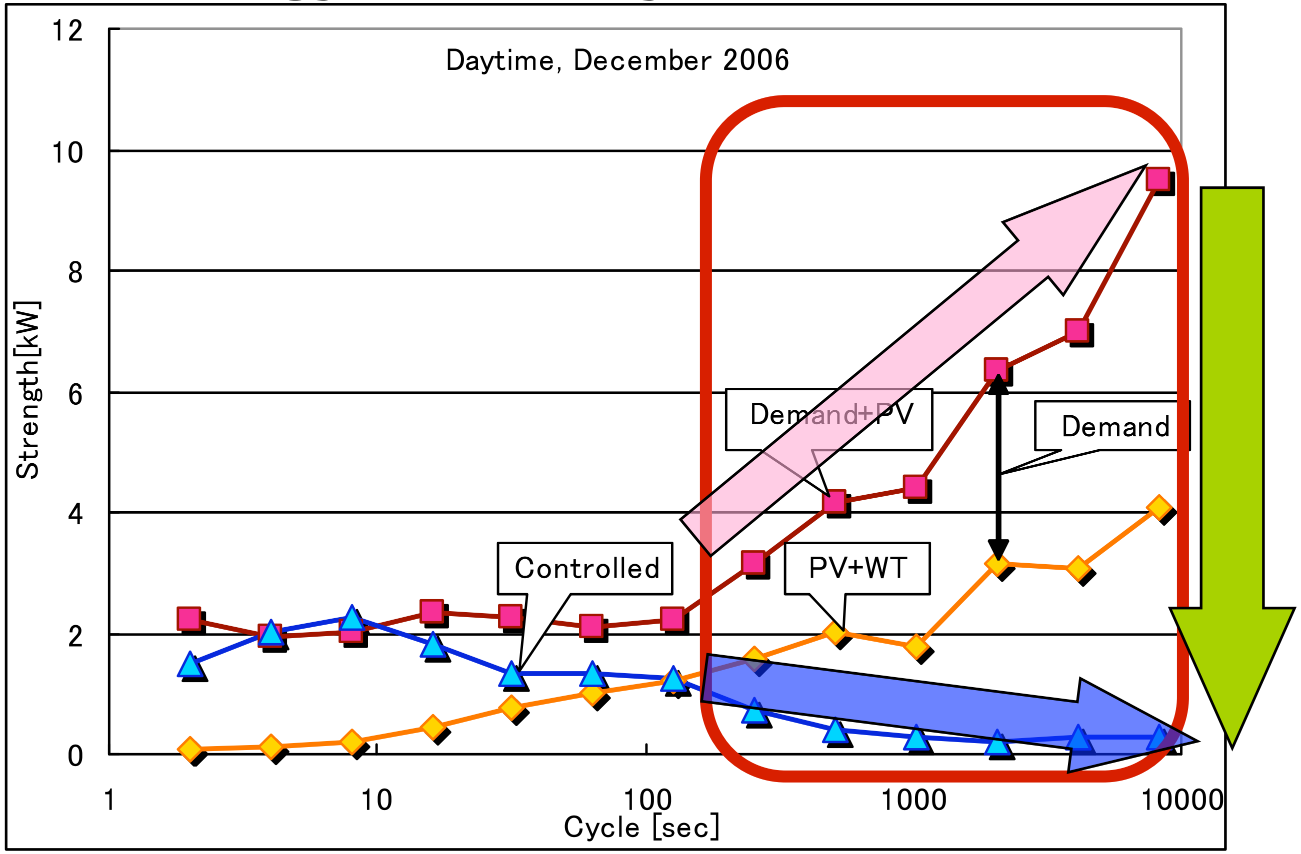
Target has been achieved in 99.99% of operation time



4.1 Interconnecting operation (2)

- **Analysis result of power quality**
  - **Fluctuation of weather-dependent energy and demand increases gradually over 1 minute,**
  - **fluctuation of control result decrease over 1minute.**

→Our control system reduce fluctuation of weather-dependent energy effectively



4.2 Islanding Operation (1)

- **One-week intentional islanding operation (disconnected from the utility grid) was performed in Nov. 2007.**

OBJECTIVE

- **Develop microgrid EMS for island or remote area**
- **Confirm the control performance in more difficult conditions**

ASSUMED PROBLEMS

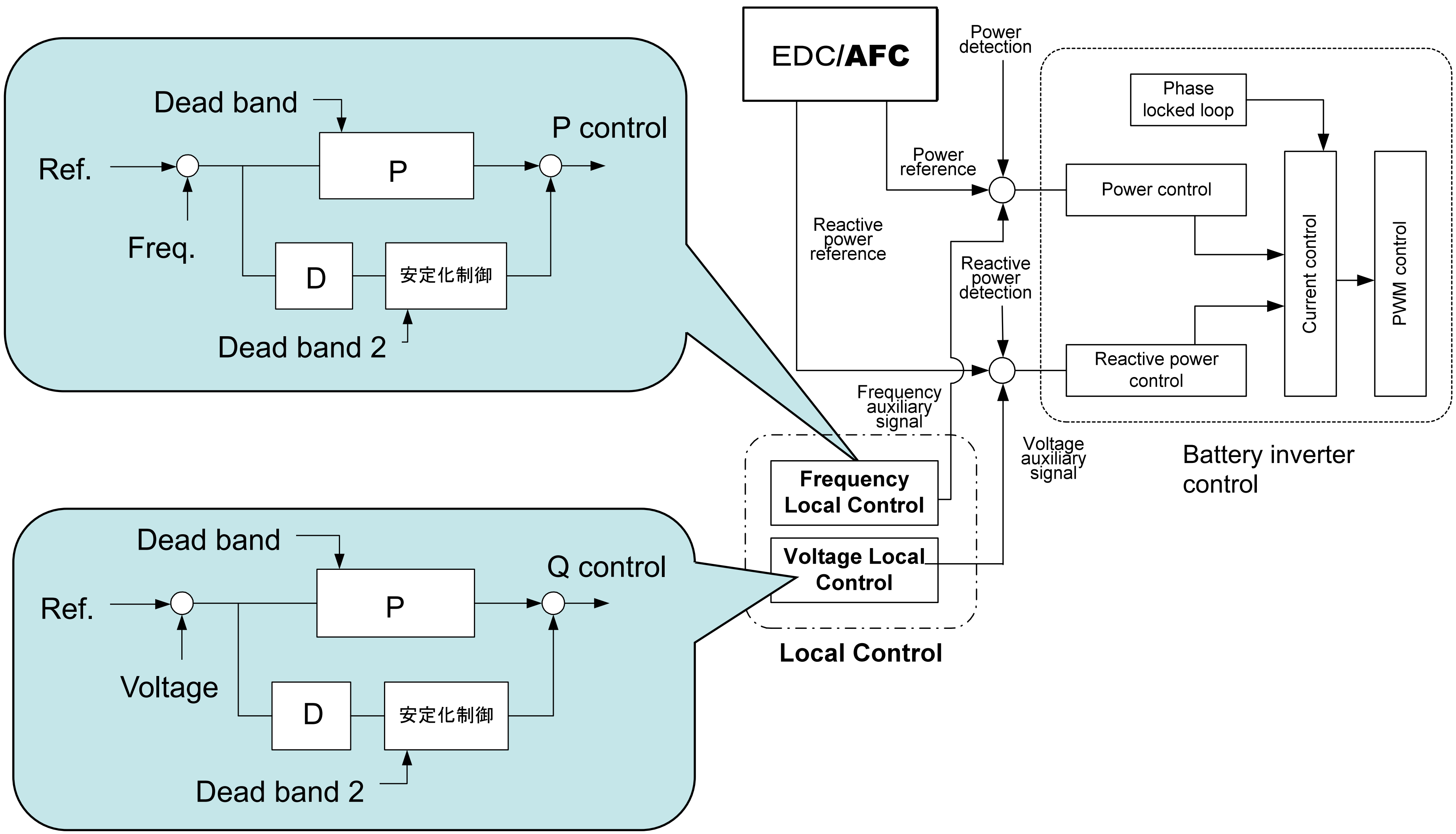
- **Frequncy**
  Inertia of the gas engine (GE) is too small to stably maintain frequency in the case of large load fluctuation.
- **Three phase unbalance**
  Negative sequence current of GE caused by three phase unbalance is bigger than tolerated dose of GEG(15%)

Assumed problems and actions

	Problems	Actions
Frequency	2.6Hz drop with 50kW AC startup with one GEG (target: 0.5Hz)	High speed (10 msec) local frequency control using battery inverter
Voltage	6% drop with AC startup (Target: 6%)	Local control using battery inverter
Phase Unbalance	10A negative sequence current (target: 2.8A)	･Phase switching reduces 5A. ･Install negative sequence compensator using PV PCS
Harmonics	No problems	Install protection relay just in case

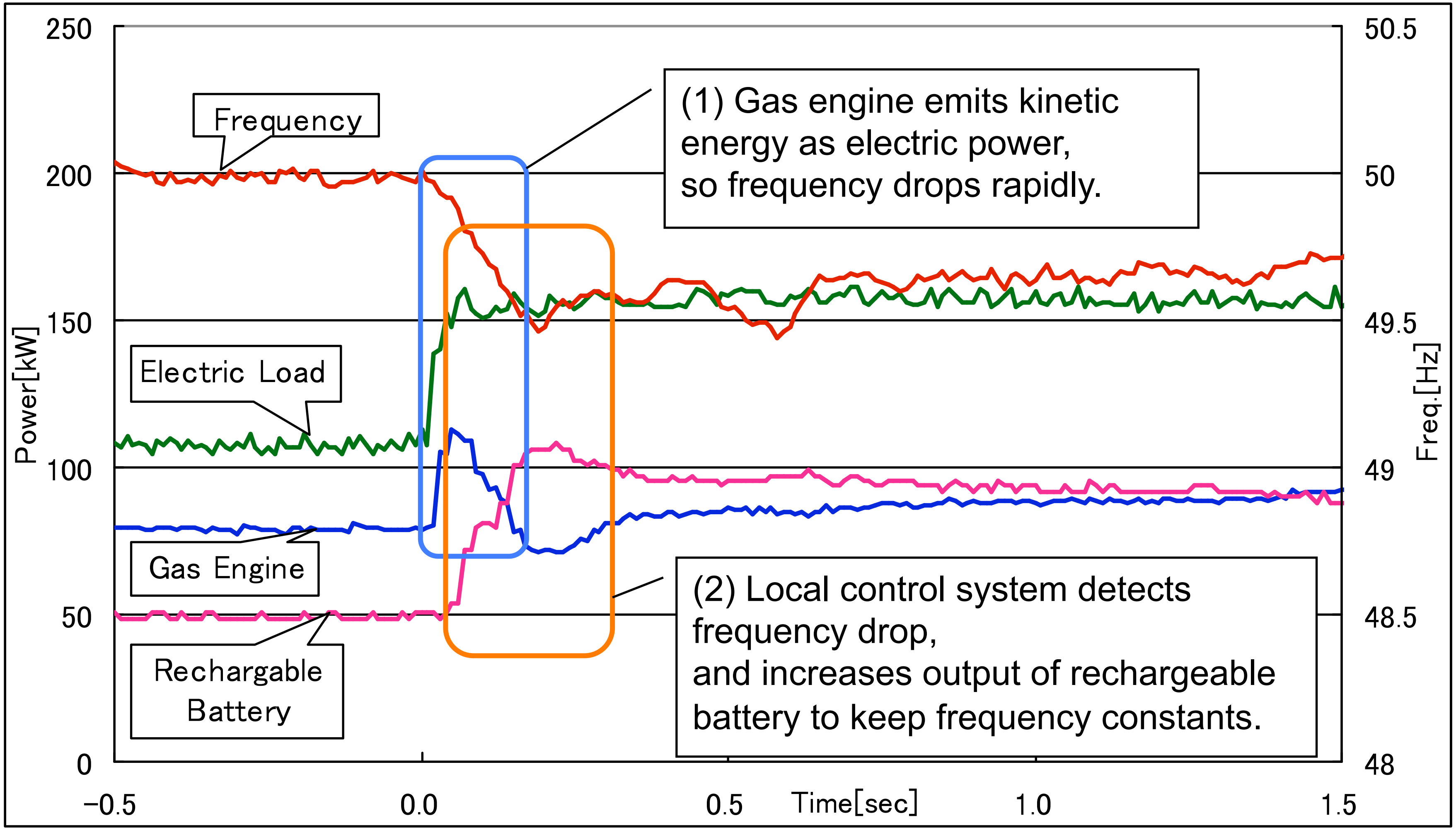
4.2 Islanding Operation (3)

Local control using battery inverter



4.2 Islanding Operation (4)

- **High speed frequency control with battery**
  - **Keep within 0.5Hz under largest power deviation**



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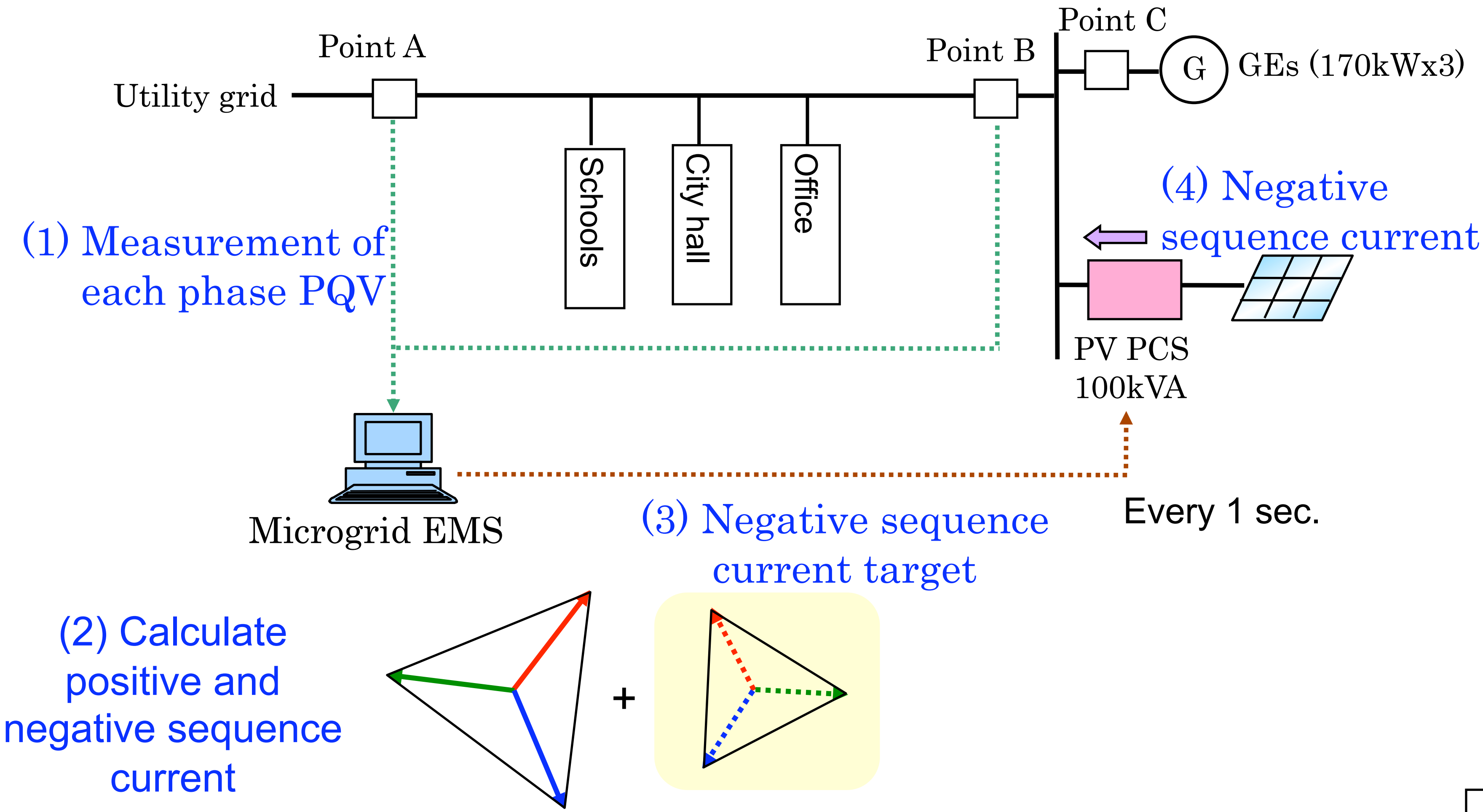
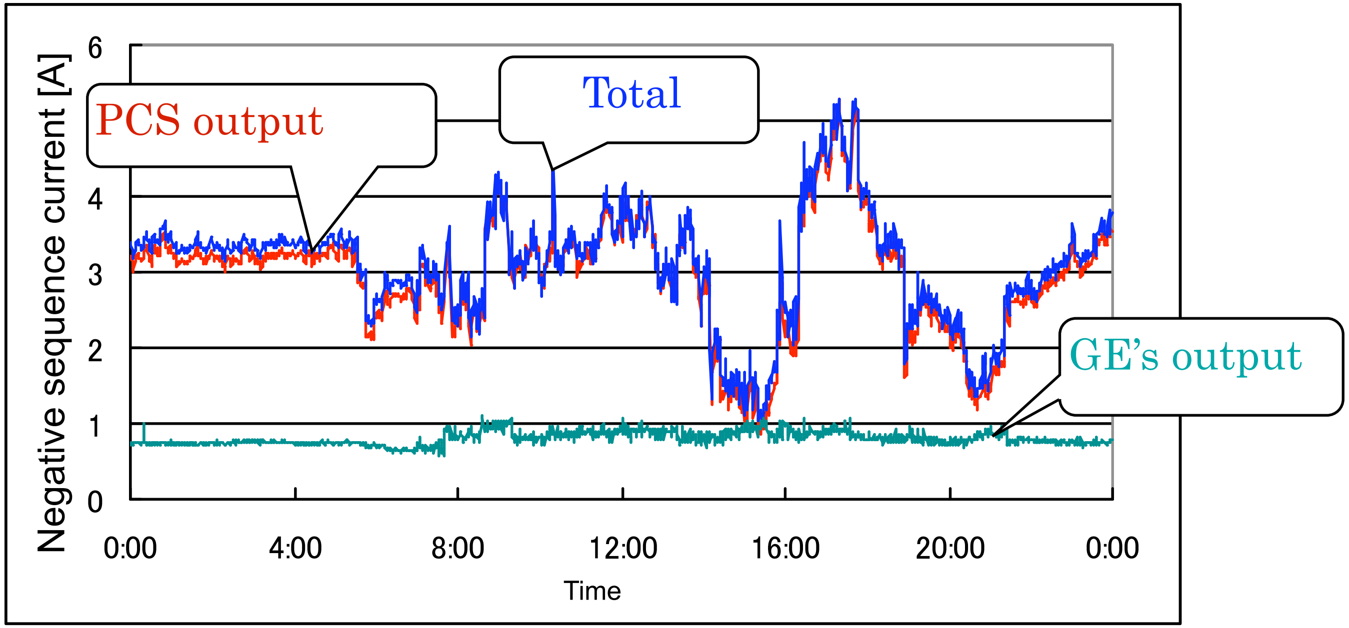
4.2 Islanding Operation (5)

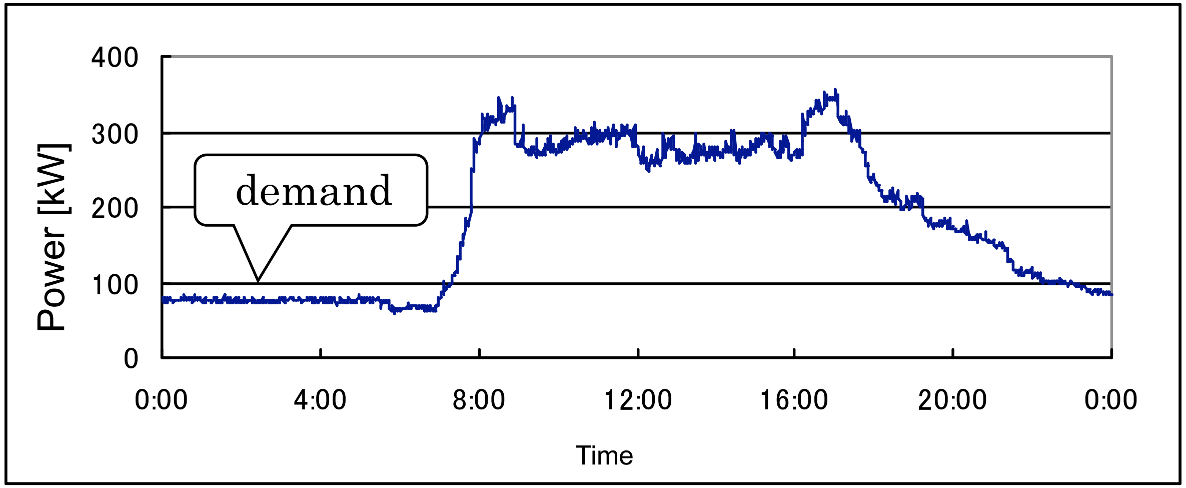
Phase unbalance control (negative sequence current compensation)



4.2 Islanding Operation (6)

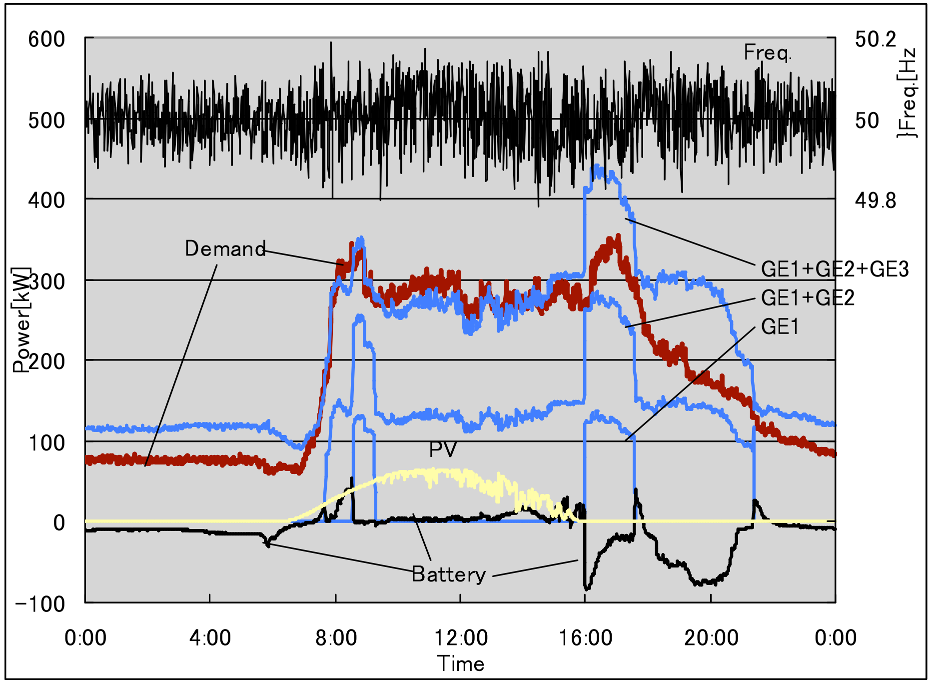
Example of phase unbalance compensation



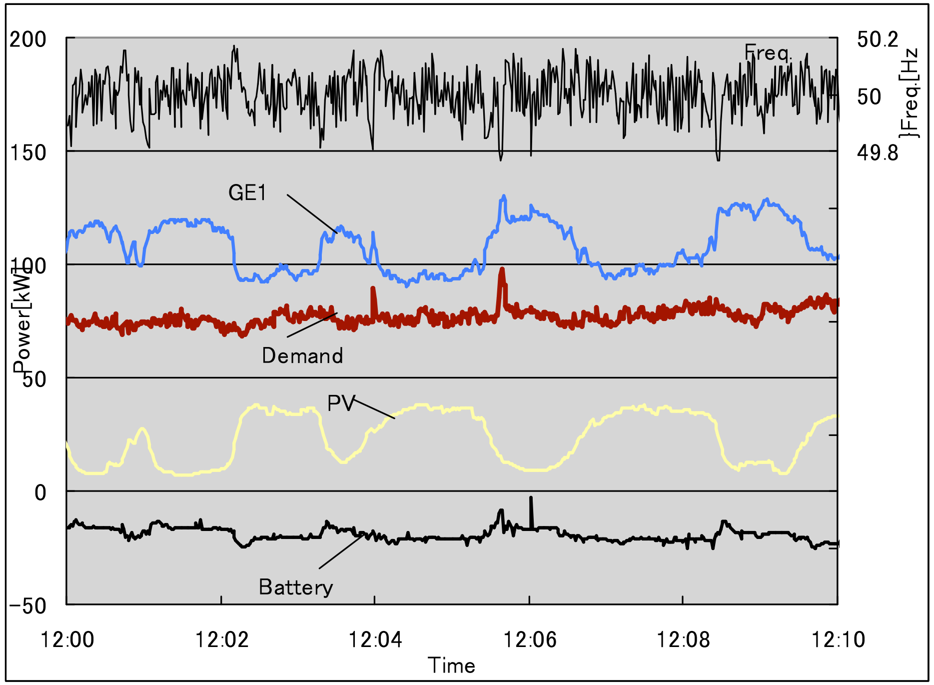


4.2 Islanding Operation (7)

- **Weekday (Left figure)**
  - **Midnight: Battery charges surplus power of GEG**
  - **Morning: Three GEs and battery track rapid rising**
- **Holiday (Right figure)**
  - **Noon: GE can track PV fluctuation**



Weekday (24 hours)



Holiday (10 mins)

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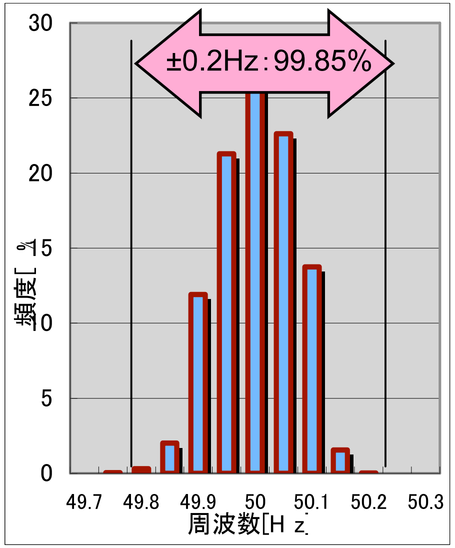
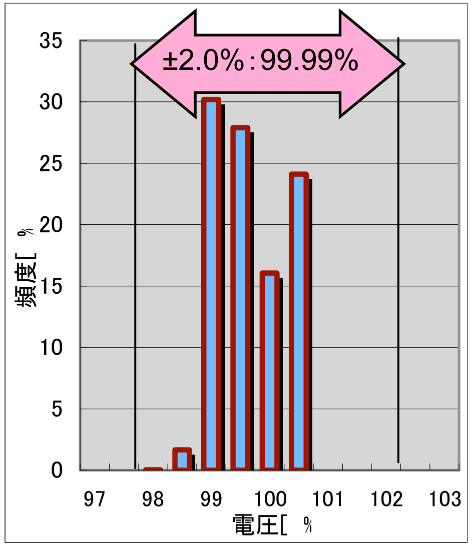
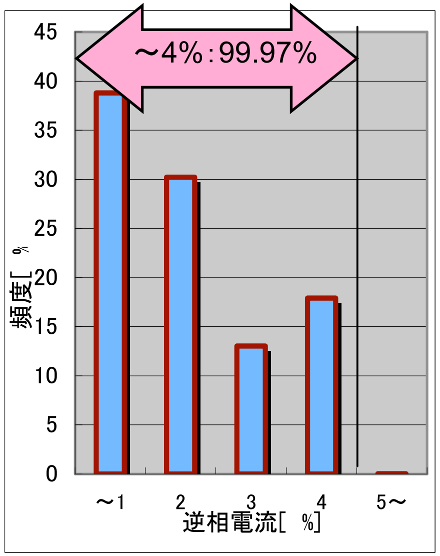
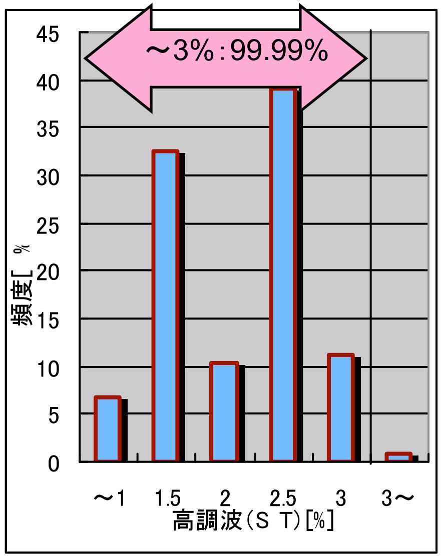
4.2 Islanding Operation (8)









【Frequency】
Target
50±0.5Hz
Result
±0.5Hz : 100%
±0.2Hz : 99.85%
Max error: −0.4Hz

【Voltage】
Target
±6%(101±6V)
Result
±6.0% : 100%
±2.0% : 99.99%
Max error : 4%

【Negative seq. cur.】
Target
within 15%
(2.8A / GE)
Result
15% : 100%
4% : 99.97%

【Harmonics】
Target
within 5%
Result
5.0% : 100%
3.0% : 99.99%
Max error 3.1%

Conclusion

- We develop 4 layers energy management system for microgrid.
- Inter-connecting operation
  - Fluctuation of weather-dependent generation is effectively reduced.
  - Over 50% reduction of CO2 emission.
- Islanding operation
  - Prove ability to supply height quality power using only renewable energy sources