Session:

Future energy mix
How will it influence hydro development?

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For more information: www.hydropower.org/congress
Merits of Pumped Storage Plants to Cope with Massive Introduction of Renewable Generation

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Merits of pumped storage power plant

1. Economical operation
   - Pump up by using low cost generation such as nuclear and coal at night and substitute high cost generation such as oil and LNG in daytime
   <Example of generation cost>
   Nuclear and Coal: 5 cents/kWh or less, LNG thermal 10 cents/kWh, oil thermal 20 cents/kWh
   Total loss of pumped storage is about 30%

2. Frequency Control
   - Start up to full generation takes only a several minutes
   - Easy, fast and wide range generation control is possible
   - Pump up is required when the electricity demand is lower than the total amount of generation which have to be operated on the grid

More and more frequency control ability is required to the power system

Variable Speed Pumped Storage has superior frequency control capacity, thus has much benefit in such situation

When renewable generations increase in power system,
- Large generation fluctuation may occur depending on natural condition, especially by the increase of wind and solar generation
- fixed or must run generators increase regardless of the electricity demand
What is the Variable Speed Pumped Storage (VSPS)?

Synchronous rotation speed can be changed both in generation and pump operation

- Pump input and generation output can be controlled very fast
- Higher efficiency than the conventional unit

Conventional unit:
- Rectifier
- Circuit Breaker
- DC
- Rotor
- Generator motor (DC excitation)
- Stator
- Pump-Turbine

VSPS:
- Frequency converter
- AC 0~±a few Hz
- Rotor
- Generator motor (AC excitation)
- Stator
- Pump-Turbine
Performance of VSPS Unit in Kansai Electric

Range of Pump input

- Pumping input range (±80MW)
- Pumping input of conventional unit (fixed)

Expanded Range of Generation

- Generating output range of conventional unit (170MW)
- Generating output range of VSPS unit (220MW)

Fast Response

- Active Power Step up Command
- 1 sec

Higher Generation Efficiency

- VSPS Unit
- Conventional Unit
- 3% UP
**Assumption**

- Demand: 10000MW, Fixed Generation 7800MW
- Required frequency control capacity is ±200MW provided by following units

<table>
<thead>
<tr>
<th></th>
<th>Rated capacity</th>
<th>Frequency control capacity</th>
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<tbody>
<tr>
<td>Thermal Power Plant</td>
<td>400MW</td>
<td>±20MW</td>
</tr>
<tr>
<td>VSPS</td>
<td>400MW</td>
<td>±80MW at pump mode</td>
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</tbody>
</table>

- 10 Thermal units must be connected to ensure frequency control capacity.
  - Output 300MW X 10units = 3000MW
- 2 pump units are necessary to absorb surplus generation (800MW)

- VSPS 1 unit ensures ±80MW frequency control capacity. So, 6 thermal units must be connected to provide frequency control capacity.
  - Output 300MW X 6units = 1800MW
  - Output 400MW(Full) X 2units = 800MW
- No conventional pump is required

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**With VSPS**

- 2 thermal and 1 pump units can be stopped
- Cost and CO2 reduced

**Generation**  | **Consumption**  |  **Generation**  | **Consumption**

- Demand: 10,000MW
- 3000 MW
- 7800 MW

- Fixed generation
- Renewables and Fixed generation

- Full output
- VSPS 400MW

- Thermal 1
- Thermal 2
- Thermal 3
- Thermal 10
- Pump 1
- Pump 2
- Thermal 6
- Thermal 7,8

- 2600 MW
- 400 MW

- Demand: 10000MW, Fixed Generation 7800MW
- 3000 MW
- 7800 MW

- Renewables and
- Fixed generation
When the ratio of renewable energy generation comes to be high in electric power system,
- Much more frequency control ability and back-up capacity is required
- Generation may exceed the demand and surplus energy has to be absorbed in low demand period.

Pumped storage hydropower plants will play an essential role to mitigate the fluctuation of renewable generation and absorb surplus energy,

Having superior frequency control ability both in pumping and generation mode, variable speed pumped storage plants can improve the operation of thermal power plants much. Reduction of operation cost and CO2 emission can be expected.
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