A Physical-Statistical Approach for the Regional Wind Power Forecasting

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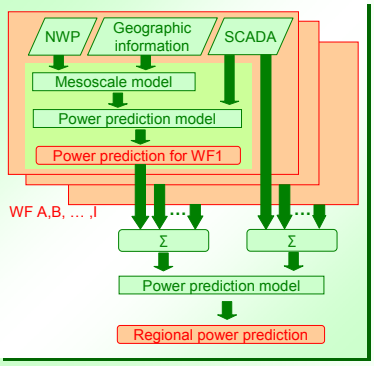
Object

Wind power forecasting has been performed operationally using the numerical weather prediction (NWP) and on-line measurement data in Northern Europe. Japan is a mountainous country and the local wind is strongly affected by complex terrain. Also, extreme weather event such as the typhoon in summer and the lightning in winter is frequently observed resulting in the trouble in the operation of the wind farm. This causes sudden change of the output from the wind farm.

In this study, NWP with fine resolution was performed to account for the effect of the complex terrain. In order to implement the NWP with fine resolution to the on-line system, transfer coefficient method was proposed. A multi-timescale model was developed to catch the sudden change of the output from the wind farm due to the operational trouble. The performance of the proposed method was verified by the measurement data from nine wind farms in northern Japan.

Overview of the Wind Power Forecasting

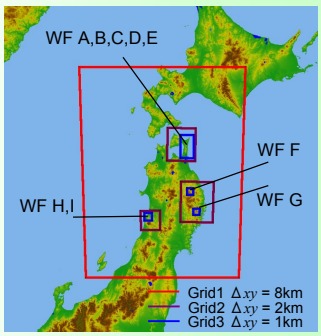
The flow chart of the wind power forecasting



Description of the sites and the input data

Sites	9WF in Tohoku Area. (Total installed capacity 243MW)
NWP data	RSM forecast data from JMA (Japan Meteorological Agency) • Horizontal resolution: 20km • Temporal resolution: 3hours • Forecast horizon: 51hours • Update time: 00UTC, 12UTC
Geographical data	DEM with 50m resolution, landuse data with 100m resolution
SCADA Data	Online 10 minutes averaged power from the nine wind farms.

Wind farms and the computational domains used in this study



Transfer Coefficient Method

In order to implement the numerical weather prediction with fine resolution to the on-line system, the transfer coefficient method was proposed.

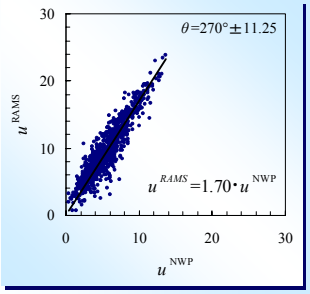
Description of the method

The ratio of the wind speed between the numerical weather prediction with fine resolution and that of the coarse resolution can be considered to be the function of the weather condition such as wind direction etc.

$$u^{fine} = f(\theta, L, \cdots) \times u^{coarse}$$

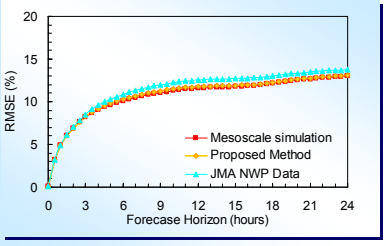
In this study, the ratio is assumed to be the function of only the wind direction of NWP with coarse resolution and estimated in advance from one year simulation by mesoscale model. Once this ratio is determined, the wind speed with fine resolution can be calculated by multiplying the ratio.

$$u^{fine} = f(\theta) \times u^{coarse}$$



wind speed ratio for the westerly wind

The prediction error of the proposed method

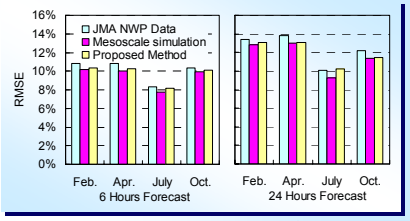


- The prediction error by mesoscale model is smaller than that by the JMA-RSM model with 20km resolution.
- The prediction error by transfer coefficient method is almost equal to that by mesoscale model.

root mean square error of the predicted power for the Tohoku area in Oct. 2006

The seasonal variation of the prediction error

- Mesoscale simulation requires 3-4 hours with the parallel computer with 8 CPUs
- On the other hand, the proposed method takes only a few seconds with 1 PC.
- The accuracy of the forecast is almost same for most of the seasons.



seasonal variation of the prediction error in Tohoku area in 2006

Multi-timescale Model

In order to account for the sudden change of the output from the wind farm due to the operational trouble, multi-timescale model was developed

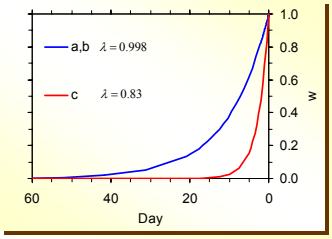
Description of the model

In addition to the conventional ARX model, which is adopted by an operational model WPPT, a new parameter c to account for the operational condition of the wind farm was introduced to the estimation of the power from wind speed.

$$P^{pred}_{t+k|t} = c_t \times f(u^{pred}_{t+k|t}) \qquad P^{pred}_{t+k|t} = a(k) P^{meas}_{t} + b(k) P^{pred}_{t+k|t}$$

c takes the value between 0 and 1 and estimated by minimizing the square of the weighted prediction error.

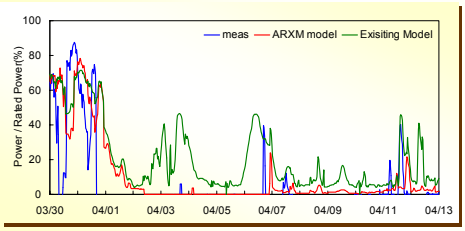
$$c_t = \arg\min_{c} \sum_{s=1}^{t} \left[\lambda^{t-s} \left(c \times f(u^{pred}_{s}) - P^{meas}_{s} \right) \right]^2$$



the forgetting factor and the weight of the error

Since the change in the operational condition has smaller time scale than the other adaptive parameters, a smaller forgetting factor λ was used for the estimation of c. The proposed method is named ARXM (Auto-Regressive with eXogenous input and Multi-timescale parameter) model.

The time series of the predicted power



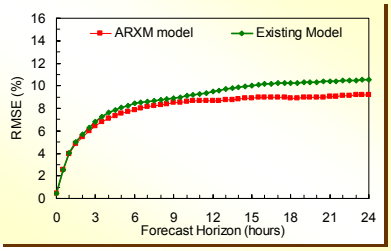
- The proposed ARXM model can simulate the decrease of the power due to the operational trouble.

the time series of the output from WF E from 30/3/2006 to 13/4/2007

The prediction error of the proposed method

- As a result, the prediction error was reduced for almost all the forecast horizon.
- In July, 2006, the prediction error for 24 hours ahead forecast was reduced from 10.5% to 9.2%

root mean square error of the predicted power for the Tohoku area in July 2006



Conclusions

In this study, transfer coefficient method was proposed for the online implementation of the mesoscale mode and multi-timescale model was proposed to take the effect of operational trouble of the wind farm into account. Following results were obtained.

- The prediction error of the power by the model based on mesoscale model is smaller than the model based on the JMA-RSM data with 20km resolution.
- The proposed transfer coefficient method takes only a few seconds with 1 PC and the accuracy of the forecast is almost same, while mesoscale simulation requires 3-4 hours with the parallel computer with 8 CPU.
- Proposed ARXM model can take the effect of operational condition into account, and as the result, the annual root mean square error was reduced.

Acknowledgements

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