EFFECT OF INTRODUCING BATTERIES INTO THE GRID ON GENERATION COSTS AND CO2 EMISSIONS CONSIDERING WIND POWER UNCERTAINTY

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Overview

As the issue of global warming increases in severity, the introduction of renewable resources has become a global challenge. However, the large scale integration of intermittent renewable resources like wind power generation into the grid presents major challenges in power system planning and operation of power plants because their time-varying nature. This time-varying nature causes inefficient operations of other power generation which increase generation costs and CO_2 emissions. For example, requiring much reserve to power system in order to address the unpredictable fluctuation of wind power results in the parallel operation of thermal power plants at low load. Therefore, in order to address this issue, the behavior of power plants and effectiveness of the way of dealing with the unpredictable fluctuation of wind power generation, e.g. adding batteries, should be numerically analyzed with consideration of wind power uncertainty and plural operational states of thermal power plants.

Methods

The descriptions of the model developed are as follows;

- This model is calculated by a linear programing (LP). The objective function is to minimize the expected value of generation costs to adopt Monte Carlo simulation approach and the constraint equation represents various constraints of the power system operation.
- This model simulates the grid of Tohoku region in Japan for one year. Namely, the data used in this model, such as power plant capacity, power demand or the output of wind power generation, are actual data.
- In order to take into account the uncertainty of wind power generation we regarded short fluctuations of wind power output as stationary random process and then generated 100 patterns of the output of wind power generation according to the stationary random process which is modelled by ARMA model approach. In this research we considered fluctuations of wind power output under 24 hour on frequency domain as the stationary random process. Optimal solution of this model is optimal power planning which can generate power under the situation of all that patterns and which minimize expected value of generation costs.
- We considered operational states of power plants: ELD operation, LFC operation, banking, hot start, cold start and stop.

Results

First, if we look at Table 1 we can see numerical results of the effect of wind power uncertainty on both generation costs and CO_2 emissions. The yearly generation costs of thermal power generation and CO_2 emissions with consideration of wind power uncertainty increase by 2.3% and by 6.4% respectively as the case without consideration of wind power uncertainty.

Table 1 Effect of wind power uncertainty on both generation costs and CO_2 emissions.

	With consideration of wind power uncertainty	Without consideration of wind power uncertainty
Generation costs for one year [million USD]	563.07	550.33
CO2 emission for one year [Mt-CO2]	35.72	33.61

Next, Fig. 1 shows generation cost reduction by introducing batteries. It indicates that the conventional methods which do not consider wind power uncertainty underestimates the generation cost reduction. The reason why the conventional methods underestimate the effect of introducing batteries is that it does not take into account operational states of thermal power plants and the wind power uncertainty which batteries can deal with.

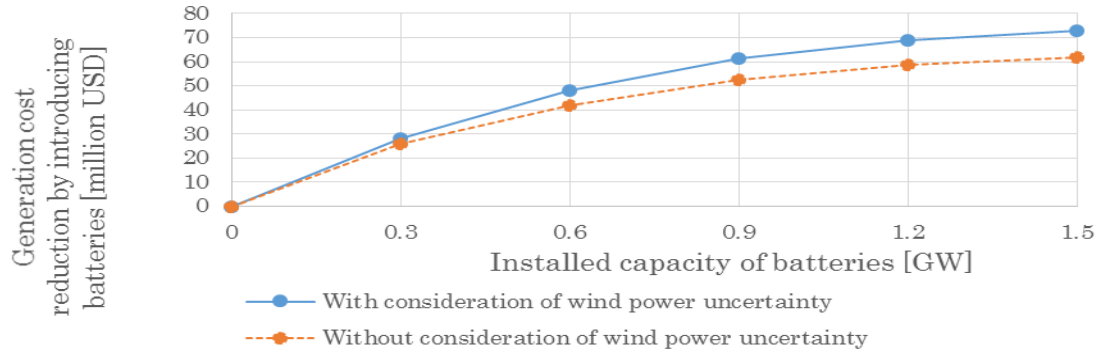

Fig. 1. Generation costs reduction by introducing batteries.

Finally, we newly see from Fig. 2 that introducing batteries can contribute to CO_2 emission reduction if we consider wind power uncertainty. The CO_2 emissions will increase without consideration of wind power uncertainty because the output of coal-fired power generation which generates low-cost electricity with high CO_2 emissions increases by operation of batteries because the model is to minimize the generation costs. However, batteries can also mitigate the effect of wind power uncertainty and improve deterioration of generation efficiency by partial load operation. In consequence, this results show that the effect of mitigating wind power uncertainty exceed the effect of increasing the output of coal-fired power generation in this case studies.

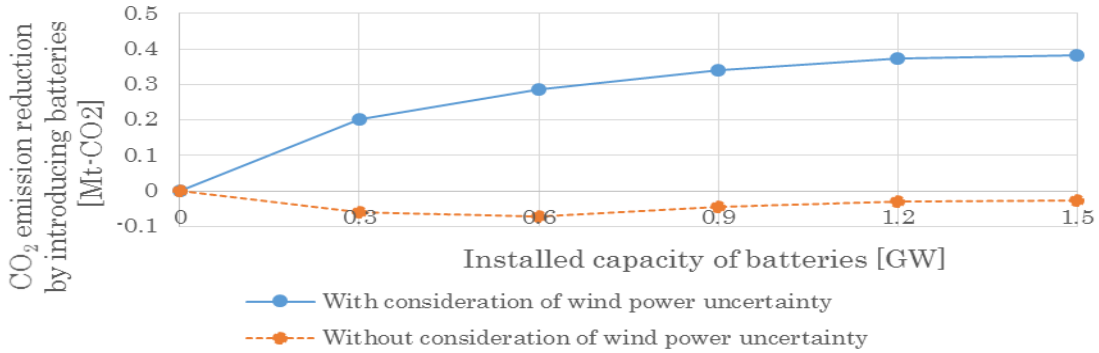

Fig. 2. CO_2 emission reduction by introducing batteries.

Conclusions

In this paper, we present optimal power planning model using Monte Carlo simulation approach we developed to analyze the behavior of power system and the effect of introducing batteries into power system with consideration of wind power uncertainty and plural operational states under the situation of large-scale wind power installation. Unlike conventional approaches, our approach can easily describe the stochastic nature of wind power fluctuation by ARMA model and the behavior of thermal power plants which can be affected by wind power uncertainty. As a result, the model presented reveled the parallel operation of GCC caused by wind power uncertainty which cannot be seen in the conventional model. Moreover, numerical results of our study clearly show that batteries can decrease both generation costs and CO_2 emissions by mitigating the effect of wind power uncertainty. While we assume the battery which is utilized for load levelling and mitigating wind power uncertainty, another use of battery such as load frequency control should be considered and optimized in the future work.