Battery Energy Storage

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Kenji Takeda
Hitachi Research Laboratory, Battery Research Div., Hitachi, Ltd.
Presentation overview

1. Storage Systems
   1-1 Trend of energy storage
   1-2 Japan’s experiences
   1-3 R&D of battery cells

2. Energy Storage Solution
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   2-2 Smart grid simulation

3. EGAT – Hitachi Joint Study
1. Storage Systems

1-1 Trend of energy storage
1-2 Japan’s experiences
1-3 R&D of battery cells
1-1 Trend of Energy Storage

Electricity storage capacity and needs

Source: IEA Technology Roadmap (Energy Storage) 2014
1-1 Trend of Energy Storage

Current global installed grid-connected electricity storage capacity

- PSH: Pumped Storage Hydroelectricity
- CAES: Compressed Air Energy Storage
- Other technologies and their capacities:
  - Sodium-sulphur, 304 [MW]
  - Lithium-ion, 100%
  - Lead-acid, 70%
  - Nickel-cadmium, 27%
  - Flywheel, 25%
  - Redox-flow, 10%

Source: IEC white paper (2011)
1-1 Trend of Energy Storage

BESS technologies and characteristics

Duration: 1sec 1min 1hour

100MW 10MW 1MW

100kW 10kW 1kW

1kWh 1MWh 1GWh

Li-ion  Redox-flow  Lead-acid  Sodium-sulfur

Source: IEC white paper (2011)
## 1-1 Trend of Energy Storage

- **Source:** IEA Technology Roadmap (Energy Storage) 2014

<table>
<thead>
<tr>
<th>Energy Storage Application</th>
<th>Size [MW]</th>
<th>Duration Time</th>
<th>Response Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voltage support</td>
<td>1-40</td>
<td>1s-1min</td>
<td>ms to s</td>
</tr>
<tr>
<td>Frequency regulation</td>
<td>1-2000</td>
<td>1min-15min</td>
<td>1min</td>
</tr>
<tr>
<td>Demand shifting and peak reduction</td>
<td>0.001-1</td>
<td>1min-H</td>
<td>&lt;15min</td>
</tr>
<tr>
<td>Variable supply resource integration</td>
<td>1-400</td>
<td>1min-H</td>
<td>&lt;15min</td>
</tr>
<tr>
<td>Spinning reserve</td>
<td>10-2000</td>
<td>15min-2H</td>
<td>&lt;15min</td>
</tr>
<tr>
<td>Non-spinning reserve</td>
<td>10-2000</td>
<td>15Min-2H</td>
<td>&lt;15min</td>
</tr>
<tr>
<td>Load following</td>
<td>1-2000</td>
<td>15min-1day</td>
<td>&lt;15min</td>
</tr>
<tr>
<td>Black start</td>
<td>0.1-400</td>
<td>1H-4H</td>
<td>&lt;1hour</td>
</tr>
<tr>
<td>Transmission and Distribution (T&amp;D) congestion relief</td>
<td>10-500</td>
<td>2H-4H</td>
<td>&gt;1hour</td>
</tr>
<tr>
<td>T&amp;D infrastructure investment deferral</td>
<td>1-500</td>
<td>2H-5H</td>
<td>&gt;1hour</td>
</tr>
<tr>
<td>Off-grid</td>
<td>0.001-0.01</td>
<td>3H-5H</td>
<td>&lt;1hour</td>
</tr>
<tr>
<td>Arbitrage</td>
<td>100-2000</td>
<td>8H-24H</td>
<td>&gt;1 hour</td>
</tr>
<tr>
<td>Seasonal storage</td>
<td>500-2000</td>
<td>Day-Months</td>
<td>Day</td>
</tr>
</tbody>
</table>

- **Comparison of applications: Li-ion**

- **Comparison of applications: Lead-acid**

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1-2 Japan’s experiences

Wind Farm Power Stabilization –

Shiura Wind Farm in Aomori, Japan

(In operation since February, 2010)

- Wind turbine output: 15.4MW (1.9MW x 8)
- Battery capacity: 10.4MWh (LL1500-W type)

Housing of PCSs and Batteries

PCS and Battery Array

Wind turbine’s power

Grid Code *

20 minutes

Less than 10% of wind farm rated power

Smoothed power

1-2 Japan’s experiences

-Wind Farm Power Stabilization-


WT without power limiting estimated from wind speed

Battery storage

Total (stabilized)

Without control (estimated)

With control

Proposed control reduces fluctuations to under 10%.
1-2 Japan’s experiences

- DC Railway system -

- Energy storage for traction power supply system (B-CHOP)
- Stabilizes feeder voltage by charge/discharge of battery

![Diagram showing DC railway system](image)

**Projects**

- **Macau Light Rail Transit** ([http://www.hitachi.co.jp/New/cnews/month/2012/06/0613.html](http://www.hitachi.co.jp/New/cnews/month/2012/06/0613.html))

Source: 日立評論 (2012)
1. Storage Systems

1-1 Trend of energy storage
1-2 Japan’s experiences
1-3 R&D of battery cells
Valve Regulated Lead Acid battery (VRLA) for Grid Use

**Features**

- Cycling use (repeated charge & discharge cycles)
- Long life: up to 17 years, or 4500 Cycles
- Large energy capacity: up to 1500Ah / cell
- Wide range suited to a variety of applications
- No special auxiliary such as heaters nor controllers
- Established recycle system for LAB (in Japan)
- Affordable price for large scale integration

**Typical Applications**

- Wind Farms and Photovoltaic Plants
- Stabilization of power grid
- Smart grid
- EMS for homes and buildings
- EV charging stations
- Power load leveling
# 1-3 R&D of battery cells

## Lithium-ion Battery Module for Grid Use

### View of CH75-6 Module

- **Controller**
- **Cylindrical Cells**

### -Lithium ion battery-

<table>
<thead>
<tr>
<th>Item</th>
<th>Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1 Nominal Capacity</strong></td>
<td>75Ah/0.2CA</td>
</tr>
<tr>
<td><strong>2 Nominal Voltage</strong></td>
<td>22.2V (3.7V/cell × 6 cells in Series)</td>
</tr>
<tr>
<td><strong>3 Voltage Range</strong></td>
<td>16.2 ~ 25.2V (2.7 ~ 4.2V/cell)</td>
</tr>
<tr>
<td><strong>4 Discharging Current</strong></td>
<td>225 A (3CA) Short Period Max. 300A (Battery temperature may not exceed 50°C)</td>
</tr>
<tr>
<td><strong>Charging Current</strong></td>
<td>225 A (3CA)</td>
</tr>
<tr>
<td><strong>5 Operation Temp.</strong></td>
<td>-20 ~ 40°C (Capacity will decline below 0 °C)</td>
</tr>
<tr>
<td><strong>6 Expected Lifetime</strong></td>
<td>6000 cycles (Operation condition- DOD : 100%, 25°C)</td>
</tr>
</tbody>
</table>

**-Monitoring**
- Cell voltage
- Cell temperature

**-Alarm**
- Cell balancing
1-3 R&D of battery cells

Lead-acid

Process: Oxidation-Reduction
Electrolyte: Aqueous

Lithium-ion

Process: Insertion-Extraction
Electrolyte: Organic

\[
\text{Lead-acid Process: } \text{Oxidation-Reduction} \quad \text{Electrolyte: Aqueous} \\
\text{Lithium-ion Process: } \text{Insertion-Extraction} \quad \text{Electrolyte: Organic}
\]
1-3 R&D of battery cells

- Lifetime forecasting -

Forecasting method

\[
Q_R = 1 - \left( A_P \cdot e^{-\frac{E_P}{RT}} \cdot \sqrt{N_p} + A_{cyc} \cdot e^{-\frac{E_{cyc}}{RT}} \cdot \sqrt{N_{cyc}} \right)
\]

Calendar Life

Cycle Life

Testing

Forecasting

Year

0 1 2 3

Capacity Fade [%]

100 90 80 70 60 50

Source: 日立評論 (2012)

- Lifetime calculation for user’s demand
- Margin design
2. Energy Storage Solution

2-1 Hybrid BESS

2-2 Smart grid simulation
HBESS enables:
✓ Optimized Energy / Power ratio
✓ Size reduction
✓ Long life time (compared to single-type)
2-1 Hybrid BESS (HBESS) – Design Concept –

Maximum Power [MW]

Maximum Capacity [MWh]

Lithium-ion

Hybrid

User Demand

LiB

Too much power

Minimum Structure

Too much capacity

Lead-acid
2-1 Hybrid BESS (HBEES) - Examination of hybrid control -

Hybrid system: 200kW, 55kWh
Capacity type: 60kW, 30kWh
Power type: 140kW, 55kWh

Hybrid control
- Fluctuation mitigation
- Power distribution
- Battery management
- Common interface

Power Simulator
AC200V
System output

PCS
DC
V, I, etc.

Power A
Power B

Hybrid control

Lithium-ion
Capacity type

Lithium-ion
Power type

0 10 20 30 40 50
Time [min]

0 200
Power [kW]

Power type
Capacity type

Examination of hybrid control
Power Simulator

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2. Energy Storage Solution

2-1 Hybrid BESS

2-2 Smart grid simulation
Past

Power flow is one way

Equipment planning depending on electricity use for consumer

Future

Power flow changes depending on weather conditions

- Prediction of Power Flow and Reverse Power Flow
- Equipment planning for the stabilization of power fluctuation

Need for Smart Grid Simulator
2-2 Smart grid simulation

- Functions of SG simulator -

**Input**

- Power System Configuration
- Weather Data
- Sensor Data
- Actual Past Data
- Operation Parameter

**Simulation**

- Weather
- Transmission
- Distribution
- Power Plant
- Power Grid
- Mega Solar
- Wind Farm
- EV
- PV
- Battery
- Electric Water Heater
- State prediction of power grid
  - Variation simulation and prediction of Power Grid (V, P, I...)
  - Simulation and prediction of fluctuation in output of renewable energy

**Output**

- Effect of distribution control
  - Effect of introducing power system stabilizer (SVC, Battery)

- Effect of introducing DSM
  - Prediction of demand fluctuation for consumer
  - Scheduling of EV charging

DSM: Demand Side Management
PV: Photovoltaic power generation
2-2 Smart grid simulation

- GUI of SG simulator -

Map mode

System diagram mode

Simulate movement of cloud

Display of electric power flow

Voltage deviation area

Behavior of SVR

Voltage profile

2-2 Smart grid simulation
2-2 Smart grid simulation

- Voltage analysis of distribution line -

Only the existing facilities

The influence of RES

With climate change

After system control (SVR, SVC)
2-2 Smart grid simulation – Voltage analysis with BESS control –

- Without BESS (overvoltage)
- With BESS
3. EGAT – Hitachi Joint Study
Objectives
To jointly explore the opportunities in introduction of battery storage in connection with wind power and solar power generation in North East region of Thailand.
3 EGAT-Hitachi Joint Study

Input

A. Hourly power demand

B. Power generation Mix

<table>
<thead>
<tr>
<th>Type</th>
<th>Type</th>
<th>Capacity (MW)</th>
<th>RAMP (%/Min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Middle</td>
<td>HydroMID</td>
<td>744</td>
<td>17.5%</td>
</tr>
<tr>
<td></td>
<td>Combined Cycle</td>
<td>535</td>
<td>7.4%</td>
</tr>
<tr>
<td></td>
<td>Hydro</td>
<td>1,999</td>
<td>7.8%</td>
</tr>
<tr>
<td>Windpower</td>
<td>Windpower</td>
<td>93</td>
<td></td>
</tr>
<tr>
<td>Photovoltaic</td>
<td>Photovoltaic</td>
<td>113</td>
<td></td>
</tr>
</tbody>
</table>

C. Climate for PV and Wind Power

D. Power output of Generators

E. Operation Curve of Middle Load

F. Fluctuation which middle load could not catch up.
Conclusion
Conclusion

① Advanced Materials from R&D
② Products Designed for Industrial Use (Batteries, PCS etc.)
③ Systems Integration Capability

Hitachi established “Complete Quality Assurance System” from materials through final integrated storage systems.
Questions?

Crystal + Energy

✓ Crystal of Hitachi’s state-of-art technology

All-in one, container-type energy storage system as a core energy product for ensuring the stable use of renewable energy.