ANALYSIS FOR EXTENSIVE INTEGRATION OF VARIABLE RENWABLES WITH DYNAMIC MULTIREGIONAL OPTIMAL POWER GENERATION MIX MODEL

Ryoichi Komiyama, Associate Professor, University of Tokyo, +81-3-5841-8970, komiyama@n.t.u-tokyo.ac.jp
Yasumasa Fujii, Professor, University of Tokyo, +81-3-5841-0249, fujii@n.t.u-tokyo.ac.jp

Overview

After the Fukushima nuclear accident, nuclear policy formulation has become complicated in Japan, and alternatively, variable renewable energy, such as wind and photovoltaic (PV), is significantly highlighted for resolving climate change and energy security issues. This paper attempts to investigates the extensive integration of variable renewables into Japan's long-term power generation mix using dynamic multiregional optimal power generation mix model which is upgraded from the authors' previously developed model [1] formulated as a large-scale linear programming model with a single period and a single region. The feature of the model allows us to explicitly consider actual wind and PV output variability in 10 minutes resolution and to analyse the impact of those significant variabilities on the optimal dispatch of power plants. In addition, the developed model takes into account power interchange through tie lines among nine regions in Japan, which is expected to ensure sufficient flexible power sources in all the country for controlling the variabilities of wind and PV.

Methods

The authors try to develop a dynamic multiregional optimal power generation mix model in 10-min resolution under various technical constraints employing linear programming technique based on the authors' previous work [1][2][3]. The minimization of the multi-period objective function, comprised of facility and fuel cost in respective power service area of Japan at each year, enables us to identify the best mix for power generation and capacity of the country's power plants. In this paper, Japan is disaggregated into nine regions and the power interchanges through tie lines among the regions are considered. The developed model is easily applicable to other country by replacing exogenous variables. Regional wind and PV output are estimated at 10-min resolution using a detailed meteorological database called AMeDAS [4] in Japan. Fig.1, Fig.2, Fig.3 and Fig.4 show the weekly and yearly output profile of wind in Tohoku and PV in Kanto area of Japan respectively.

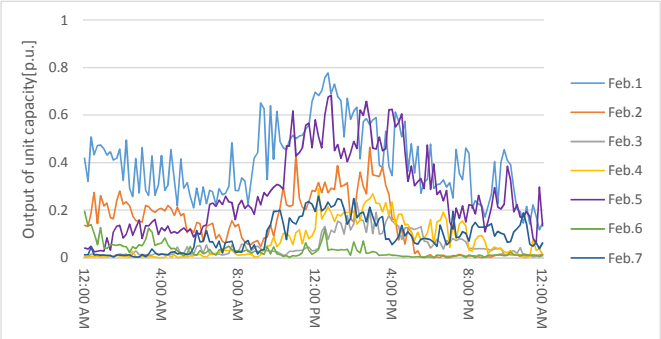

Fig.1 Weekly wind profile in Tohoku area of Japan on 10-min.

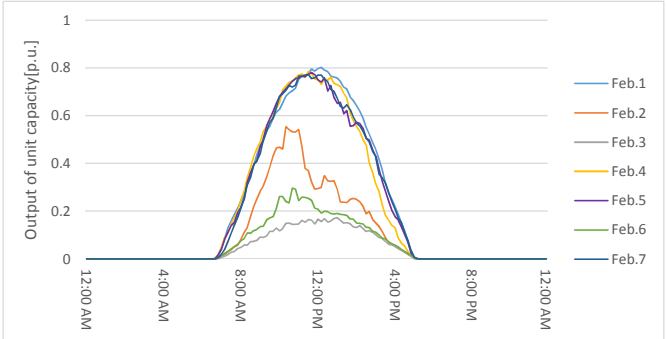

Fig.2 Weekly PV profile in Kanto area of Japan on 10-min.

Results

As a preliminary analysis so far [3], it turns out that tie line expansions encourage the installation of variable renewables extensively in the region where the higher usage ratio (capacity factor) of the variable renewables, mainly provided by better climate conditions, could be expected. For example in Japan, the expansion of regional tie line capacity makes PV installation concentrated in the Kyushu and Shikoku regions, which have better conditions of solar insolation in Japan, and promotes the transmission of this PV power from the both regions to other regions, and eventually saves the country's toal installed PV capacity.

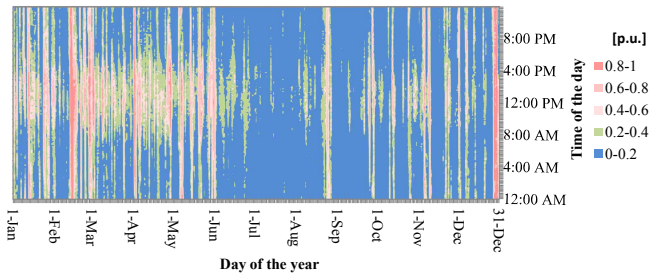

Fig.3 Yearly wind profile in Tohoku area of Japan on 10-min.

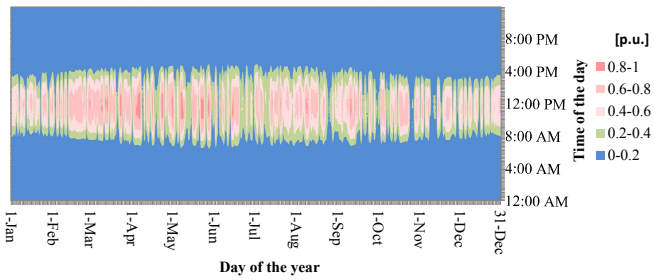

Fig.4 Yearly PV profile in Kanto area of Japan on 10-min.

Conclusions

Extensive integration of variable renewables is a great technical challenge due to its uncertain variable output. This paper develops a dynamic multiregional optimal power generation mix model in 10-min resolution which is capable of analyzing the integration of extensive variable renewables into electricity system in the long-term perspective. For policy maker, this model is expected to support the efficient decision-making for a adequate integration of variable renewable and could provide elaborate insight for the intensive grid management for controlling the surplus output and variability of wind and PV. Future agenda consists in considering the power network topology such as the network structure of high-voltage power transmission line and refining ramp-up behavior of thermal power plants.

References

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