Microgrid systems for remote island

Yasuhiro KOJIMA
Mitsubishi Electric Corporation
Power System ICT Center
Power System Engineering Department
Demand and Supply control with Battery

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

**Optimal supply control technology**
Coodinated control based on each characteristics
- Middle-long term: Thermal and Hydro
- Short term: Large scale battery

![Diagram of supply control system]

- Coordinated of conventional generator and battery
- Weather-dependent
- Demand and supply balance control with renewable energy
- Coordinated supply control considering various generators

![Diagram of control system]

- Thermal
- Pumped hydro
- Battery

![Diagram of demand and supply]

- Demand
- Supply
- Frequency
- Time
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

**Batteries System**

**Diagram:**
- DC-AC converter
- PCS
- Controller
- PC
- SCADA
- Communication Network
- Grid Network

*1 Currently, MELCO doesn't produce battery
<table>
<thead>
<tr>
<th>No.</th>
<th>Area</th>
<th>Location</th>
<th>Purpose※</th>
<th>Battery type/capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Tohoku</td>
<td>Hachinohe/Aomori</td>
<td>Balancing</td>
<td>Lead acid</td>
</tr>
<tr>
<td></td>
<td>(2005-’08)</td>
<td>(Microgrid)</td>
<td>Short term</td>
<td>200kW 1,400kWh</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Long term</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Kyusyu</td>
<td>Iki/Nagasaki</td>
<td>Balancing</td>
<td>Lithium</td>
</tr>
<tr>
<td></td>
<td>(2013-')</td>
<td>(Island)</td>
<td>Short term</td>
<td>4,000kW 1,600kWh</td>
</tr>
<tr>
<td>3</td>
<td>Kyusyu</td>
<td>Tsushima/Nagasaki</td>
<td>Balancing</td>
<td>Lithium</td>
</tr>
<tr>
<td></td>
<td>(2014-')</td>
<td>(Island)</td>
<td>Short term</td>
<td>3,500kW 1,400kWh</td>
</tr>
<tr>
<td>4</td>
<td>Chugoku</td>
<td>Oki/Shimane</td>
<td>Balancing</td>
<td>Lithium</td>
</tr>
<tr>
<td></td>
<td>(2015-')</td>
<td>(Island)</td>
<td>Short term</td>
<td>2,000kW 700kWh</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Long term</td>
<td>Sodium-sulfur</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4,200kW 25,200kWh</td>
</tr>
<tr>
<td>5</td>
<td>Kyushu</td>
<td>Buzen/Fukuoka</td>
<td>Balancing</td>
<td>Sodium-sulfur</td>
</tr>
<tr>
<td></td>
<td>(2016-)</td>
<td></td>
<td>Lower Margin</td>
<td>500,000kW 300,000kWh</td>
</tr>
<tr>
<td>6</td>
<td>Obayashi</td>
<td>Kushiro/Hokkaido</td>
<td>Mitigate output</td>
<td>Lithium</td>
</tr>
<tr>
<td></td>
<td>Corp.</td>
<td></td>
<td>fluctuation</td>
<td>10,000kW 6,750kWh</td>
</tr>
<tr>
<td></td>
<td>(2017-')</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

※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)

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

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

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

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

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

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

Battery control vs. Without battery

- **Tie-line P**
- **Frequency**
- **Battery**
- **Renewables**
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).

Coordination

Enhanced Renewable

Demand change

Base generation (Diesel)

Output

Time

“Fast and small fluctuation” caused by cloud passage, etc.

Shift “Slow and large fluctuation” (surplus caused by PV generation, etc.) to night-time

Fast and small fluctuation
⇒ High power Lithium ion battery

Slow and large fluctuation
⇒ Large capacity Sodium-sulfur battery

Short & Long Term Pilot System (Oki)

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

Nishinoshima S/S Hybrid battery system 6,200kW
LiB: 2,000kW
+ NaS: 4,200kW

Enhanced capacity for renewable penetration
3,000kW⇒11,000kW

Reference: The Chugoku Electric Power Co., Inc. home page http://www.energia.co.jp/okihybrid/project
Concept of energy control (Long & short term)

Control interval
- **30min**: Long term demand control
  - GE:commitment
  - NaS: SOC
- **3min**: Mid term demand control
  - Portfolio
- **100ms**: Short term control (delta F)
  - Set point
  - Battery (LiB)
  - Battery (NaS)
  - Gas Engine generator

Main purpose
- **Economics**
- **Power quality**

Control interval
- **30min**: Long term demand control
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Main purpose
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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

<table>
<thead>
<tr>
<th>Unit commitment</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Objective</strong></td>
</tr>
<tr>
<td>Fuel cost + constraint violation</td>
</tr>
<tr>
<td><strong>Constraint</strong></td>
</tr>
<tr>
<td>- Shortest operation/stop time</td>
</tr>
<tr>
<td>- Minimum operation units, etc.</td>
</tr>
<tr>
<td><strong>Variables</strong></td>
</tr>
<tr>
<td>- Generation status: $U(t)$</td>
</tr>
</tbody>
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<table>
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<th>Output determination</th>
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<tr>
<td><strong>Objective</strong></td>
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<tr>
<td>Fuel cost</td>
</tr>
<tr>
<td><strong>Constraint</strong></td>
</tr>
<tr>
<td>- Demand and supply balance</td>
</tr>
<tr>
<td>- Upper/lower limits, etc.</td>
</tr>
<tr>
<td><strong>Variables</strong></td>
</tr>
<tr>
<td>- Output of thermal gen. : $P_i(t)$</td>
</tr>
<tr>
<td>- Charge/discharge of battery: $BAT \tau(t)$</td>
</tr>
</tbody>
</table>

Determine generation status (Discrete optimization)

Determine generation output (Continuous optimization)
Example of control results

Total demand

GE+NaS+LiB

GE generator

Renewables(PV+WT)

NaS

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

Battery container

＜NaS battery＞

＜Li-ion battery＞
