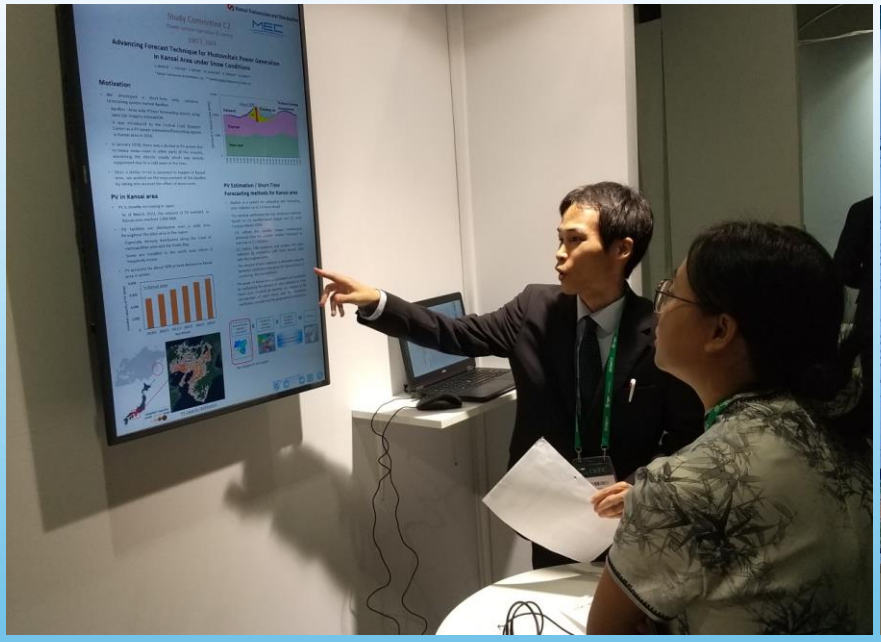

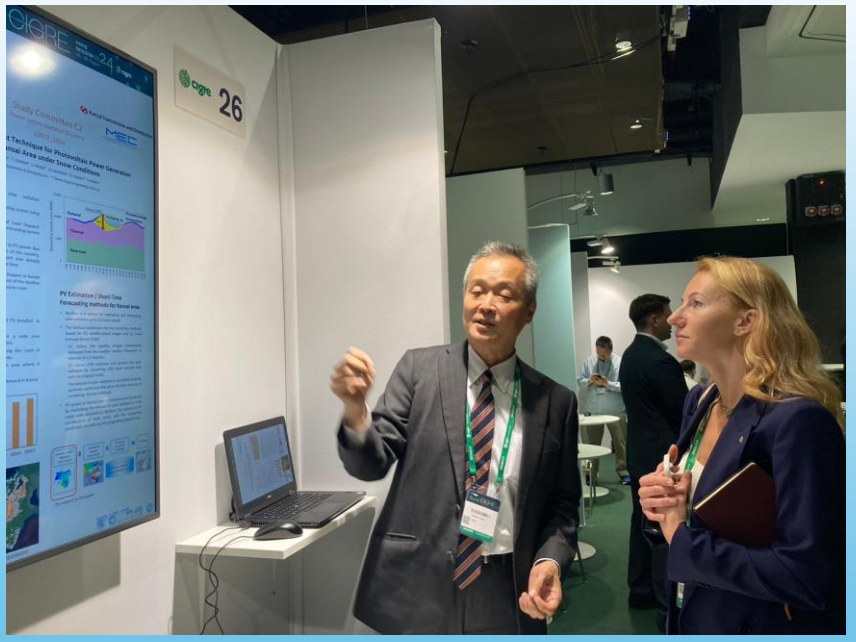

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Power system operation & control

10872_2024

Advancing Forecast Technique for Photovoltaic Power Generation in Kansai Area under Snow Conditions

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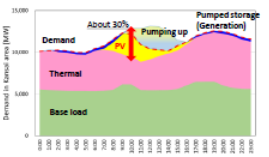
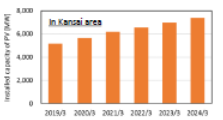
Motivation

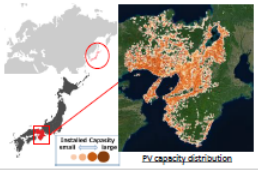
- We developed a short-time solar radiation forecasting system named Apollon.
  - Apollon : Area solar POwer forecasting system using sateLLite imagery estimatiON
  - It was introduced to the Central Load Dispatch Center as a PV power estimation/forecasting system in Kansai area in 2016.
- In January 2018, there was a decline in PV power due to heavy snow cover in other parts of the country, worsening the electric supply which was already suppressed due to a cold wave at the time.
- Since a similar event is assumed to happen in Kansai area, we worked on the improvement of the Apollon by taking into account the effect of snow cover.



PV in Kansai area

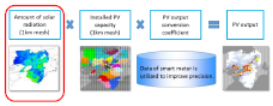
- PV is steadily increasing in Japan.
  - As of March 2023, the amount of PV installed in Kansai area reached 7,000 MW.
- PV facilities are distributed over a wide area throughout the plain area in the region.
  - Especially densely distributed along the coast of metropolitan area and the Osaka Bay.
  - Some are installed in the north area where it frequently snows.
- PV accounts for about 30% of total demand in Kansai area in winter.





PV Estimation / Short-Time Forecasting methods for Kansai area

- Apollon is a system for estimating and forecasting solar radiation up to 3.5 hours ahead.
- The method synthesizes the two prediction methods based on (1) satellite-based images and (2) Local Forecast Model (LFM).
  - (1) utilizes the satellite images continuously delivered from the weather satellite "Himawari" at intervals of 2.5 minutes.
  - (2) utilizes LFM estimates and predicts the solar radiation by converting LFM cloud amount data with the original model.
  - The amount of solar radiation is calculated using the synthesis coefficient that gives the best accuracy in combining the two methods.
- PV power in Kansai area is estimated and predicted by multiplying the amount of solar radiation in 1 km mesh units obtained by Apollon, the amount of PV introduction of each mesh, and the conversion coefficient, considering the geographical distribution.



The subject in this paper

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Proposed : The PV prediction method under snow condition

- In Apollon, the amount of solar radiation on the ground surface is predicted for each 1 km × 1 km grid.
- In order to improve the accuracy for predicting PV power generation during snow cover, the amount of solar radiation on the PV panels were predicted instead of the ground surface.
- As a forecast technique which takes into account the effect of snow cover, this paper tested the three different methods;
  - Snow Depth method
  - Snow Albedo method
  - Combined method which combines the above two

1.Snow Depth Method

Description

- The temporal change of snow depth is predicted using a part of snow melting model from the latest meteorological data.
- The amount of solar radiation is calculated based on the ratio of PV power generation according to the depth of snow cover.
  - SR_D : The amount of solar radiation with consideration of the effect of snow
  - SR_0 : The amount of solar radiation with no consideration of snow
  - K : The PV power generation ratio by Snow Depth Method

Advantages

- Small decrease in forecast accuracy over time

2.Snow Albedo Method

Description

- The temporal change of snow albedo(light reflectance obtained from satellite images, which is defined to be reflected by snow) is predicted using data from a meteorological satellite called Himawari.
- The amount of solar radiation is calculated based on the ratio of PV power generation according to snow albedo.
  - SR_A : The amount of solar radiation with consideration of the effect of snow
  - T : The PV power generation ratio by Snow Albedo Method

Advantages

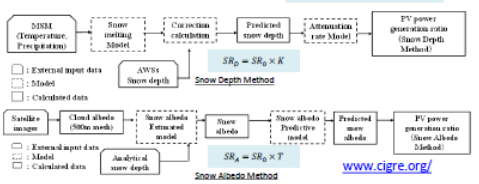
- Greater accuracy for latest predictions compared to the snow depth method

3.Combined Method

Description

- Method 1 and 2 have differing accuracies according to lead times.
- In order to gain the greatest accuracy for respective lead times, this method combines the solar radiation calculated from the two methods by a composition ratio.
- The composition ratio is obtained by using the least squares method based on the errors of each method with respect to the forecast time.
- The solar radiation is calculated from the values of each method and the composition ratio.
  - SR_{mix} : The amount of solar radiation with consideration of the effect of snow
  - r : The combined ratio

$$SR_{mix} = r \times SR_A + (1-r) \times SR_D$$



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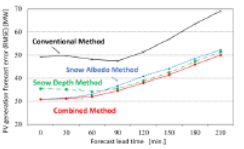
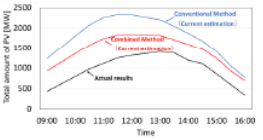
Validation

- Using the data for winter from 2017 to 2020, we estimated the total PV output of only the mesh with snow.
  - The combined method reduced the error by 26-37% compared to the conventional method.



The result for the whole Kansai area

- By applying the combined method, the prediction accuracy was improved at any one time, and the errors were reduced by 43-64%.

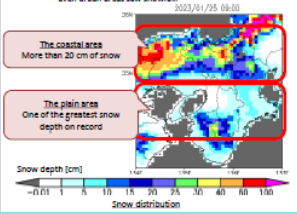


Implementation into real-life operations

- As the practicality of the combined method was verified in the validity test, the method has been reflected into Apollon and implemented into real life operations since December 2022.
- The effectiveness of the newly introduced method was verified.

Weather conditions

- From the afternoon of January 24th to 25th in 2023, there was heavy snowfall in Kansai area, causing massive disruptions.
  - The north coast and mountainous areas saw thick snow.
  - Even urban areas saw snowfall.



Conclusion

- We proposed the PV power prediction method considering the effect of snow in Kansai area, which also demonstrated the effectiveness in improving accuracy when implemented into the actual operation.
- If the effect of snow on PV is not considered, the predicted value of PV power generation is likely to be far off from the true value. And, if the effect of snow melting is not considered, it will be impossible to predict the recovery rate of the PV power generation.
- As a forecast technique of solar radiation which takes into account the effect of snow cover, we tested three different methods; the snow depth method, the snow albedo method and the combined method which combines the two.
- We verified the effectiveness of the combined method on a day with heavy snowfall.
- We confirmed the new method improved the accuracy of predictions as RMSE of PV power outputs was reduced by about half compared to the conventional method.

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