Generation Scheduling for Supply and Demand Balancing in Power Systems with Renewable Power Generation

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論　文　内　容　の　要　旨

The installation of renewable power generation makes a good effort on reducing the emission of greenhouse gas. However, the outputs of some renewable generations are highly affected by nature condition, which contains the fluctuation and uncertainties. The conventional methods for dealing with the uncertainties of forecasts are to make the extra spinning reserves for controllable generators to fix the possible variation of power demand. However, in the case of high penetration of renewable power generation, the spinning reserves cannot always get ready for the variation of demand, and then the imbalance of power supply-demand happens more often. The supply-demand balance issue becomes more complicated. Therefore, this thesis aims to keep the supply and demand balance in power systems with renewable power generation, photovoltaic generations in particular. For this purpose, three issues are investigated in this thesis: the solar insolation prediction, the error estimation of solar insolation forecasts, and the economically optimal generation scheduling of controllable generators which are discussed in three chapters respectively.

First, this thesis improves the wavelet-based solar insolation prediction method which is one of the good prediction methods proposed so far. The prediction of renewable generation outputs is essential to schedule the controllable generators, so the prediction of solar insolation, which is the most important parameter to predict the outputs of photovoltaic generations, is addressed in this thesis. Given that some variables are well relevant in some time-frequency domains of solar insolation but are weakly relevant in other domains, we only use the well relevant time-frequency components of a certain input variable instead of its all time-frequency components to predict the value of solar insolation. The results of a comparison indicate that the proposed method is more accurate than the method which uses the same input variables in all time-frequency domains. Therefore, selecting relevant input variables in different time-frequency domains independently is helpful to improve the accuracy of wavelet-based prediction method.

Second, this thesis puts forward the error estimation method, which can extract more useful information about the solar insolation from the input variables employed in the solar insolation prediction to complete the forecast results of solar insolation. The errors of solar insolation forecasts are unavoidable, and some of them are extremely big. However, no relevant researches have focused on estimating the errors yet. Given that some big errors concentrate in a certain interval of a variable, we extract the significant variables and areas to tell the big errors (positive and negative). The proposed error estimation method can provide the operators with what types of

error the forecast is likely to have with high confidence. Since the big errors cause either large over expectation or large under expectation of PV outputs, the results of error estimation are useful for operators to identify the extreme situations which cause the large deviation of power.

Finally, this thesis proposes a useful strategy to deal with the uncertainties of forecasts of renewable generation outputs, which can achieve the economically optimal generation schedule with the less total cost compared with the conventional methods, which use the spinning reserves to prevent the possible imbalance incurred by the uncertainties of forecasts. The conventional methods minimize the operation cost with a constraint to guarantee that the operating generators can readily change their outputs to meet the net load demand variation. High penetration of renewable power generation makes it harder for operating generators to compensate the variation of forecasts. The events of supply-demand imbalance happen more often, and the shortage or excess of electric power should be compensated from the outside power systems. Therefore, in this research, the damage caused by possible supply-demand imbalance arising from the large uncertainties of forecasts of renewable generation outputs are evaluated by penalty which represents the necessarily additional cost to fix the imbalance. Due to the random nature of the forecast errors, the penalty is evaluated as an expectation. The optimal generation schedule is obtained by minimizing the summation of expectation of penalty and the operation cost. The proposal is validated by the simulation results.

論 文 審 査 の 結 果 の 要 旨

本論文は，再生可能エネルギー電源を含む電力系統において，再生可能エネルギー電源出力が持つ不確実性に対処して，経済的に需給一致を達成することができる発電計画の立案手法を，これに必要な日射量予測手法も含めて提案したものである．この成果は，電力供給の質を損なうことなく再生可能エネルギー電源の導入を促進することに貢献するものであり，電気電子工学上価値ある業績であると認める．