The Japanese Power System and the future after Fukushima

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◆ Current Status of Electricity Supply in Japan
◆ Recent Political Movement
◆ Role of Demand Response for Smarter Energy Systems in Japan after Fukushima
◆ Conclusions
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Current Electricity Supply System in Japan

Wholesale Power Exchange Market (JEPX)

- Wholesale Electricity Utilities (J-Power, etc.) and Wholesale Suppliers (IPPs, etc.)
- Power Producers and Supplier (PPSs)

Power Plants

ESCJ: Electric Power System Council of Japan ➔ OCCTO from 2015

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Status of Nuclear Power Plants in Japan

◆ There are 48 units and all of them are in a state of temporary shutdown.
◆ Among them, old and small 5 units (X sighed) were recently abolished.
◆ 24 units are under safety review by the Nuclear Regulation Authority and 5 units were approved as they met new safety standards.

Source: Federation of Electric Power Companies
Electric Utilities and Transmission Lines

Ten privately-owned vertically integrated utilities (so called general electric utilities, GEUs) serves residential customers under regulation (retail market for C&I customers has been liberalized).

There is a difference in frequencies between the east (50Hz) and the west (60 Hz) and the interconnection capacity with FC is limited. 
Total capacity of FC: 1.2GW ➔ 2.1GW in 2020
Rapid Introduction of PV by FIT Scheme and Related Problems

Rapid introduction of PV has been continuing after the start of FIT scheme on July 2012. It has already brought various problems on electricity supply system in some local areas in Japan.

**Installed Capacity of Renewable Power**

- **PV**: 32% per year
- **Wind**: 9% per year
- **Biomass**: 5% per year

**End of Dec. 2014: Approved PV 70.8 GW
Installed PV 20.3 GW**

**Related Problems**

- **Deficit capability of frequency control** by rapid fluctuation of output
- **Requirement of suppression** by excess output than demand for supply (actual demand minus output of base-load power plants and spinning reserve)
- **Voltage deviation of distribution line** from control target by the reverse flow from roof-top PV
- **Deficit transmission capacity** in the areas of small electricity demand
Installation Schedule of Smart Meter for Low-Voltage Customers in Japan

Smart meter will be fully equipped by 2024 in Japan and be installed most rapidly in Tokyo area (TEPCO) by 2020. Load data will be provided for all retail suppliers.
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Policy Discussion in Japan

Strategic Energy Plan (Basic Energy Policy)

- Energy Efficiency and Conservation Subcommittee
  - Long-term Energy Outlook
    - Energy-origin CO₂ Target
      - Energy-origin CO₂ occupies about 88% of total GHG emission.

- New and Renewable Energy Subcommittee

- Nuclear Energy Subcommittee

- Working Group on System Design concerning Electricity System Reform
  - Regulation of Electricity Industry

Electricity System Reform

- Experts’ Committee on Electricity System Reform
  - Approved by the Cabinet in April 2013

Strategic Energy Plan

- Approved by the Cabinet in April 2014
Principles for the Energy Policy after Fukushima

Safety

“3E+S” – the basic viewpoint of the energy policy

Energy Security

Establishing “Multilayered and Diversified Flexible Energy Supply-Demand Structure”
New Target of Power Generation Mix, Primary Energy and CO₂ emission in 2030

Power Generation Mix
Diversification to four energy kinds

- Before Saving
  - Renewable 19-20%
  - Nuclear 18-17%
  - LNG 22%
  - Coal 22%
  - Oil 2%

- After Saving
  - Renewable 22-24%
  - Nuclear 22-20%
  - LNG 27%
  - Coal 26%
  - Oil 3%

- Saving 17%

Primary Energy
9.8% reduction from 2013 level

- Renewable 572 TWh
- Nuclear 542 TWh
- LNG 489 TWh
- Coal 600 TWh
- Oil 500 TWh

Energy-origin CO₂
24.9% reduction from 2013 level

- Industry 1.139 Billion t-CO₂
- Commercial 1.25 Billion t-CO₂
- Residential 0.927 Billion t-CO₂
- Transportation 1.3 Billion t-CO₂

(Sources: Advisory Committee for Natural Resources and Energy)
Schedule of Regulatory Reform of Electricity Market in Japan

1st Step 2015

Establishment of the organization for cross-regional coordination of transmission operators (OCCTO)

2nd Step 2016

Full retail competition

Period of transitional arrangement for retail tariff

Abolishment of retail tariff

3rd Step 2018-2020

Establishment of new system for securing supply capacity and real time market

Legal unbundling of transmission/distribution sector
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What is desirable for “Smarter” Energy Systems in Japan under current circumstance?

◆ Tackling the problems caused by rapid installation of intermittent renewables is urgent

◆ Harmonized application with regulatory reform is important in the mid-term

DR is important and related research examples in CRIEPI

1. Efficient and effective information supply for peak shaving
2. Cost/benefit analysis of DR for PV reverse flow reduction
3. Utilization of DR for secure supply of electricity (e.g. frequency control, spinning reserve)
   - Possibility of ancillary service DR for frequency control by air conditioner
Classification of Demand Response (DR)

Demand-Side Management

Demand Response

Energy Efficiency

Dispatchable

Energy Voluntary

Energy Price

Non-Dispatchable

Ancillary

Dispatchable

Reliability

Capacity

Economic

Economic

Time-Sensitive Pricing

Economic

Emergency

Demand Bidding & Buy-Back

Time-of-Use (TOU)

Critical Peak Pricing (CPP)

Real Time Pricing (RTP)

System Peak Response Transmission Tariff

Direct Load Control

Interruptible Demand

Critical Peak Pricing (CPP) with control

Load as a capacity Resource

Spinning Reserves

Non-Spin Reserves

Regulation

Direction of Evolution

Example 1: Efficient and Effective Information Supply for Peak Shaving

◆ Purpose
  ➢ Develop an efficient and effective method of information supply using smart meter / HEMS data

◆ Method
  1. Unique TOU rate (Peak time price: +38%)
  2. Information Supply (Monitor + Energy Saving Advice Report)

◆ Period, Site and Samples
  ➢ August 2013 ~
  ➢ Apartment in Funabashi, Chiba
  ➢ About 500 Households
    (1st period: 230 + 2nd period 270)
National Smart Community Projects in Japan

Keihanna (Kyoto)*
- Large-scale deployment of PV (1,000 households)
- Nano-grids in homes/buildings
- Local energy production for local consumption

Kitakyushu
- Real time energy management by smart meters
- New energy (10% of energy consumption)
- System to transfer the outcomes to Asia

Toyota*
- Efficient energy use in households (70 households)
- Efficient energy use in communities
- Low carbon transport system

Yokohama*
- Large-scale deployment of PV (27MW)
- Smart house/building (4,000 locations)
- Next generation transport system

* Local electric power company is involved

Source: Japan Smart City Portal

DR demonstration revealed CPP contributed to electricity saving up to 20%, but price elasticity is small. Such a high CPP price may not be accepted by the customers in the actual practice phase.
An Example of Story

Appealing the energy saving of air-conditioner at peak-load time by showing multilateral data for customers. This customized advise for each customer is created automatically by our system.
The Result of Energy Saving (with TOU Rate)

**TOU rate**

<table>
<thead>
<tr>
<th>Demand in 30 minutes</th>
<th>TOU rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-400Wh/h</td>
<td>24 yen/kWh</td>
</tr>
<tr>
<td>400-1500Wh/h</td>
<td>29 yen/kWh</td>
</tr>
<tr>
<td>1500-Wh/h</td>
<td>40 yen/kWh (less than +40%)</td>
</tr>
</tbody>
</table>

Our method can achieve about 10% saving with the effect of relatively low price increase and saving advise. This method is assumed to be acceptable for a lot of customers.
Example 2: Cost/benefit Analysis of DR for PV Reverse Flow Reduction

◆ The reverse power flow in distribution systems with PV causes a voltage rise problem. (The range of customer voltage: 95V-107V)

◆ Electric utilities have to invest heavily in distribution systems, such as installing Static Var Compensators (SVC).

The cost of SVC (300kvar) : about 15 million yen (about US$ 125,000 )
[Case 1] Evenly at the whole distribution line

[Case 2] Only in half of the area of case 1
The condition of case 2 is severer and PV output should be suppressed more often. This frequency corresponds to DR request.
Avoided cost by implementing DR and Its Benefit

◆ Avoided number of SVC units and its annual costs

<table>
<thead>
<tr>
<th>PV installation</th>
<th>Case 1</th>
<th>Case 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>SVC number, cost</td>
<td>30%</td>
<td>40%</td>
</tr>
<tr>
<td>Number of 300kvar SVC</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Annual costs [10^3 yen/year]</td>
<td>1600</td>
<td>3200</td>
</tr>
</tbody>
</table>

◆ Benefit of DR

In the 30% case, plenty benefit which can overcome the income of FIT is expected and DR program may be realized.
Example 3: Utilization of DR for Ancillary Service

It is expected utilizing ancillary demand response will increase in the U.S. in next decade.

It may be used also in Japan after transmission/distribution sector will be unbundled in 2018-2020.

We have done a simulation study about the possibility of ancillary service DR for frequency control with air conditioner.

Average Daily Contingency Reserve Availability over One Year, by Resource in U.S.


Air conditioning (cooling) has a lot of reserve availability in U.S.
Simulate Model for Frequency Control with Commercial Air Conditioners

- Frequency Analysis Model
- Concept of Hierarchical Control

- 24 hours, 1 second interval sampling
- 6 thermal power + 2 nuclear power units (9.4GW)
- Governor-free operation and load frequency control by thermal power plants are modeled

- Air conditioners are hierarchically controlled to increase response frequency and efficient use of capacity
- Aggregator will collect information
- Lower control system will manage the controllable capacity of its group
Control of Frequency Fluctuation with Thermal Power and Air Conditioner

Responsive property of air conditioners in power down mode is quick and using air conditioners for frequency control will improve minus side frequency deviation.
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◆ Even though the serious accident in Fukushima, maintain a certain dependence on nuclear power is important to achieve the “3E+S” energy policy goal.

◆ Enhancing electricity demand control is one of the key issue to increase the share of intermittent renewables with nuclear utilization. DR may play a certain contribution by:
  - Reducing reverse flow in distribution line by offering an incentive to customers
  - Maintaining grid stability (e.g. spinning reserve and frequency control)

◆ Utilizing the data of smart meter is a key for new service and smarter energy systems after 2016.
Further Information


Thank you for your attention!

any comments are welcome.

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