Features of Power System and Issues on International Connection in Japan

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Features of Power System in Japan
Features of Power System in Japan

Energy Resources (Scarce)
Self-sufficiency rate: 4%

Natural Condition (Harsh)
- Ambient temperature: -20 ~ 40 °C
- Earthquake intensity: 8.2
- Instantaneous wind speed: 70 m/s

Social Environment (Narrow, Crowded)
- Population density:
  - Tokyo area: 5875 people/km²
  - Metropolitan area: 1132 people/km²

Energy saving
- High reliability
- High efficiency
- Cost benefit

Environmental issue
- Environmental countermeasures:
  - Underground S/S,
  - Underground Cable,
  - Insulated Wire

Diversification of power sources
- Renewable energy, LNG, Coal, Hydro, Oil, Nuclear

Light & compact


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Ten Electric Power Companies and Interconnected Network

60Hz ↔ 50Hz
Available Transfer Capacity of Interconnection Lines

- 10 Vertically Integrated Electricity Power Companies (EPCOs)
- TWO frequencies, 50Hz and 60Hz

Frequency in West: 60Hz
- DC – Direct Current
- FC – Frequency Conversion

Frequency in East: 50Hz
- Hokkaido [2012] 5.52 GW
- Tohoku [2012] 13.72 GW
- Tokyo [2012] 50.78 GW
- Chubu [2012] 24.78 GW
- Hokuriku [2012] 5.26 GW
- Kansai [2012] 26.82 GW
- Chugoku [2012] 10.85 GW
- Kyushu [2012] 15.21 GW
- Shikoku [2012] 5.26 GW
- DC Tie line 1.4GW
- BTB 0.3GW
- DC Tie line 0.6GW
- FC 1.2GW
Reinforcement of Interconnection lines between 50Hz and 60Hz Areas

- Reinforcement of interconnection between 50Hz and 60Hz areas by HVDC line
- Capacity of East-West interconnection will be increased from 1,200MW to 2,10MW (2,50MW in the future)
- The project is undergoing aiming at operation commencement in 2020

Current Situation of East-West Interconnection Facilities
Frequency Converter Station
- Sakuma (J-Power EPCO) : 300 MW
- Shin-Shinano (Tokyo EPCO) : 600 MW
- Higashi-Shimizu (Chubu EPCO) : 300 MW
- Total Capacity: 1,200 MW

- By the constriction of 900MW HVDC Line toward Nagano, the transfer capacity increases to 2,100 MW in 2020.
- The Expert Committee on the Electricity Power Systems Reform requested further increase of capacity up to 3,000 MW under political support by the government in June 2016.
Generation Mix and Total Capacity of EPCOs in 2015 and 2020

Generation Mix in 2010

Before Disaster 2010

- Nuclear: 28.6%
- Hydro: 8.5%
- Oil: 6.6%
- LNG: 29.3%
- Others: 9.9%

Renewable: 1.1%

Generation Mix in 2013

After Disaster 2013

- Nuclear: 30.3%
- Hydro: 1.2%
- Oil: 13.7%
- LNG: 43.2%
- Others: 2.2%

Renewable: 2.2%

2011

Transmission Line (500kV)
Transmission Line (154kV~275kV)
DC Transmission Line
Switching Station or Substation
Frequency Converter Facility (F.C.)
AC-DC Converter Facility

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Reinforcements of Facilities for Large Scale Wind Generation

- Construction Unit Cost: 300,000 Yen/KW Estimated
- Construction Period: April 2014 to March 2019
- Operational Capacity: 0.6GW (in 2014) 0.3GW (in 2019) Extension Total Capacity: 0.9GW

- Total Construction Cost: 159 billion Yen
- Construction Period: 7 years to 11 years
- Operational Capacity: 5.7 GW (in 2021 Fiscal year) 5.5 GW (Expansion) Total Capacity: 11.2GW
## Reinforcement Plans of Interconnection between 50/60 Hz Areas

<table>
<thead>
<tr>
<th>Areas to be Interconnected</th>
<th>Project Name</th>
<th>Voltage</th>
<th>Construction Commencement</th>
<th>In Operation</th>
</tr>
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<tbody>
<tr>
<td>Hokkaido-Tohoku</td>
<td>Hokuto-Imabetsu DC Trunk Line</td>
<td>HVDC 250 kV</td>
<td>April 2014</td>
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<tr>
<td>Tokyo-Chubu</td>
<td>Tokyo-Chubu DC Trunk Line</td>
<td>HVDC ±200 kV</td>
<td>2017 Fiscal Year</td>
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<tr>
<td>Chubu-Kansai</td>
<td>Sekigahara-kitaoumi Line</td>
<td>500 kV</td>
<td>Undecided</td>
<td>Undecided</td>
</tr>
</tbody>
</table>

**Construction rules:**
According to the recommendation by OCCTO, a related electric power utility are obliged to construct or expand the interconnecting line and subsequently the construction or expansion cost is collected by the wheeling charge from all users and customers.

Reference: OCCTO, Summary of electricity supply plan in 2015, June 2015
Reference: https://www.occto.or.jp/en/occto/about_occto/images/figureforOCCTO.png

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Transfer Capacity after Reinforcement of Interconnection in 2024

Unit: 10 MW

Hokkaido EPCO

90 (2019 In Operation)

90 (2019 In Operation)

Hokuriku EPCO

Tohoku EPCO

Chugoku EPCO

Kansai EPCO

Chubu EPCO

Kyushu EPCO

Shikoku EPCO

Undecided (120)

Undecided (250)

210 (2020 In Operation)

300 (Recommended)

500KV Line Planned but Undecided

210 (2020 In Operation)

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Deployment of Super Grid into Asian Countries

- Necessity of feasibility studies for international interconnection toward the targeted year, 2020 or 2030
- In the future, expansion to multi-national Super Grid including the North East Asian countries (ASEAN) and Australia
- Creation of a platform for effective use of renewable energy such as solar and wind
- As electric power companies in Japan have been protected by monopoly and regulation, even domestic transfer between areas was not sufficient because of poor tie line capacity.
Reinforcement of Tie lines for Cross-Regional Operation Toward Super Grid in Japan

Increase of Cross-regional electricity transfer

- To avoid blackout occurred by natural disasters by transferring electric power between areas

- To mitigate output fluctuation of large scale renewable energy installation by enhancement of nationwide demand and supply balancing capability

- Establishment of OCCTO: Organization for Cross–regional Coordination of Transmission Operators, Japan

Reference: OCCTO, Summary of electricity supply plan in 2015, June 2015
Issues on International Connection in Japan
Disaster by Tohoku/Pacific Coast Tsunami
Current Situation of Nuclear Plants After Disaster in Japan

Decommissioning
Frozen/Suspended
Emergency Stop
In Maintenance
In Operation

Capacity
- In Operation
- Under Const.
- Planned

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Paradigm Shift toward Best Energy Mix from Nuclear-Centered Generation Mix

Best Energy Mix based on Distributed Generation and Network

Generation Mix based on Large Scale Plants

Tsunami 2011

Transmission Network

Distribution Substation

Distribution Network

Residence

Factory

Storage

Wind

Generation Mix based on Large Scale Plants

Energy Saving

Local Generation

Best Energy Mix based on Distributed Generation and Network

Generation with Fossil Energy
- LNG Thermal Plant (1GW)
- Gas Combined Cycle (0.3GW)
- Gas Engine (10KW – 1MW)
- IGCC (Clean Coal Generation)
- Fuel Cell

Generation with Sustainable Energy

Battery Energy Storage

Lead Battery
Ni-MH Battery
EDLC
Li-Ion Battery

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Issues in Power System Operation by Large Scale Instillation of Sustainable Energy

- By large scale installation of sustainable energy such as PV generation, new problems in power grids; Excess energy, Voltage increase and Shortage of frequency control capacity occur.
- Necessity of power stabilization control to keep their own functionality of power networks.
Autonomous Micro Grid for Effective Use of Sustainable Energy
Changes of Power System Structure by Introducing Smart Technology

Smart Grid
- Nuclear power plant
- Thermal power plant
- Hydraulic power generation
- Renewable energy
- Photovoltaic
- Wind generator
- Ecological vehicle
- Cities and offices
- Factories
- Homes
Toward Future Power Delivery Networks

Stable Power Supply

Reasonable Price

Low Carbon Society

Vulnerability to
Natural Disaster

Remote Generation
Long Transmission

Parasite

Cost/Benefit

Micro Grid

Future Social Infrastructure

Smart Grid

Anti-Disaster Network

Smart & Eco Life

Power Transfer
crossing the Border

Local Government Driven
Autonomous Network

Electricity, Heat,
Transportation

Inter-regional Connection

Cluster-Oriented
Distribution Network

Smart Community
Eco City, Compact Town

Super Grid

Large Scale Power System

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Oversea Smart Community Developments by NEDO

- Conclusion of MOU concerning Smart Community Projects
- 6 Demonstration Projects; 4 in Implementation stage and 2 in Construction stage

Reference: New Energy and Industrial Technology Development Organization, Japan
Eco City Development in China

Eco City Project in Tianjin

- Chinese and Singapore governments attained the agreement to corporate the development of Tianjin Eco City in 2007.
- Budgets are supplied by both sides by 50% and development corporation was established.
- Singapore side utilized the government fund.

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Design has been undertaken by Singapore Government-own Corporation.

International Deployment in the Future

- PV Generation
- Regional Air Conditioning
- Eco City
- Electricity Saving
- Water and Waste Treatment
Configuration and Components of Cluster–Oriented Smart Distribution Grid

Configuration of Single Cluster

Effective Use of Sustainable Local Energy

Utility Grid
(Power System)

Interconnection Inverter

Main Inverter

Cluster for Power Supply

Battery
CVCF/PQ Control

Rapid Charging of EV

Biogas

PV Generation

Wind Generation

Biomass

Gas Engine

Micro Hydro

Customers

Facilities

Wave Generation

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Interconnection and Expansion of Cluster–Oriented Smart Distribution Grid

Power System (Utility Grid)

Interconnection Inverter (PQ-Mode)

Battery Energy Storage System

EMS

Cluster A

Main Inverter (CVCF-Mode)

Interconnection Inverter

Cluster C

Main Inverter (PQ-Mode)

Battery Energy Storage System

EMS

Cluster B

Main Inverter (CVCF-Mode)
The North Sea Countries’ Offshore Grid Initiative by EWEA
European Super Grid
DESERTEC Industrial Initiative
ASEAN Power Grid (APG) Initiative

- ASEAN Power Grid Connection for Effective use of Energy Resources
- Reconciliation of Neighboring Countries through Power Transfer
- Revitalization of these Regions

Reference:
Jack Casazza
Forgotten Roots: Electric Power, Profits, Democracy and a Profession
Asian Super Grid
International Energy Interconnection

Wind Farm in Mongolia
The Gobi Desert
Solar Thermal Farm
Benefit of Asian Super Grid
Difference of Electricity Prices in Countries

Electricity Price

**Mongolia**
- Ulaanbaatar ($0.06)
- Vladivostok ($0.09)

**India**
- New Delhi ($0.14)
- Bhutan ($0.03)
- Chengdu ($0.09)
- Dhaka ($0.13)
- Hong Kong ($0.25)
- Bangkok ($0.12)
- Kuala Lumpur ($0.16)
- Singapore ($0.19)

**Japan**
- Tokyo ($0.25)
- Seoul ($0.06)
- Shanghai ($0.15)
- Taipei ($0.21)
- Manila ($0.22)

**Total Transmission Length:**
- 3,800Km
Mandatory Conditions for realizing Super Grid

- **In the DESERTECH Project of European countries including the Middle East and the North Africa,**
  - *Solar Thermal energy* in deserts of the North Africa and the Middle East
  - *Wind power energy* in the coast of the North-West Africa, the North and West Europe
  - *PV generation* in strong solar radiation, such as Spain
  - *Hydro energy* in mountain areas of the Alps mountains, Pyrenees, Atlas Mountains
  - *Biomass energy* in the middle of Europe, such as, Germany and France

- **International interconnections between Africa, the Middle East and Europe by low loss, long distance HVDC**

  - Countries must be stable politically, Economically and Socially
  - Interconnecting countries have cordial relations each other
  - Diversification of energy resources in different areas
Thank you for your attention

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