ESIG Spring Workshop
Session 1: Evolving Thinking on Resource Adequacy for High VG Scenarios

Resource Adequacy Considerations for RE Integration in Japan

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Agenda

I. The situation of RE deployment in Japan

II. System operation in Kyushu

III. System operation enhancement in Kyushu

IV. Emerging Resource Adequacy issue and mitigation

IV. Conclusion

For further information:
2019.10.15_K. Ogimoto, et. al., General Flexibility Model Analysis for Mass PV Deployment, Solar Integration WS, No.253 (2019)
Specified figure and table numbers are those in this article.

RE Deployment under FIT

- In Japan, under FIT program, RE increased by 22% annually.
- The total applications of PV installation under the FIT program reached around 80 GW, and actual PV deployment is 40GW, while the current national target is 64 GW in 2030.
- Much of these applications were for installations of PV in smaller balancing areas where demand is low and price is cheaper.

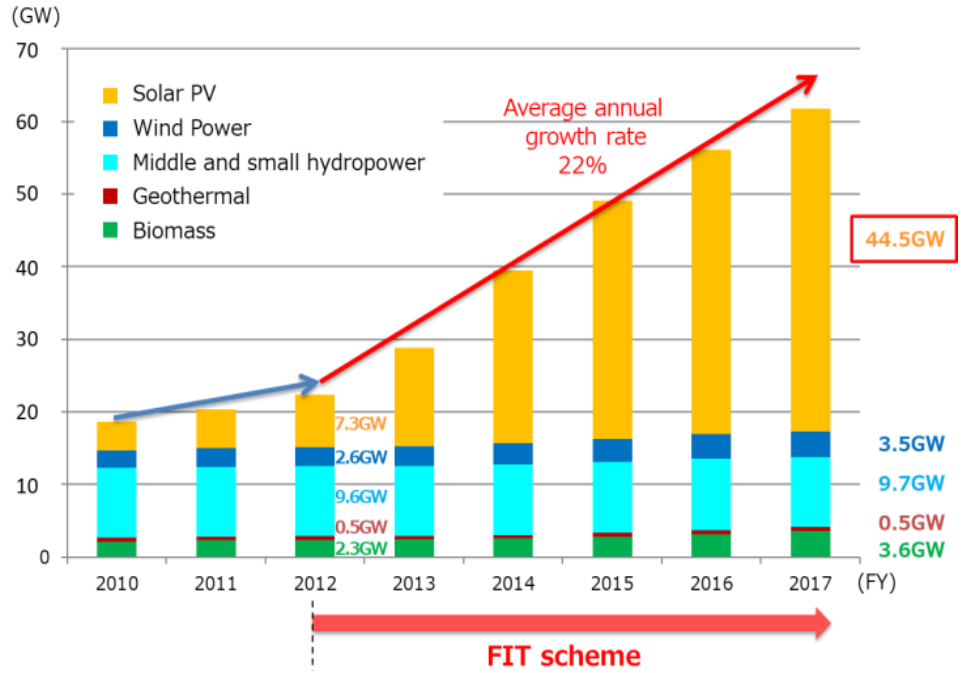
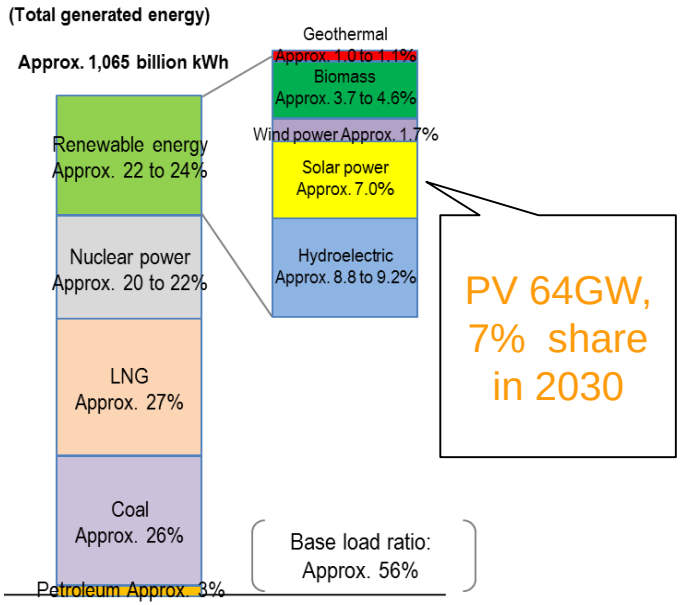


Figure 1. RE deployment in Japan
(by courtesy of METI)



Generation outlook in 2030
(by courtesy of METI)

PV penetration in Kyushu

- Kyushu, the southernmost island of the four main islands of Japan, is the area where the power system operation has been most severely affected by PV penetration of more than 8.5 GW.
- In Kyushu, the peak power demand is 16 GW in summer and winter, and the minimum day-time load is 8 GW. There are four nuclear units of 4.6 GW which are currently in operation.

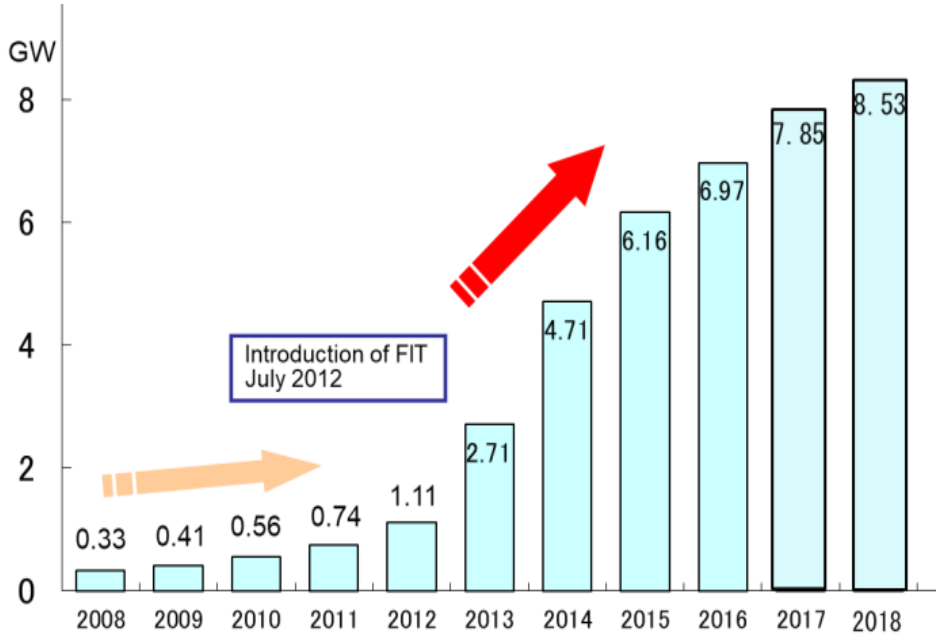


Figure 3. PV deployment in Kyushu
(Source: Kyushu EPCO)

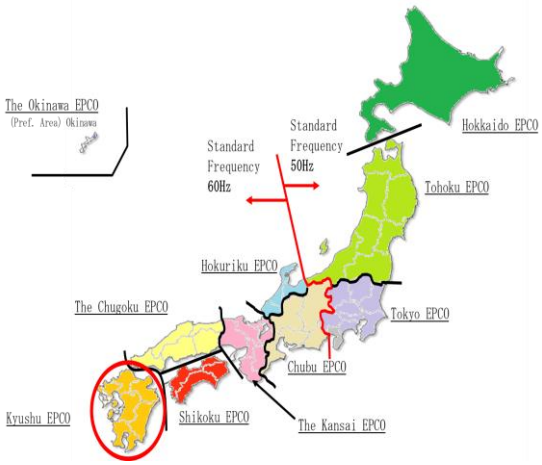
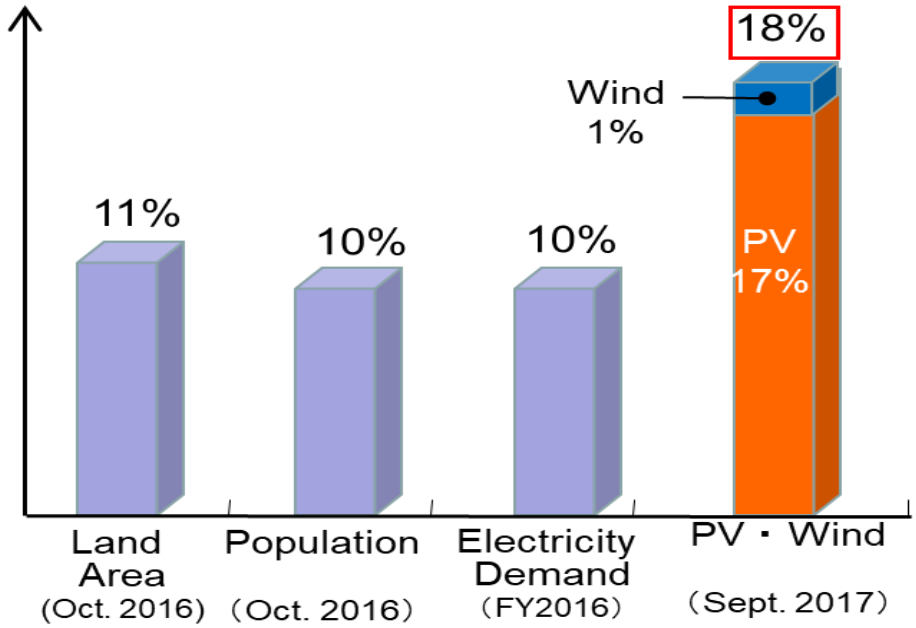


Figure 2. Ten balancing areas in Japan

PV penetration in Kyushu

- With Kyushu, the PV deployment share of 17% is almost double of other shares of land area, population, and electricity demand of around 10%.



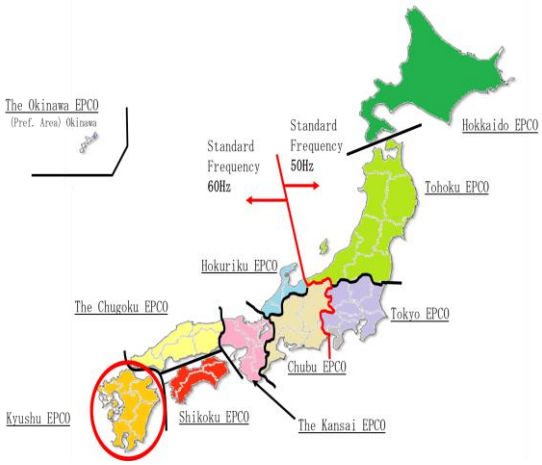


Figure 4. PV deployment and other shares of Kyushu

(Source: Kyushu EPCO)

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Renewable energy curtailment in Kyushu

- Since the first RE curtailment on October 13th in 2018 in Kyushu, there were 56 RE curtailments up to June, 2019.
- From March to May when the demand is low due to the minimum air-conditioning loads and maximum irradiation, there were more frequent RE curtailments with the maximum curtailment of 2.57 GW.

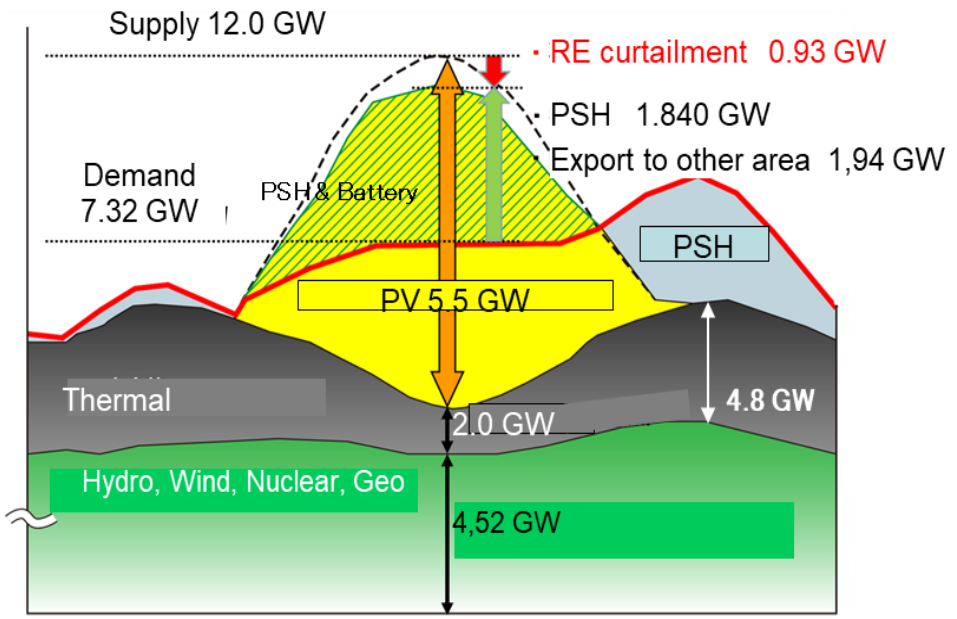
The experiences of RE curtailment up to June, 2019

		2018						2019		
		Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June
Number of Operation	times	4	4	0	1	1	16	20	10	0
Max. curtailment	GW	0.93	0.93	—	0.35	0.44	1.80	2.57	1.90	—
Curtailments per unit	times	5 - 6						8 - 9		

(Source: Kyushu EPCO)

Renewable energy curtailment in Kyushu

- As a typical system operation with curtailment, the demand-supply situation at 12:00 o'clock on October 21st was as follows:
  - 0.93 GW of RE curtailment,
  - 7.3 GW of power demand,
  - 4.5 GW of base load generation,
  - 2 GW of thermal generation,
  - 1.8 GW of pumping of PSH. and
  - 1.9 GW of power export via an interconnection line.



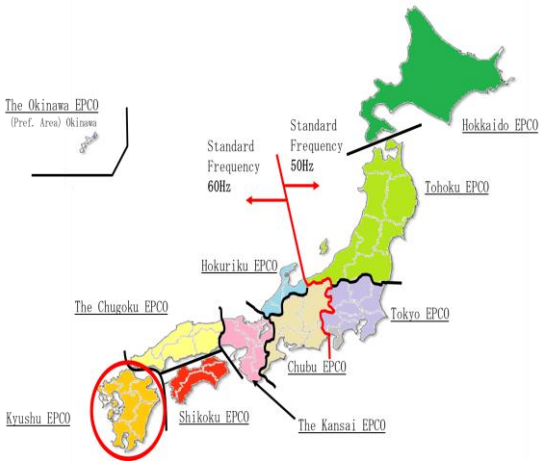
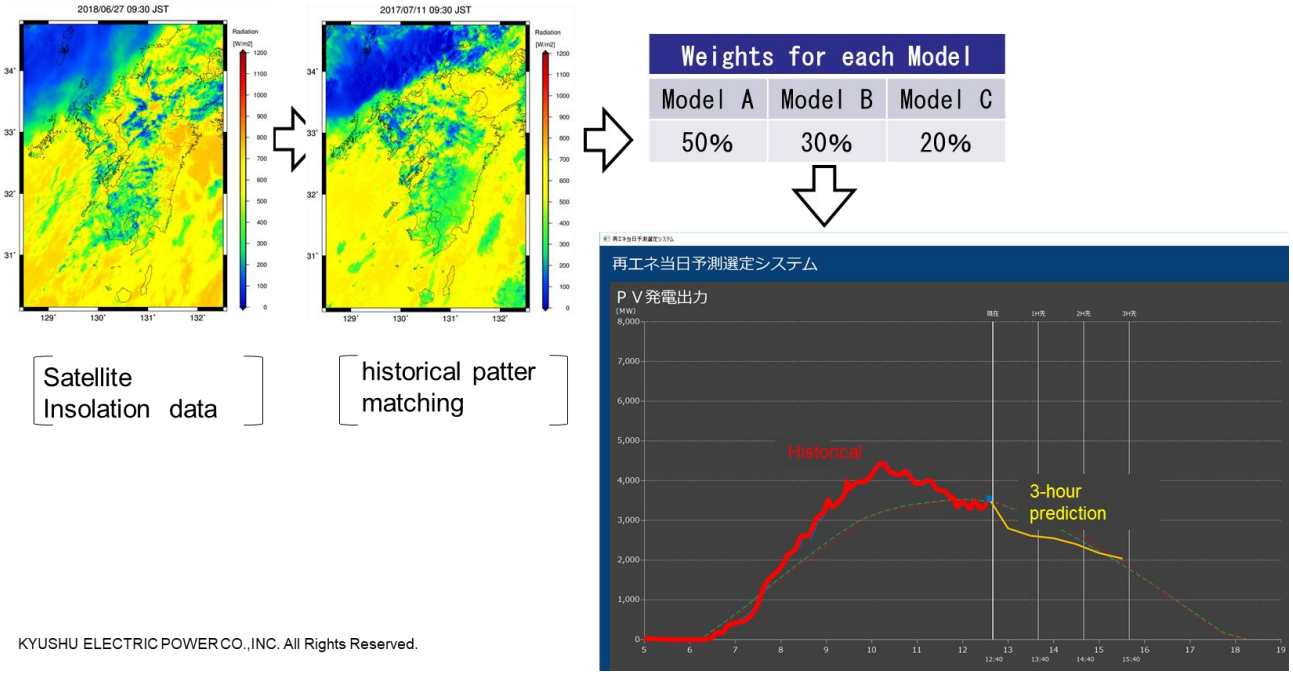


Figure 5. Demand and supply operation on Oct. 21st, 2018

(by courtesy of Kyushu EPCO)

System op. under the PV penetration

- In the system operation, PV output predictions are carried out using 3 different PV output prediction models, each having its strength and weakness depending on the weather pattern.
- In the actual operation, according to matching of the satellite monitoring data with a historical insolation pattern, the three predictions are weighted to yield the averaged prediction of 3-hour horizon.



Improvement of PV generation forecast (Source: Kyushu EPCO)

System op. under the PV penetration

- As a fundamental flexibility resources, CCGT (Combined Cycle Gas Turbine) plants with shorter start-up time meet a ramp-up of the residual demand in the evening.
- A typical CCGT start generation two hours after the operator's order, while a steam-turbine generator more than 10 hours.
- On April 30th, four CCGT units were made on-line in every 15 minutes.

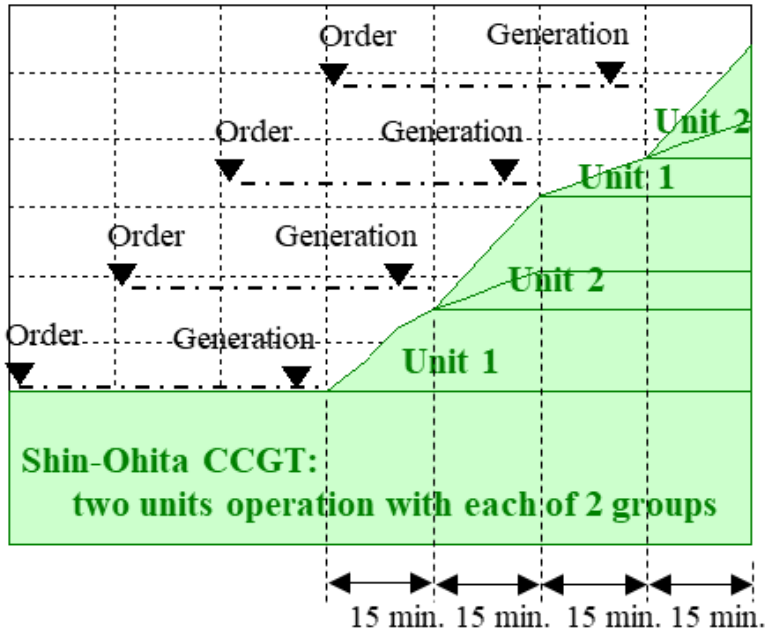


Figure 6. Image of CCGT Units Operation during a ramp-up of residual demand in the evening on April 30th, 2018. (Source: Kyushu EPCO)

RE curtailment operation: On-line control

- Online RE curtailment is a key for security and efficiency of the system operation and reduction of the required RE curtailment.
- Under a collaboration of the Japan government, Kyushu EPCO, and RE generators, Kyushu EPCO installed on-line control devices with 22 PV units of 394MW.
- Efforts have been continued to increase the on-line-controlled PV capacity.

Installations of on-line RE curtailment system. (MW, units)

Category	Target capacity	Installation in FY2015	Installation in FY2016	Installation in FY2017	Capacity accumulated at March 2017
66 kV or more	390 (20)	72 (2)	110 (3)	204 (14)	386 (19)
Below 66 kV	10 (1)	3 (2)	0 (0)	5 (1)	8 (3)
Total	400 (21)	75 (4)	110 (3)	209 (15)	394 (22)

(Source: Kyushu EPCO)

RE curtailment operation: Target system

- PV capacities of 8.5 GW in Kyushu are categorized by on-line/off-line control and by connection voltages.
- The units of 4.7 GW, approximately 60% of the total PV capacity in pink zones are currently subject to RE curtailment.
- Among these, as of June, 2019, a total of 26000 PV units of 1.7 GW can be on-line controlled, while around 2000 units of 3.1 GW cannot.

PV systems in Kyushu categorized by on-line/off-line, connection voltage
(pink-zones are the current targets of RE curtailment)

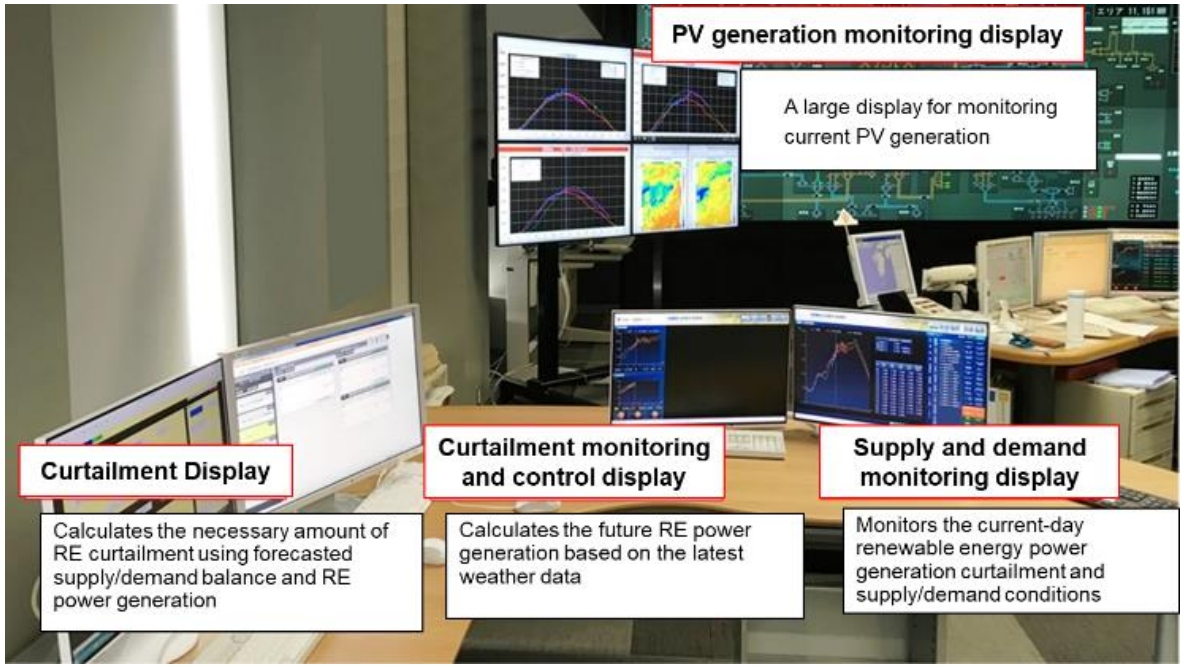
		Off-line Control (manual control) (Old-rule Units)		On-line Control (Automatic control) (New-rule units)	
66kV and above		47 units	730 MW	26[*1] units	470[*1] MW
MV	>=500kW	2000 units	2340 MW	312 units	340 MW
	<500kW	2000 units	400 MW	402 units	90 MW
LV	>=10kW	6,3000 units	1750 MW	25,000 units	840 MW
	<10kW	29,7000 units	1330 MW	74,000 units	410 MW

Note 1: Include Old-rule 19 units of 400 MW

(Source: Kyushu EPCO)

Renewable Energy Management System

- The Photo shows the Renewable Energy Management System in an EMS office of Kyushu EPCO.



Renewable Energy Management System in the EMS Office
(Source: Kyushu EPCO)

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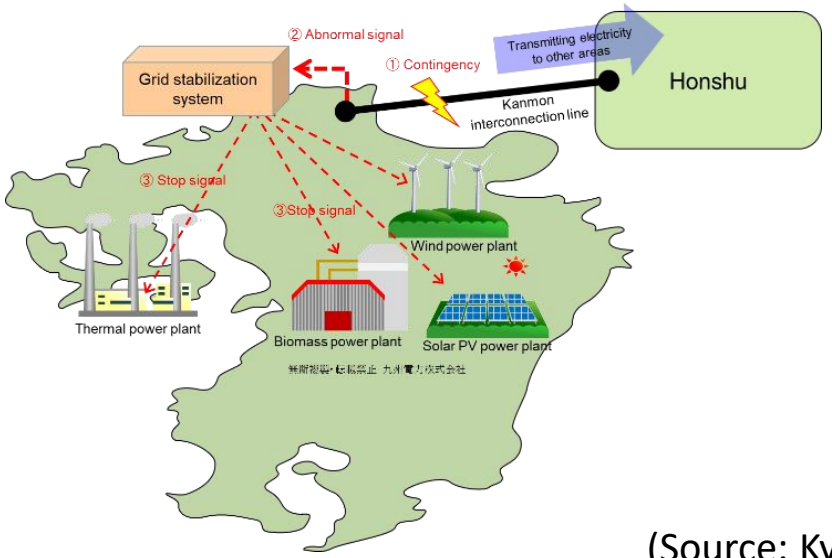
Operation enhancement: Interconnection

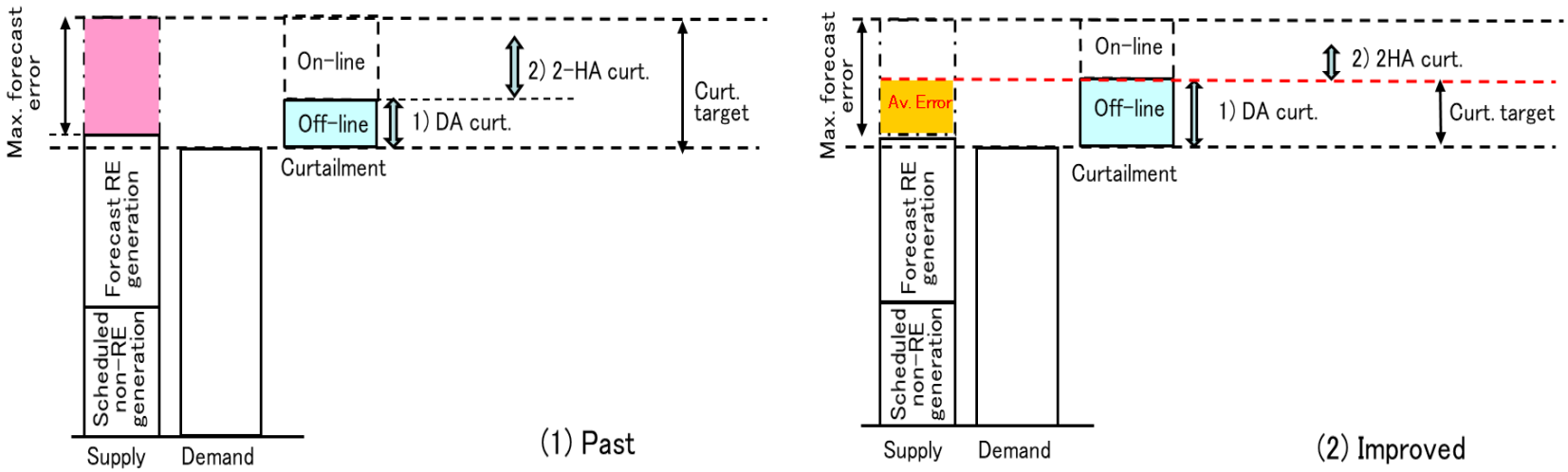
- For less curtailment, it is effective to increase operational export capacity of the AC 500 kV interconnection with the main island, “Kanmon Interconnecting Line” with a thermal capacity of 2.5 GW.
- Over-frequency relays were equipped with 5 geothermal and 81 hydro plants to increase the operational capacity by 500MW.
- A grid stabilization system was installed to immediately and selectively trip multiple major generation plants in case of a failure of the interconnection. This system increased the operational capacity by 300 MW.



(Source: Kyushu EPCO)

Operation enhancement: More real-time operation

- Since the autumn of 2019, the RE curtailment procedures were improved by a more real-time operation.
- The target amount of RE curtailment, which was calculated based on the "historical maximum" forecast error in the same month, is now calculated based on the smaller "historical average" forecast error in the same month.
- Off-line units are ordered curtailments in a previous day, while on-line units, making the best use of on-line control, are ordered curtailment two hours before the real time only when necessary.



Improvement of curtailment operation using average forecast error (Source: METI)

Operation enhancement: Battery

- Recently, in Kyushu area and other balancing areas in Japan, utility-scale battery plants are also being deployed.
- They add small but fast flexibility services to the power system operation. In Kyushu, a 50 MW and 6-hour Sodium-Sulphur (NaS) battery plant is in operation.

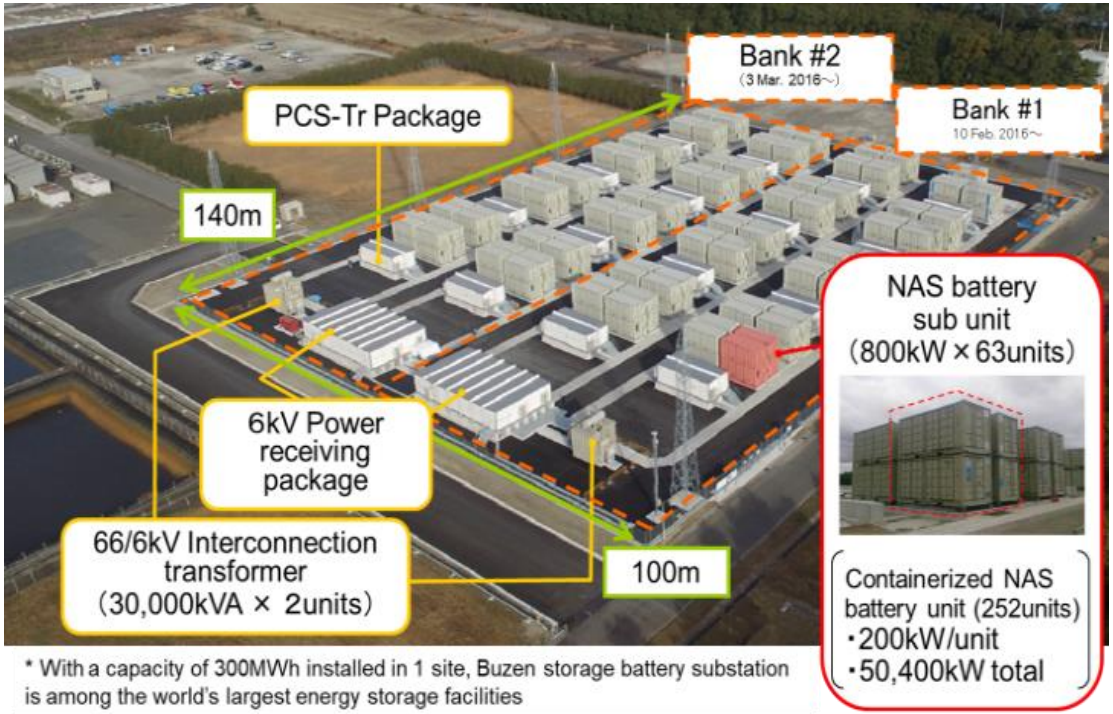


Figure 7. Utility-scale battery plant in Kyushu (50 MW, 300 MWh).
(Source: Kyushu EPCO)

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A new operation issue: An extreme forecast error

- On March 2nd, 2019, the actual PV generation was 3.5 GW lower than the forecasted 8.5 GW of the previous day and the morning. The demand was 0.9 GW more than the forecast.
- The operator revised the schedule of PV curtailment, PSH and thermal plants, although the storage of PSH came to its bottom in the evening.
- It is crucial for a security of supply that, in winter, a reduction of PV generation often comes with a increase of demand.

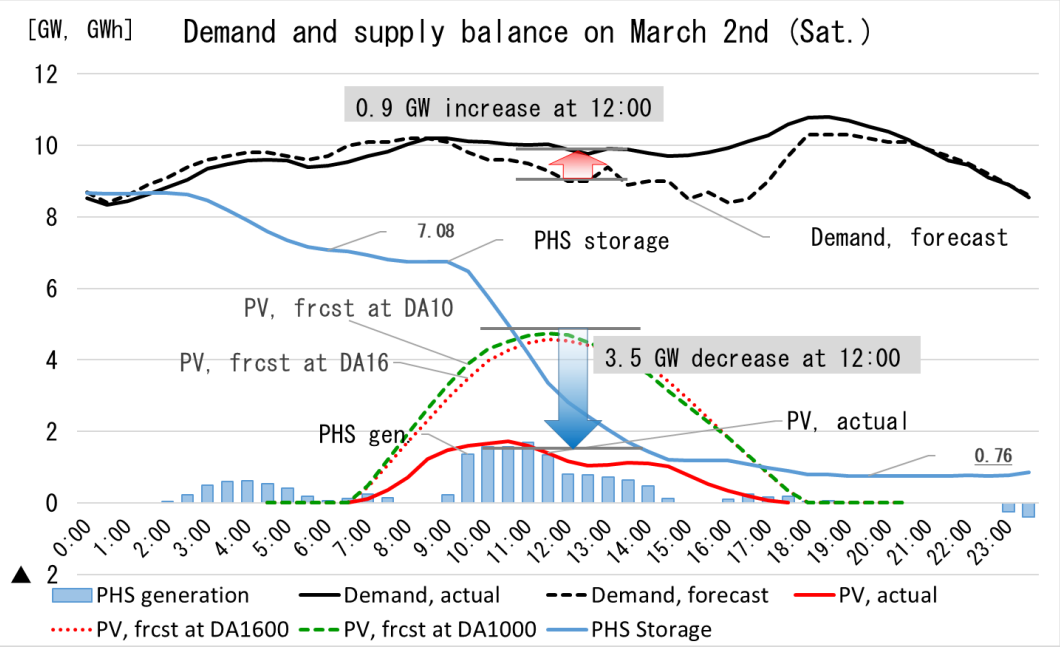
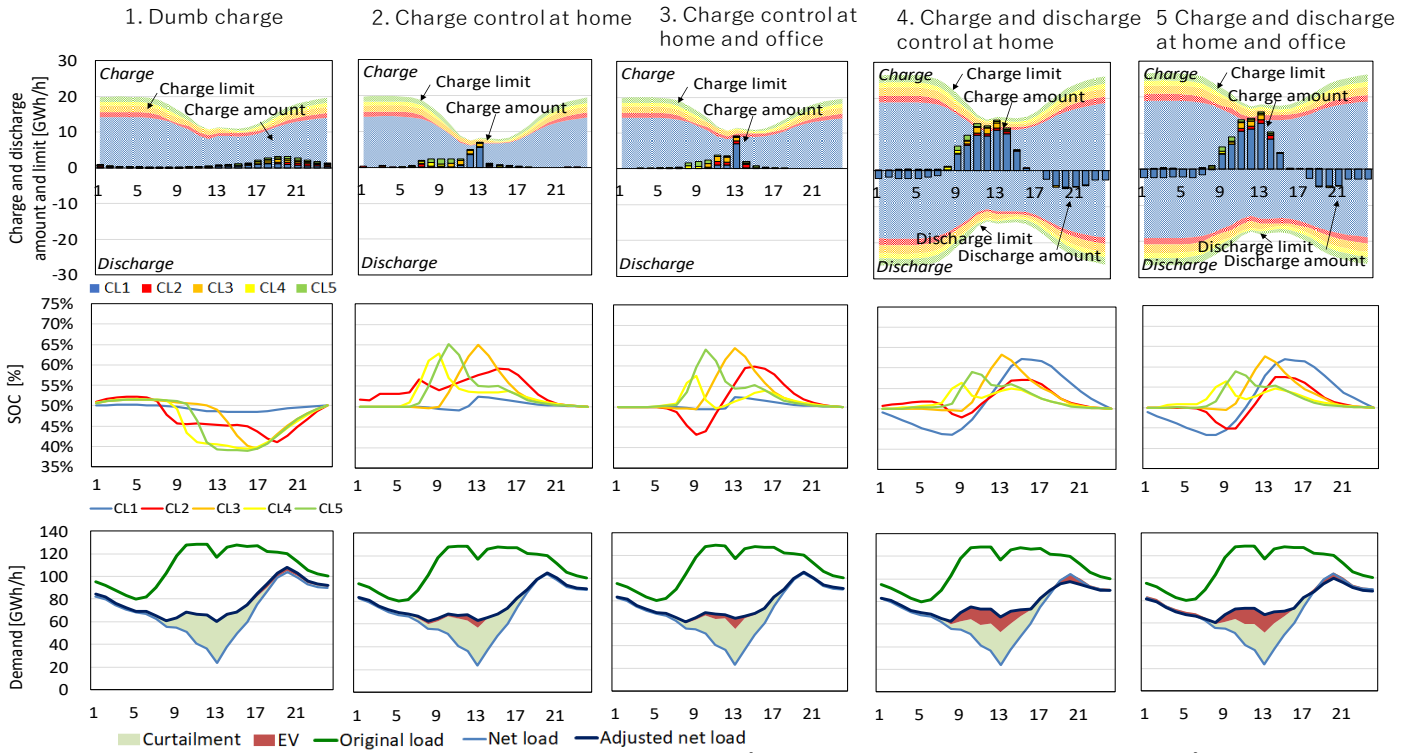


Figure 8 Demand and supply operation on March 2nd, 2019. (Source: Kyushu EPCO)

Possibility of mitigation: Manageable demand

- Manageable demands such as Heat Pump Water Heater (HPWH) and EV charging/discharging tend to be in full operation during the period of high generation forecast.
- The demand of HPWHs and EVs can be effectively reduced in case of an extreme forecast error under certain arrangements in advance between aggregators and customers.



Dumb charging smart charge at home/w. place smart charging/discharging

Possibility of mitigation: Analysis by GFM

- General Flexibility Model can analyze different reserve requirements met by different reserve resources including distributed ones.
- In the analysis for Kyushu, demand of “Tertiary-slow reserve” is defined as an extreme forecast error, and the reserve can be met by EV and HPWH as well as carry-over of Tertiary-fast resources .

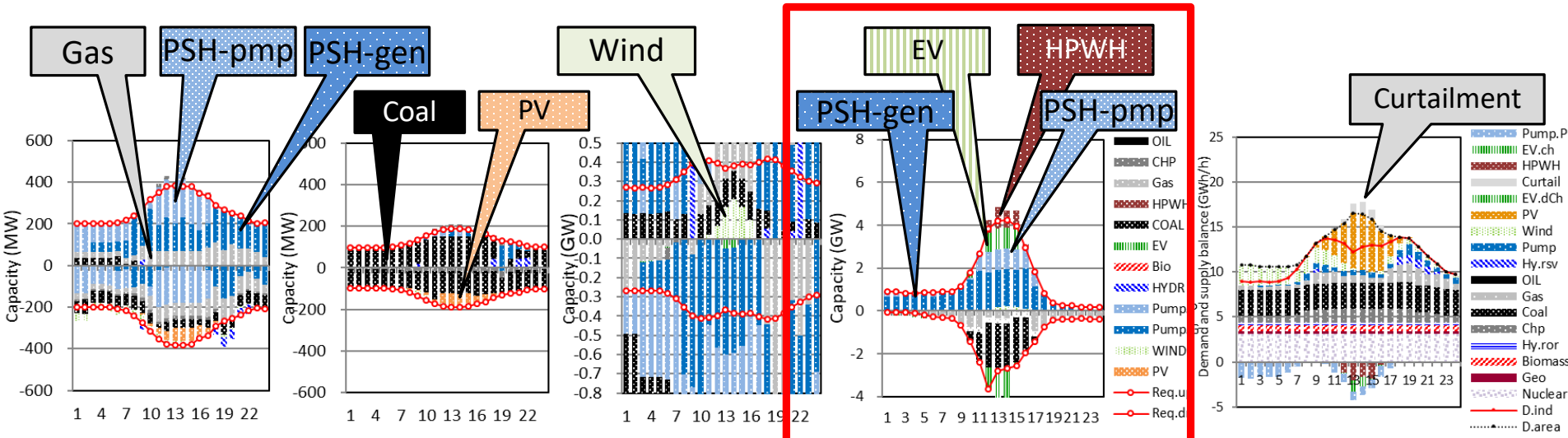
Table 1. Setting of flexibility requirement and supply

Category		Secondary-fast			Secondary-slow			Tertiary-fast					Tertiary-slow		
		Ratio	UP	Dn	Ratio	UP	Dn	Ratio	UP	Rng	Dn	Rng	Ratio	UP	Dn
Req.	Dmnd	±2%	67%	67%		33%	33%		3%		3%				
	PV	±5%/gen.	67%	67%		33%	33%						Extreme F. Error		
	Wind	±5%/cap.	67%	67%		33%	33%						Extreme F. Error		
Supply															
Teerm.	Coal	unit	5	5	—			unit	O.P.	max.	O.P.	min.	—		
	Gas	unit	5	5	—			unit	O.P.	max.	O.P.	min.	—		
	Oil	unit	5	5	—			unit	O.P.	max.	O.P.	min.	—		
	CHP	20	5	5	20	5	5	30	O.P.	50%	O.P.	50%	—		
Hydro	Pump	unit	15	15	—			unit	O.P.	max.	O.P.	min.	—		
	Rsrvr	100	5	5	—			100	O.P.	Firm	O.P.	min.	—		
	RoR	—	—	—	—			—	—		—		—		
RE	PV	20	—	5	—			20	Curt.	50%	O.P.	50%	—		
	Wind	30	—	5	—			30	Curt.	50%	O.P.	50%	—		
	Geo	—	—	—	—			—	—		—		—		
DR	EV				10	±5%		20	O.P.	20%	O.P.	20%	70	50	100
	HPWH												50	100	—

O.P.: changes from the operation point

Analysis: Supply of reserves

- HPWH and EV are available to reduce demand anytime when large generation is forecast with PV and wind.
- Thermal plants are not economical to keep ready for a rare event.
- In the analysis, the requirement for upward “tertiary slow” reserve of 4 GW is met by PSH, EV and HPWH.



Secondary Fast | Secondary Slow | Tertiary Fast | Tertiary Slow | Demand/Supply

Optimum system service allocation between resources
(April 1st , total of 10 areas in Japan)

Conclusion

- Kyushu area is one of the power system whose system operation has been mostly affected by VRE penetration.
- The system operation of Kyushu area has been improved to accommodate growing RE while keeping stability and reliability.
- One of the emerging issues in Kyushu area is an extreme forecast error of corelated RE and demand. The energy storage capacity of PSH plants is becoming short to meet the extreme error.
- Among several alternatives, manageable demand such as EV charging/discharging and HPWH have a possibility to mitigate the extreme forecast error in a secured and economical manner.
- We need to continue data collection, analysis and improvements.

Thank you

Ogimoto Laboratory, Institute of Industrial Science, the University of Tokyo
http://www.ogimotolab.iis.u-tokyo.ac.jp/html_e/research_e.html

Shinjuku Gyoen (March 22nd)

Chidorigafuchi (March 22nd)

Now, cherry blossoms are coming into full bloom in Tokyo as always, although almost all festivals are cancelled due to COVID-19. Please find the usual way of OHANAMI below.
https://japan-attractions.jp/special-cherry-blossoms/