Priority Subjects — **Development of a Supply/Demand Infrastructure for Next-Generation Electric Power**

Development of Precise Power Output Estimation and Prediction Techniques of Photovoltaic Power Generation

Background and Objective

Development of precise power output estimation and prediction techniques of photovoltaic power generation (PV) is necessary to suppress the impact of massive PV penetration on a utility power system such as a remarkable increase in reserve margin which is necessary for proper electric supply and demand operation. In order to contribute to cost reduction of utility system operations (such as the supply and demand operation), we are developing real-time estimation methods for the PV power output of not only local areas but also the entire area of the utility system, for the short-term ahead, less than several hours, prediction method of PV power output, long- term ahead prediction method of PV power output and a precise estimation and prediction system integrating the above methods.

Main results

1 Development of real-time solar irradiance prediction methods from geostationary satellite images for PV power output prediction

Reliable prediction of photovoltaic power yields is essential for balancing the supply and demand of electricity and a prediction interval of 1 minute is required for the network management. Geostationary satellite images are a promising data source for the photovoltaic power yield prediction. Although the interval of the data supply is 30 minutes at present, linear interpolation of the images is expected to permit us to predict large areal PV power output with a shorter interval owing to the smoothing effects of high frequency fluctuations of solar irradiance. Thus, spatially averaging 1 minute irradiances obtained by this interpolation were evaluated for one year (2011) in the Kanto district. Root mean square errors were 61.6 W/m^2 (12.9% of the average solar irradiance), which was comparable to those of 30 minutes average. As the forthcoming geostationary satellite has a high specification, the results have indicated the satellite is a promising candidate as a data source of PV power output prediction (Q14012).

2 Development of a method for estimating diffuse solar fraction toward precise PV power output predictions

For accurately estimating PV power output in electric demand and supply operation, a solar irradiance incident to a tilted PV array is to be used. In order to calculate the incident solar irradiance, the fraction of diffuse radiation to global radiation*1 is necessary. Therefore, using a radiative transfer model, we have developed a new method for estimating "cloud optical thickness" and also diffuse solar fraction from observed global solar irradiance. Comparing estimated diffuse solar fractions with observed ones, we obtained temporal variations similar to observations (Fig. 2), which suggests the potential for this method to be used in making precise PV output predictions (V14018).

3 Development of analyzing techniques for solar irradiance data observed at many sites to forecast fluctuation of PV power output

A statistical technique using solar irradiance observed at many sites is one of the promising methods for a short-term, thirty minutes to a few hours, forecast of PV power output fluctuation. However, due to the fact that one set of solar irradiance data is extremely large, data analysis techniques for preprocessing are indispensable to achieving a successful forecast. We have developed two methods; (1) Regression analysis by automatically selecting observation sites and weather data appropriate for the forecast according to their contribution to the forecast, and (2) Prediction of moving time of a large cloud by evaluating relevance among wave-forms of solar irradiance at different observation sites (Fig. 3). We have confirmed that the method (1) can select observation sites and weather data which are effective to the precise forecast. Furthermore, we will use the moving time of a large cloud guessed by the method (2) to improve the forecast (R14019) (R14014).

*1 Sum of the direct solar radiation, which reaches the ground surface directly from the sun, and the diffuse solar radiation, which has been scattered once or more by clouds and/or aerosols.

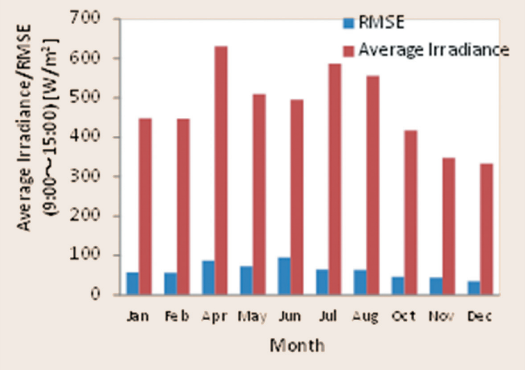

Fig. 1: Monthly errors of solar irradiance predictions from geostationary satellite images

This figure shows root mean square errors (RMSEs) of 1 minute irradiance prediction between 9:00-15:00. As March and September were used for training data of statistical parameters, we did not carry out the evaluation of these months. The resulting annual RMSE was 61.6 W/m^2 (12.9% of the average solar irradiance).

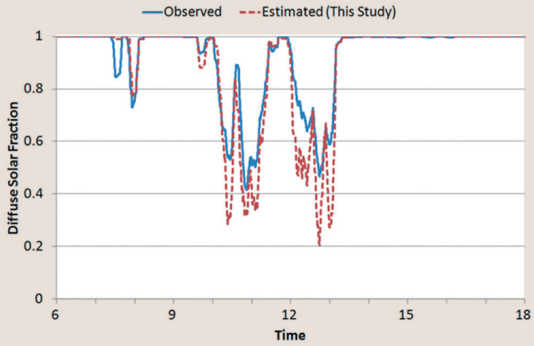

Fig. 2: An example of validating the new method for estimating diffuse solar fraction (in CRIEPI Abiko, Nov. 6, 2014)

Although some empirical methods for estimating diffuse solar fraction already exist, the new proposed method based on a solar radiative transfer model enables more accurate estimations in various atmospheric conditions. Estimated values tend to be somewhat smaller than observed ones when clouds are optically thin, but estimated temporal variation of diffuse solar fraction agrees reasonably well with the observation.

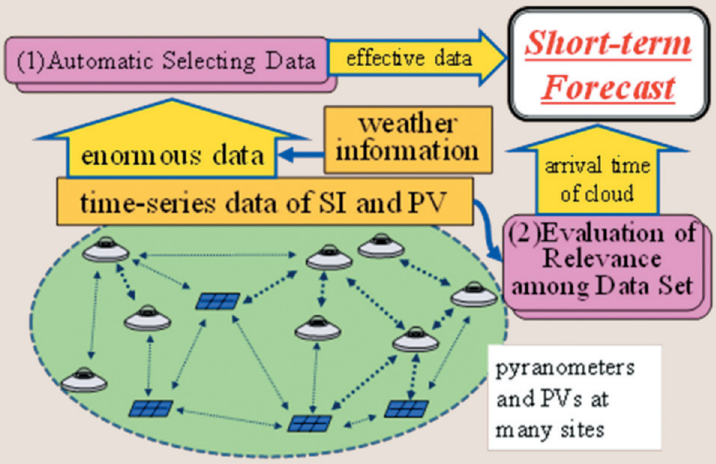

Fig. 3: Outline of Analysis Techniques for Solar Irradiance and PV Data

(1) We have developed a technique to select effective observation sites for forecast of short-term fluctuation of PV power output, as some sites supply noise data to increase the forecast error. The selection is based on the degree of contribution to the forecast. The technique has selected 15 sites from approx. 60 sites. As a result, the forecast accuracy has been better than that using all sites.

(2) We have developed a technique to realize a time-lag of PV power output fluctuation patterns between different sites based on evaluation of the degree of relevance among the patterns, as the time-lag can be regarded as arrival time of a large cloud from one site to another. The technique has demonstrated an appropriate time-lag of PV power output fluctuation pattern measured at 30 sites.