Approach to High Renewable Penetration Grid and Its Challenges in Japan

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New Energy and Industrial Technology Development Organization
Smart Community Department

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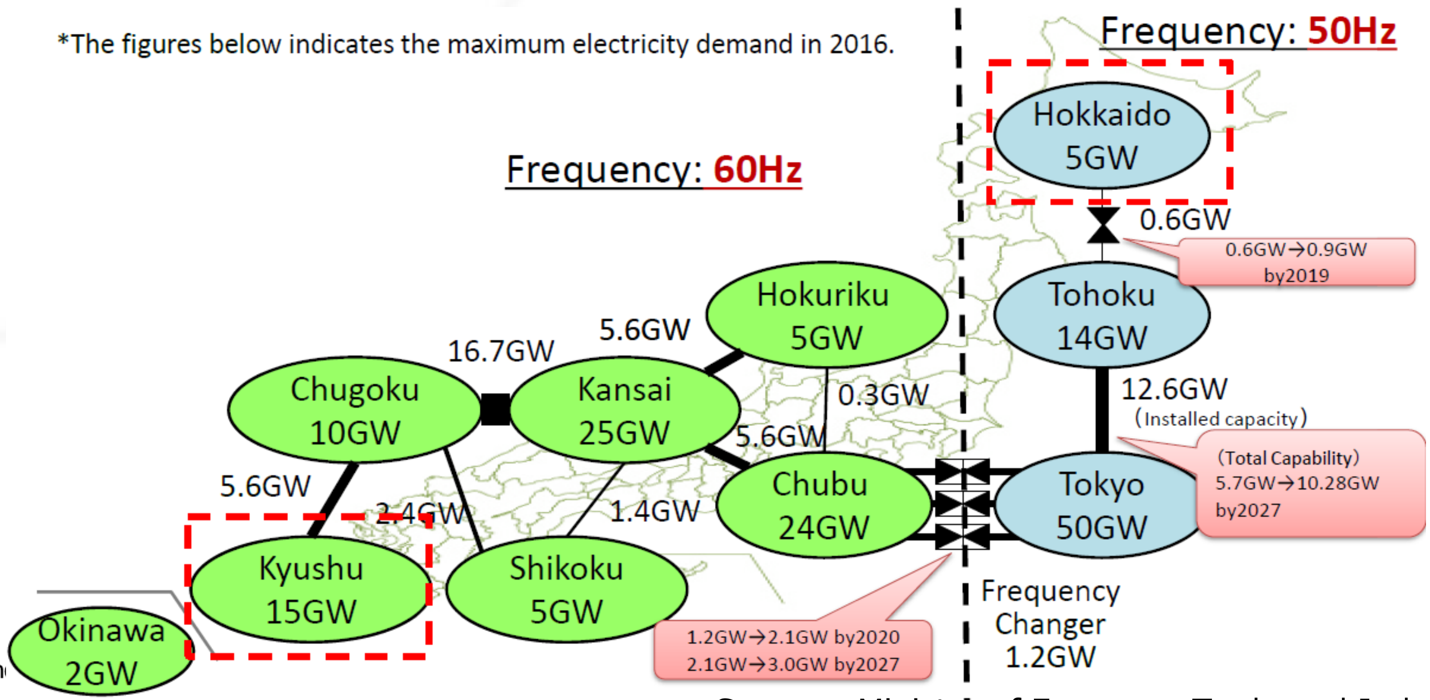
Contents

1. Energy Situation in Japan

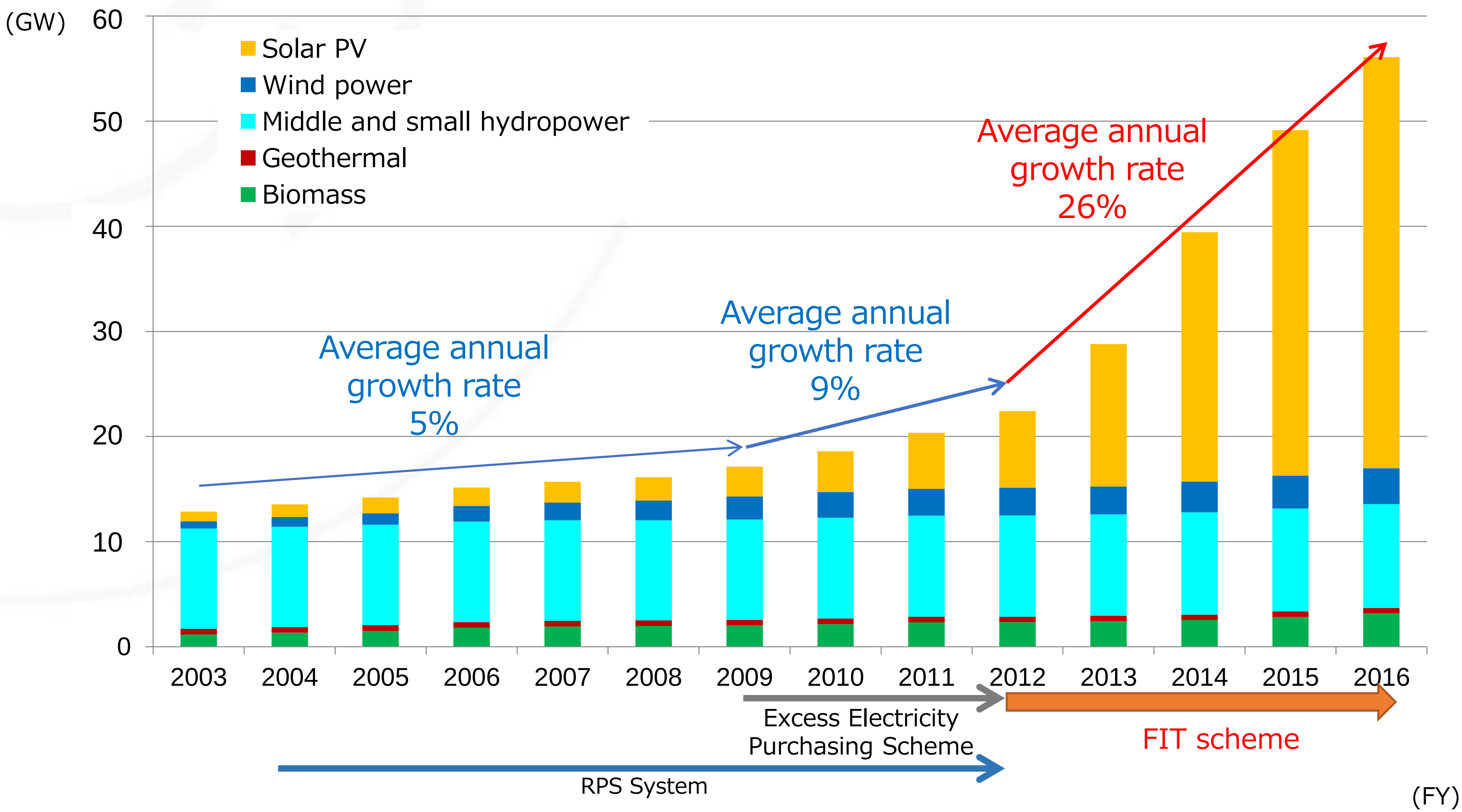
Power grid and power supply system in Japan

- Historically, the power grid in Japan has been organized into 10 General Electricity Utilities (GEUs), vertically integrated with a monopoly on the production and sale of power.
- In April 2016 Japan introduced Licensed Unbundling.
  - Generation: Competitive, with Notification to METI
  - Transmission & Distribution: Regional monopolies, licensed
  - Retail: Competitive, with registration
- In April 2020 all GEUs must be separated into TSOs and DSOs, necessitating **TSO/DSO Coordination**
- Interconnection grids are expanding mainly to assure a stable supply of Renewable Energy. Hokkaido (in the north) is a favorable area for wind power; Kyushu (in the south) for solar power.



Source : Ministry of Economy, Trade and Industry (METI)

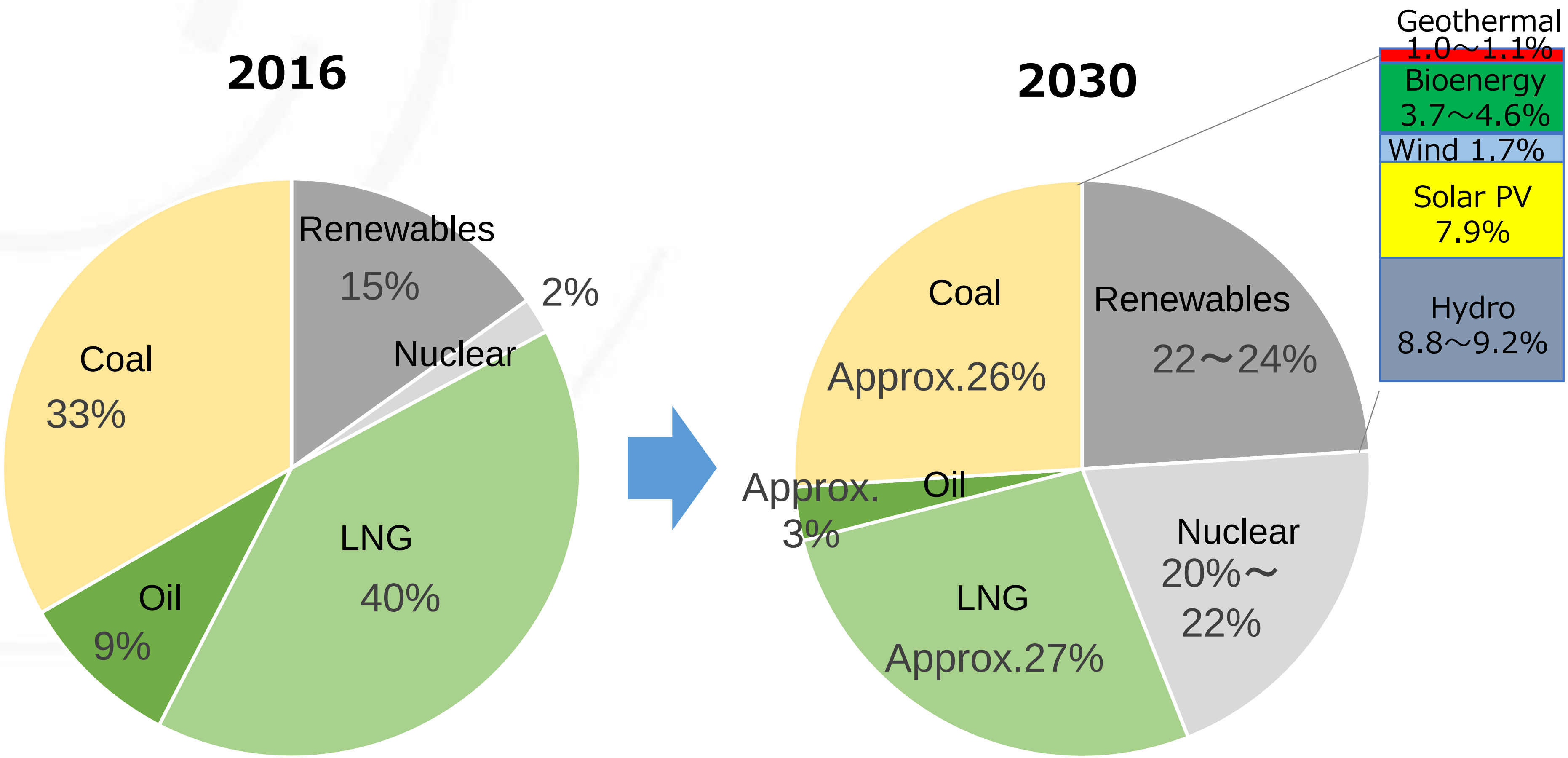
History of Renewable introduction in Japan



Source：Ministry of Economy, Trade and Industry (METI)

Electricity Generation – Energy Mix 2016 to 2030

5th Strategic Energy Plan, July 2018



1,065TWh (Target)

Source : Ministry of Economy, Trade and Industry (METI)

Renewable Energy towards 2030

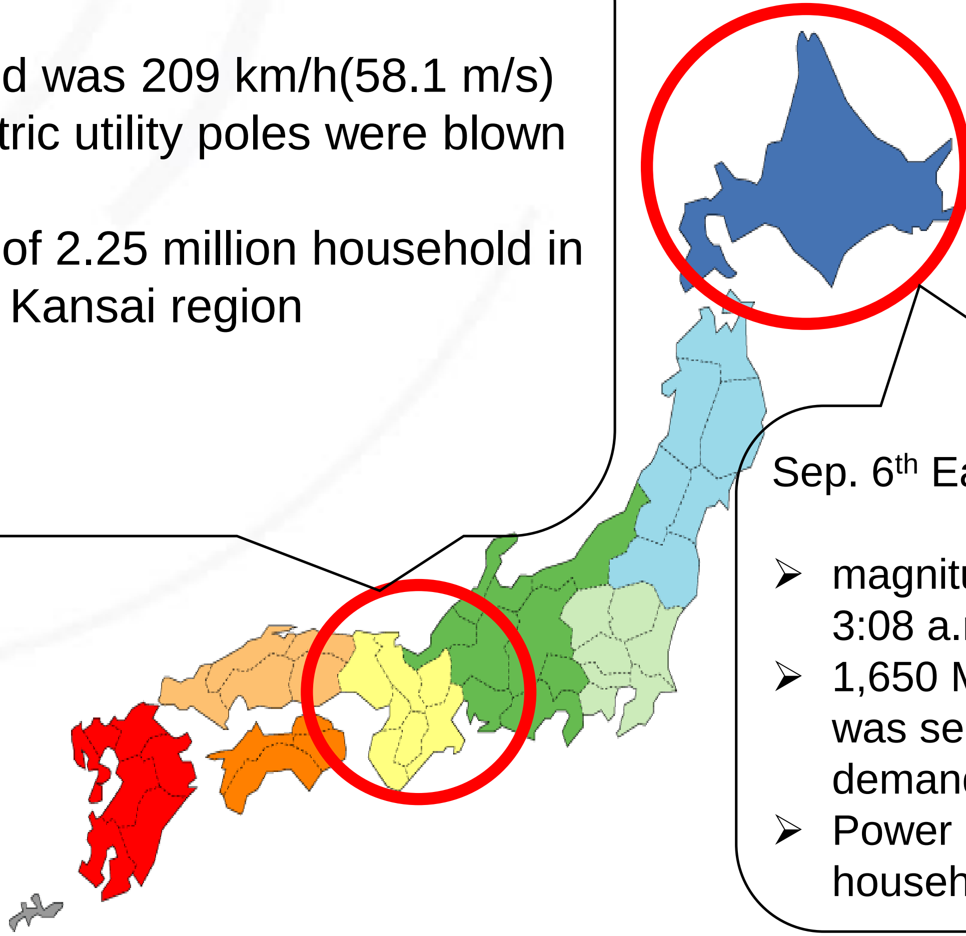
	Before FIT (June 2012)	After FIT [A] (as of Sep 2017)	Target [B] (FY2030)	Progress [A]/[B]
Geothermal	0.5GW	0.5GW	1.4 - 1.6GW	33%
Biomass	2.3GW	3.5GW	6.0 - 7.3GW	53%
Wind	2.6GW	3.4GW	10GW	34%
Solar PV	5.6GW	42.4GW	64GW	66%
Hydro	48.1GW	48.4GW	48.5 - 49.3GW	--

Source：Ministry of Economy, Trade and Industry (METI)

Outage by Typhoon and Blackout by Quake this September

Sep. 4th Typhoon hit Kansai

- Wind speed was 209 km/h(58.1 m/s)
- 1,100 electric utility poles were blown down
- Power cut of 2.25 million household in total in the Kansai region



Sep. 6th Earthquake hit Hokkaido

- magnitude of 6.7 Mj Earthquake at 3:08 a.m.
- 1,650 MW Coal-fired power plants was serious damaged (Cover 50% of demand at 3.08 a.m.)
- Power cut of all 2.95 million household in Hokkaido

2. NEDO Activities and Results

What is NEDO ?

■NEDO is one of the largest R&D funding and management public organizations in Japan.

- Established : 1980
- Number of employees : around 900
- Annual budget : around 160 billion Yen

■Smart Community Department in NEDO manages R&D for grid technology issues in Japan and demonstration projects for smart grid solutions and or smart cities internationally.

Projects related to the electric power system in Japan

2014	2015	2016	2017	2018	2019

1. R&D Projects on Grid Integration of Variable Renewable Energy :
- (I): Wind power output forecast and enhanced control technology
- (II): Power system simulation with the forecast technology
- (III): Enhanced renewable energy connection with power grid

2. Demonstration Projects for Advanced Power Grids with Distributed Energy Sources
- (I): Development of advanced voltage control equipment and control system
- (II): Development of common fundamental technology for constructing Next-generation distribution system
- (III): Feasibility study on development of future smart grid

3. Next Generation Offshore HVDC System Research and Development Projects
- (I): System design
- (II): Component development

1. R&D Project on Grid Integration of Variable Renewable Energy :

Mitigation Technologies on Output Fluctuations of Renewable Energy Generations in Power Grid
～Improving technologies on prediction, control, and operation for addressing the output fluctuations～

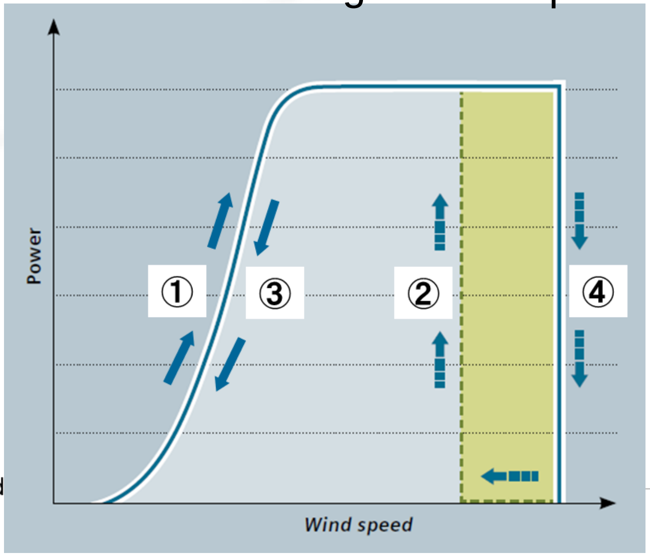
Development Items:

Item (I): Wind power output forecast and enhanced control technology
Item (II): Power system simulation with the forecast technology
Item (III): Enhanced renewable energy connection with power grid

Purpose:

- Focus on variable output "ramp" of wind power generation which affects power system operation. Develop proper forecast and appropriate control technologies for "ramp" is wind power output change by 30% or more in 6 hours.
- Forecasting methodologies, an approach that combines Meteorology (including ensemble forecasting) and Statistics (including machine learning)
- Remote output control systems: to be developed and established for the stable and maximum use of renewable energy.

Image of wind power output curve

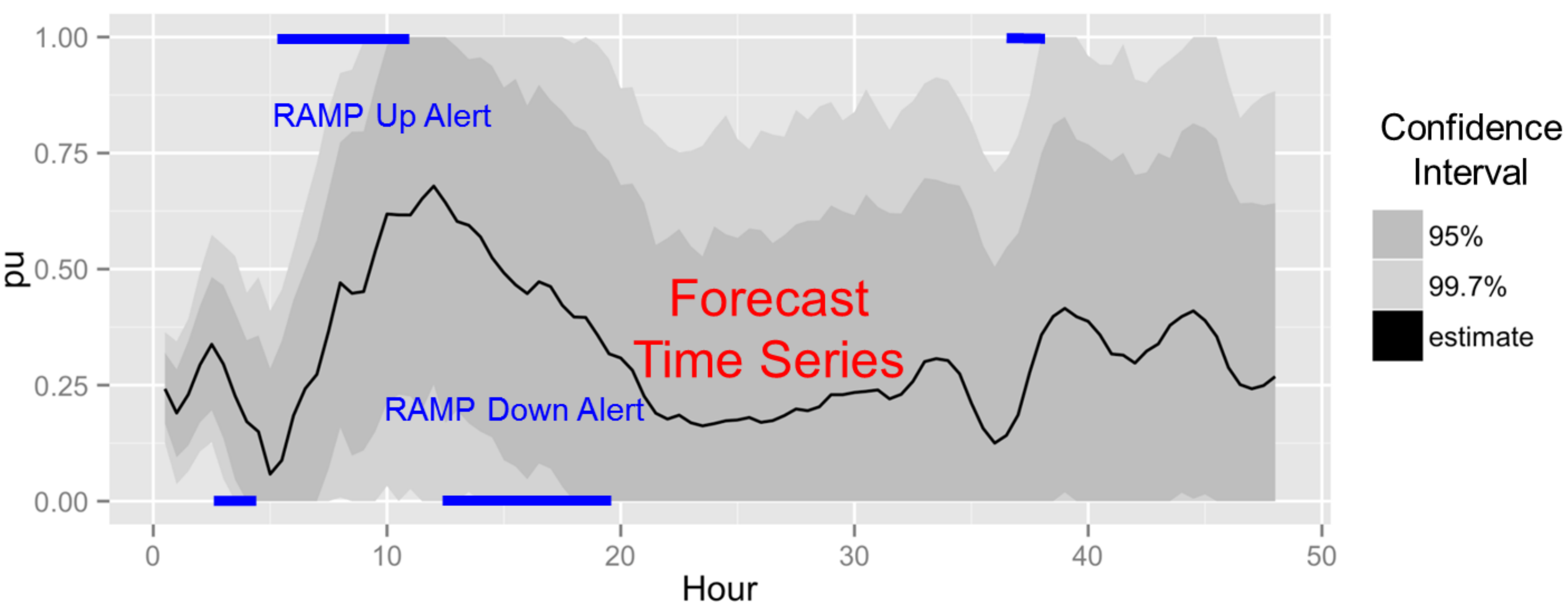


Ramp-up
①Increasing wind speed
②Re-start after cut-out
Ramp-down
③Decreasing wind speed
④Cut-out
(e.g more than 25m/s speed)

Latest Achievements①

Specification of WindRamp Forecasting System

Update per 10min.
Time resolution:0～6h ahead (10min.)
6h～48h ahead (30min.)
in Each TSO Operating Zone



Source : Japan's R&D Project of Ramp Forecasting Technology: Project Overview, T. Suga, Takahiro, N. Hayasaki (ITOCHU Techno-Solutions Corporation, Japan), K. Ogimoto (The University of Tokyo, Japan)

1. R&D Project on Grid Integration of Variable Renewable Energy :

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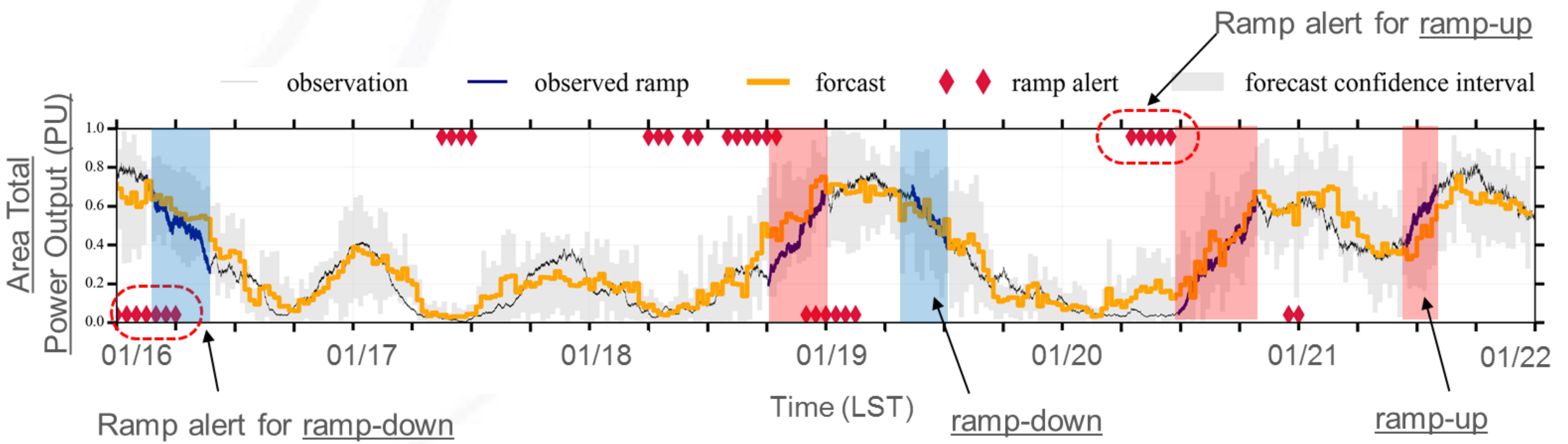
Latest Achievements②

Time series example (16 - 21 Jan. 2018, Tohoku)



- The ramp alert ◆ mean that a ramp event will occur within 6 hours from the marked point.
- The power output forecast & ramp alerts predict well especially the ramp-down of 01/19.
- The confidence interval (95%) covers the actual power output well.

Source : Japan's R&D Project of Ramp Forecasting Technology: Meteorological, Pattern Analysis Method M. Okada, T. Ichizawa, Y. Nakamura, K. Yamaguchi, R. Kodama, N. Ogasawara (Japan Weather Association, Japan), H. Kato, Y. Nagano (Nihon University, Japan), R. Ikeda, V. Q. Doan, H., Kusaka, T. Araki, N. N. Ishizaki (University of Tsukuba, Japan)

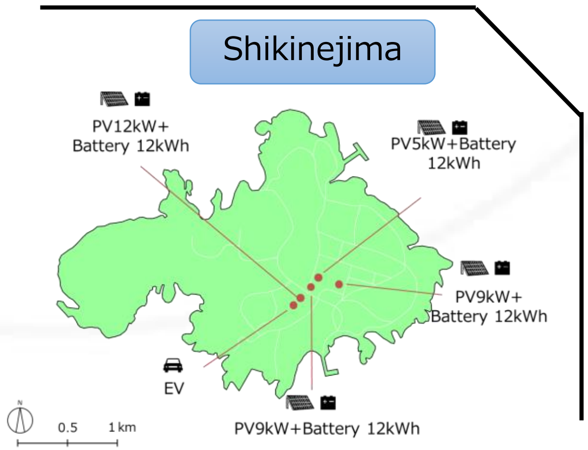
1. R&D Project on Grid Integration of Variable Renewable Energy :

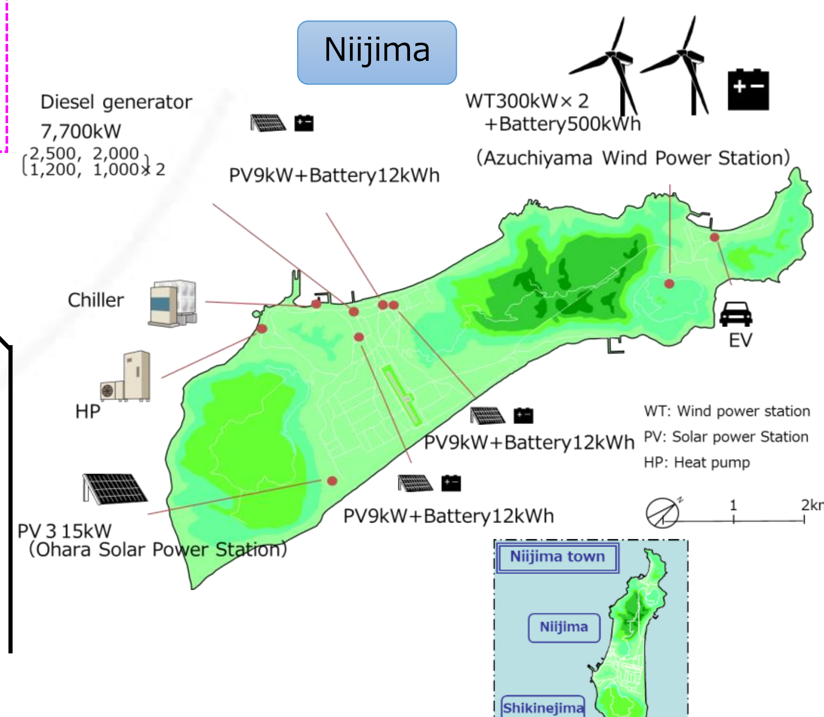
Mitigation Technologies on Output Fluctuations of Renewable Energy Generations in Power Grid
～Improving technologies on prediction, control, and operation for addressing the output fluctuations～

Demonstration Test on Power Grid System

A demonstration test which simulates the 2030 Energy Mix has been conducted in Niijima town. The purpose of the demonstration is to establish an advanced power grid system by upgrading technologies on prediction, control, and operation for the stable utilization of renewable energy.

Demand scale: about 1,900～4,400kW
Renewable energy: about 1,060kW
(including existing facilities)
WT600kW, PV about 460kW





※Niijima and Shikinejima are connected using an undersea cable.

Azuchiyama Wind Power Station

Ohara Solar Power Station

Development of Voltage Control Equipment and Evaluation on Grid

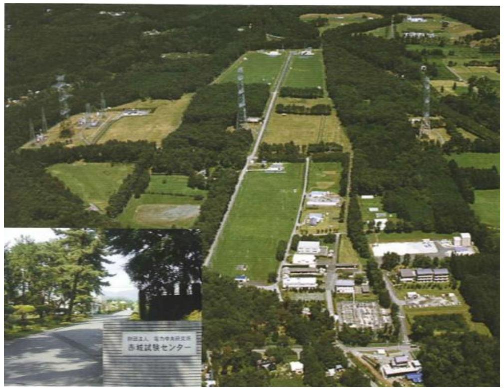
Voltage control equipment being developed in this project

3.3kVSiC module

SVC
(Static Var Compensator)

Advanced TVR(CVC™)
(Continuous Voltage Compensator)

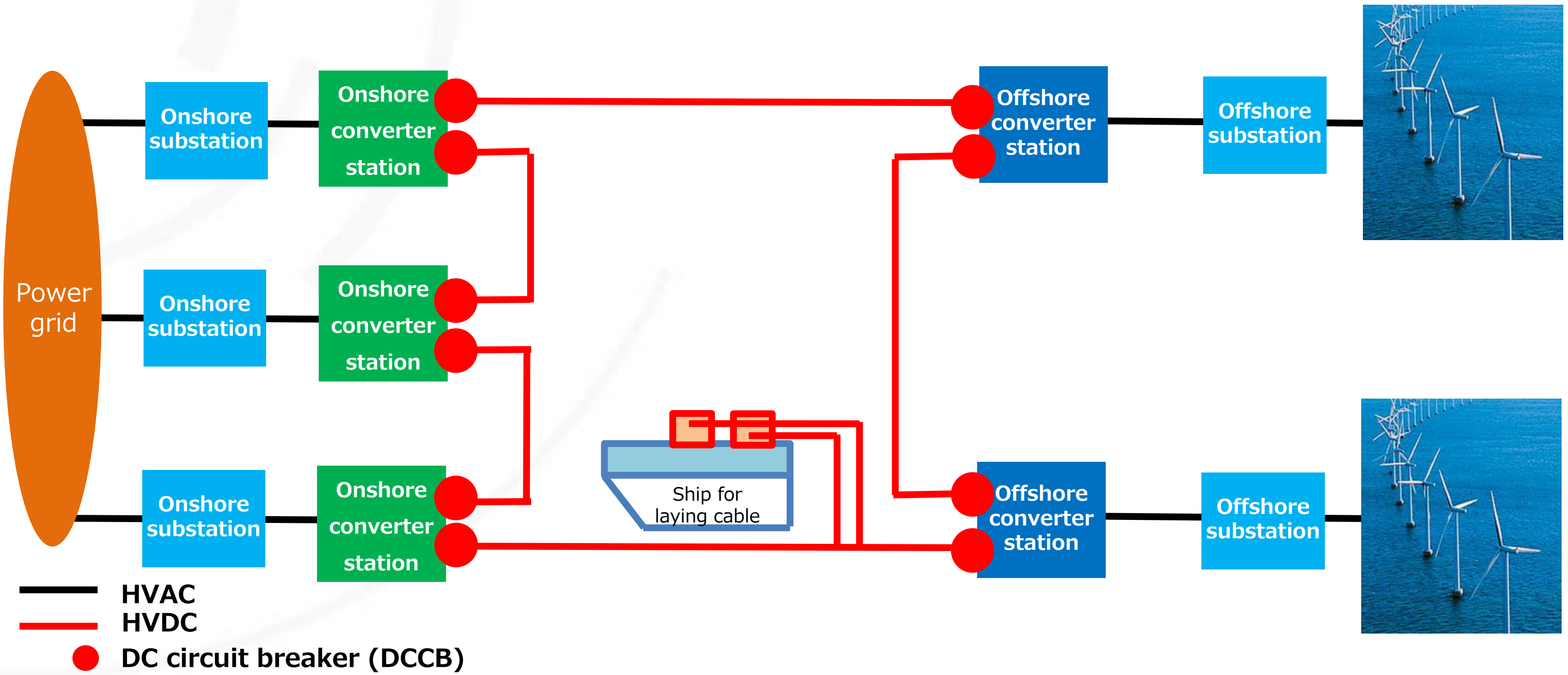
Demonstrational distribution grid
(Akagi Testing Center of Central Research Institute of Electric Power Industry)



Example of testing items of demonstration in demonstrational distribution grid

	SVC	Advanced TVR（CVC™）
Rated capacity	300kVA	3,000kVA
Rated voltage	6,600V	
Size, weight	W:1,300mm、D:1,000mm、H:2,500mm、 Weight:1,800kg	W:1,595mm、D:1,468mm、H:2,250mm、 Weight: 2,600kg
Operability	Capable of installing to a single pole	Capable of installing by the pole erection vehicle
Main features	Voltage fluctuation suppression Imbalanced voltage compensation FRT※ compensation ※Fault Ride Through	Compensate voltage(6600V±300V) Compensate unbalanced voltage & current Compensate reactive power Detect power direction

Development of Multi Terminal - HVDC system



System design

- Study on functional specifications and equipment specifications of MT-HVDC system through system planning and design
- Feasibility study of MT-HVDC system through cost estimation of EPC and O&M

Component development

- Development of new component prototypes to implement high reliability and low cost MT-HVDC system
- Study on performance specifications for element technologies through prototyping and property testing

Standard Specifications (Draft) for HVDC

1 Purpose

2 Components and Main Functions of Multi-terminal HVDC System

- 2.1 Entire System
- 2.2 Offshore Wind Farm, Offshore Substation, and Power Collection System
- 2.3 Converter Station (Terminal)
- 2.4 AC-DC Converter (Pole)
- 2.5 High-order Control System

3 Stationary-state Control Plan

- 3.1 Basic Principle of Multi-terminal HVDC System Control
- 3.2 MMC Control Block Diagram
- 3.3 DC System Local Control Characteristic (PDC-VDC Characteristic)
- 3.4 Collaboration of Converter Stations
- 3.5 High-order Control System

4 Multi-terminal HVDC System C

- 4.1 Line Idling Status
- 4.2 Termination Status
- 4.3 Onshore Converter Stat
- 4.4 Offshore Converter Stati
- 4.5 Ordinary Operation Stat
- 4.6 Offshore Converter Stati
- 4.7 Onshore Converter Stat
- 4.8 Operation Failure Status
- 4.9 Activation/Termination Failure Status
- 4.10 Fallback Status
- 4.11 Specific Example of Fallback (five-terminal HVDC System)
- 4.12 Re-interconnection

5. Assumed Faults of Multi-terminal HVDC System and Responses at Component Faults

3. Challenges for the Power System

New Issues on the Power System

High Penetration of Renewable Energy

Uncertainty in Balancing Operations

Need for forecasting

Application of Energy Storage

Flexibility in the Power System

New Concepts: N-1 Power Control &Non-firm Power Flow Management

●N-1 Power Control

Technology that maximizes transmission from renewable energy when faults and disruptions occur on grid. This is being studied in a NEDO Demonstration Project in Poland, with lessons learned for the grid in Japan.

●Non-Firm Power Flow Management

Technology that maximizes transmission from renewable energy. This will start with a R&D project to develop concepts of reverse power flow management.

Stability issues

- ## Shortage of Inertia

  Due to the increase in renewable energy, the future power system must think about a reduction in inertia which is necessary to maintain stability on the grid. Issues related to inertia will be addressed in upcoming R&D projects.

- ## Less Synchronous

  Dependency on inverter based resources and load management will make it difficult to keep the power system synchronous. This issue will be addressed in upcoming R&D projects as well.

Conclusion

- Generation from renewable energy sources has grown substantially in the past 5 years and is expected to grow even further by 2030 to a level of high penetration on the grid. Strengthening the power system to accommodate this change in energy mix is extremely important in order to maintain the grid – a robust grid to withstand natural disasters.

- A stable power supply system resistant against natural disasters is a major issue in Japan.

- NEDO has been developing grid management tools, such as forecasting and remote output controls, and will continue with the following efforts:
  - Grid management and control (technology maximizing transmission from renewable energy)
  - Grid stability (issues related to inertia and synchronous generation)

- Through R&D projects in these areas, NEDO hopes to contribute to the understanding of coordination between Transmission and Distribution Operations under conditions of high penetration of DER.

Thank you for your attention!