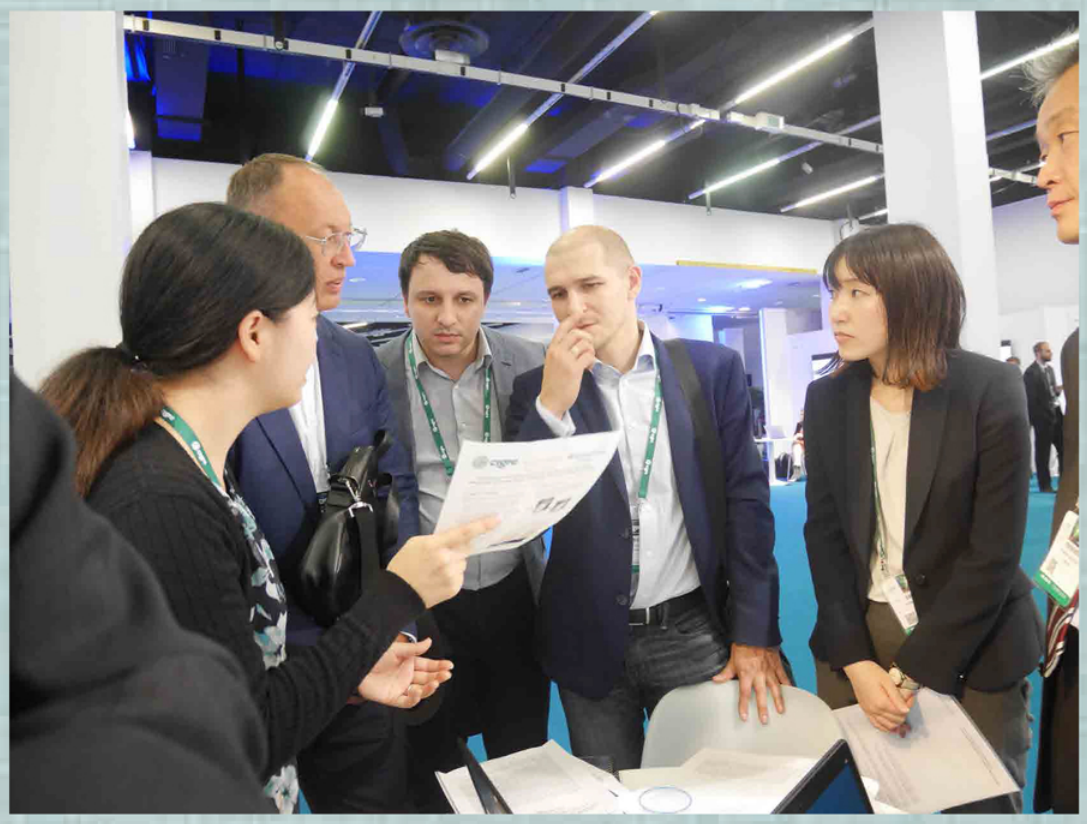

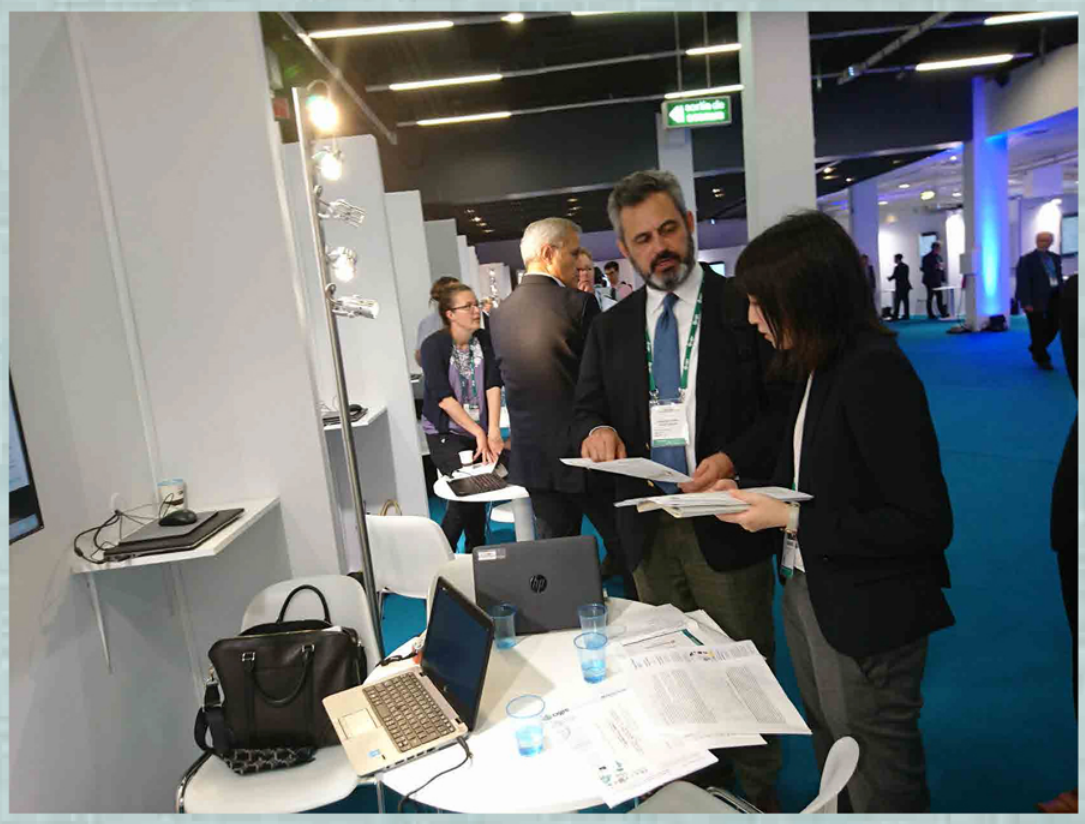

国際大電力システム会議（CIGRE）パリ大会（2018年8月29日）

Study Committee C2
System operation and control
Paper C2_210_2018

Improvement in Estimation Accuracy for Current and Short-Term Future Photovoltaic Generation Output through Big Data Analysis Using Smart Meters

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Introduntion

- In the “Long-term Energy Supply And Demand Outlook” published by the Japanese government in July 2015, the target for the installed PV capacity was set to 64 GW.
- The installed PV capacity in the Kansai region is approximately 5.0 GW as of the end of June 2018.
- We developed ‘Areal solar power forecasting system using satellite imagery estimation (Apollon)’ with the aid of the Meteorological Engineering Center, Inc. and introduced a system for estimating the PV output based on Apollon at the central load-dispatching centre in March 2016.

Development of PV Estimation System using Satellite Images

- Apollon uses the satellite imagery transmitted from the meteorological satellite, Himawari 8 every 2.5 minutes to forecast the amount of solar radiation up to 3.5 hours ahead.
- Fig. 1 shows an outline of Apollon and the method for estimating the PV output.
- The PV output is estimated in two steps considering the geographical distribution as shown below, because the solar radiation varies from location to location.
- Step 1 involves multiplying the following three elements in each 1 km × 1 km gridded tile. Step 2 involves the summation of the estimated PV output over the entire service area.

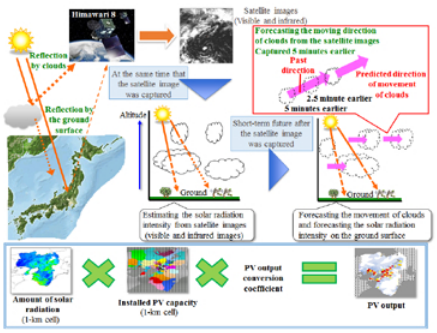

Fig. 1 Apollon and the method for estimating the PV output

Improvement in Estimation Accuracy of PV Output through Big Data Analysis

- The conversion coefficient which features the PV output in the entire service area was calculated using the measured data obtained from the smart meters with the statistic approach.
- As shown in Fig. 2, the smart-meter-measured data are used as the reference values, then, the PV output is estimated based on the method described in Fig. 1. The estimated error of the PV output is calculated comparing those two data obtained at the same location and at the same time.
- The proposed method searches for the conversion coefficient which minimises the estimated error and treats the derived conversion coefficient as the optimal conversion coefficient.

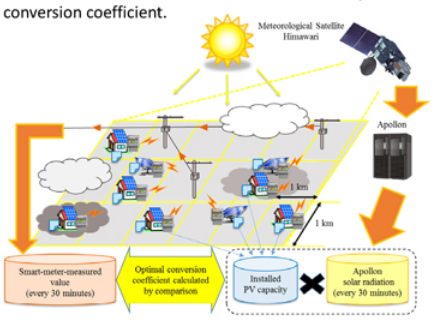

Fig. 2 Improvement in estimation accuracy

Utilizing PV Output Estimation System in Demand and Supply Operations

- In comparison with the estimated error employing the previous conversion coefficient, this estimated error decreased by 5.1% from 7.9%.
- On a premise that the necessary amount of frequency response and reserve capability during the peak daytime hours under sunny weather conditions is provided, the number of operating thermal units may be reduced and only the most economical thermal units may be operated.
- In one year after introducing this system, 11.2 thermal units by monthly average (which were more than twice of 4.6 units in two years before introduction) were stopped.

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1. Outline of Apollon

Apollon(*Areal solar power forecasting system using satellite imagery estimation*)
consists of estimation and forecasting process of solar radiation.

- In the estimation process, solar radiation at the ground is estimated with visible and infrared satellite images of Himawari-8* by considering the characteristics of clouds which interrupt sunshine.(shown in the left of Fig.1)
- In the forecasting process, motion vectors of clouds are estimated from time variation of images of Himawari-8, and position of clouds are forecasted.(shown in the right of Fig.1)

*Himawari-8: The geostationary meteorological satellite which Japan Meteorological Agency administers.

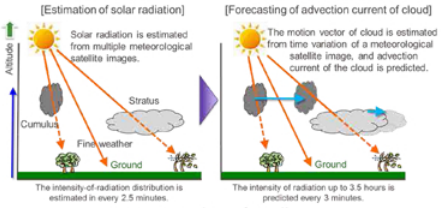
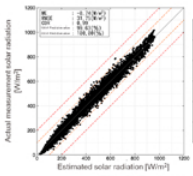


Fig.1 Outline of Apollon

2. Method to estimate

- From satellite images of every 2.5 minutes, cloud albedo is calculated. The cloud albedo is the reflectance of solar radiation by clouds. The amount of solar radiation is found from the amount of solar radiation at fine weather and cloud albedo, and a correction factor. The amount of solar radiation at fine weather is calculated theoretically. The correction factor is a coefficient calculated with visible and infrared satellite image data.
- Fig. 2 shows the scatter plot of actual measured solar radiation (vertical axis) and estimated solar radiation by Apollon (horizontal axis). Data of 99.6% are settled within observed data ±100W and all data are settled within observed data ±200W, it is understood that Apollon data is high accuracy.



Accuracy evaluation index	Accuracy
Error: RMSE (W/m²)	31.75
Signed error: ME (W/m²)	-0.74
Coefficient of correlation	0.99
±100 W Predictive value (%)	99.63
±200 W Predictive value (%)	100.00

Fig.2 Estimated accuracy of Apollon

3. Method to forecast

- Himawari-8 catches images every 2.5 minutes. Movement of clouds is grasped from continuous satellite images, and movement vector field of cloud is estimated. Distribution of clouds are forecasted by moving the observed cloud field with the movement vector field.

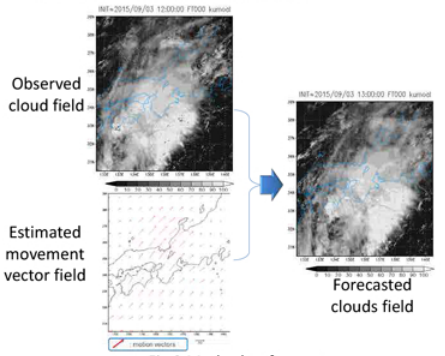


Fig.3 Method to forecast

4. An actual use of Apollon

- Fig.4 shows examples of the PV output forecast. In the central load dispatching centre (CLDC) of the Kansai Electric Power Company, Inc.(shown in Fig.5), Apollon is utilized for estimation of the photovoltaic generation(PV) output in Kansai area. Watching PV output forecasted by Apollon, operators of CLDC control electric power supply.

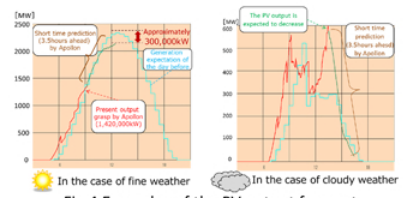


Fig.4 Examples of the PV output forecast

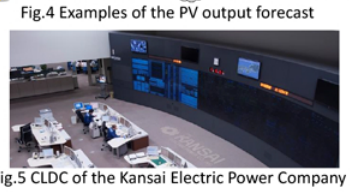


Fig.5 CLDC of the Kansai Electric Power Company

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