Trunk Power System Planning and Operation Under Large Penetration of Intermittent Generations

Background and Objective

The expected large penetration of renewable generations, especially photovoltaic generations in the future may cause deterioration in quality of voltage and frequency. Therefore, a more sophisticated operation and control scheme, which harmonizes the operations of trunk transmission system and distribution systems, is necessary to maintain power quality, while utilizing the large number of intermittent generations. As one of steps to develop such a new scheme, demonstration projects are in progress, where renewable generations are installed in power systems on small islands to assess their impact on power quality and to develop suitable control schemes for such power systems.

In this project, we focused on the operation of trunk power system to efficiently maintain power quality under the large penetration of renewable generations by a harmonization with operation of autonomous demand area power systems. Currently we develop assessment tools for trunk power system planning and operation, which explicitly consider renewable generations, to identify the impact of large penetration of intermittent generations on power quality.

Main results

1. Development of assessment tools of power balancing in trunk power systems

(1) Development of a generation adequacy assessment tool

A reliability assessment tool has been developed, which explicitly considers the probabilistic characteristics of intermittent generations output to assess generation adequacy under a large penetration of renewable generations (Fig. 1). The developed tool can assess generation adequacy under heavy load condition and generation surplus under light load condition, taking hourly probabilistic distributions of PV generation output into account.

(2) Development of a power balancing assessment tool

An assessment tool for generation operation has been developed, which considers day-ahead generation planning and hourly PV generation output scenarios (Fig. 2). The output of renewable generations may considerably differ from its day-ahead forecast and this difference may have a large impact on generation reserve requirement and operation of generations supplying reserve power. The developed tool can assess such an impact quantitatively (Fig. 3).

2. Development of a simulation tool of supply-demand control of small island power systems

A simulation tool of supply-demand control of small island power systems has been developed. The developed tool can simulate the behavior of PV generations, wind power generations and battery storage systems as well as diesel and gas turbine generation systems, which are usually installed in small island power systems (Fig. 4(a)). The tool can analyze how fluctuation of demand and PV systems output influence frequency deviations, taking both long-term (e.g. hourly) fluctuation and short-term fluctuation into account. One of the useful applications of the developed tool is the study of control schemes of battery storage systems to suppress frequency fluctuations (Fig. 4(b)).

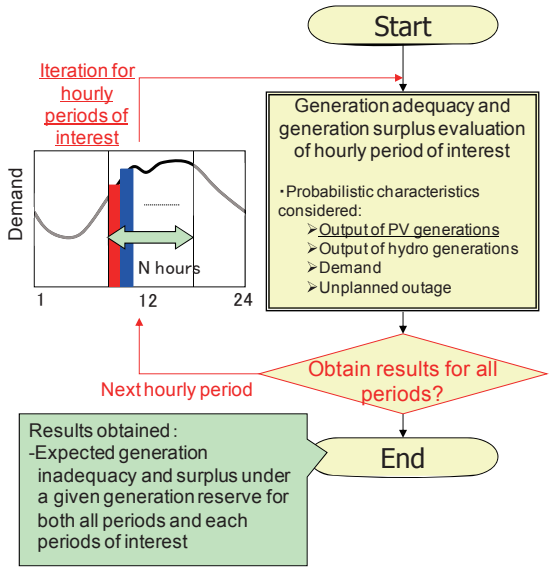


Fig.1 Flowchart of the developed generation adequacy assessment tool

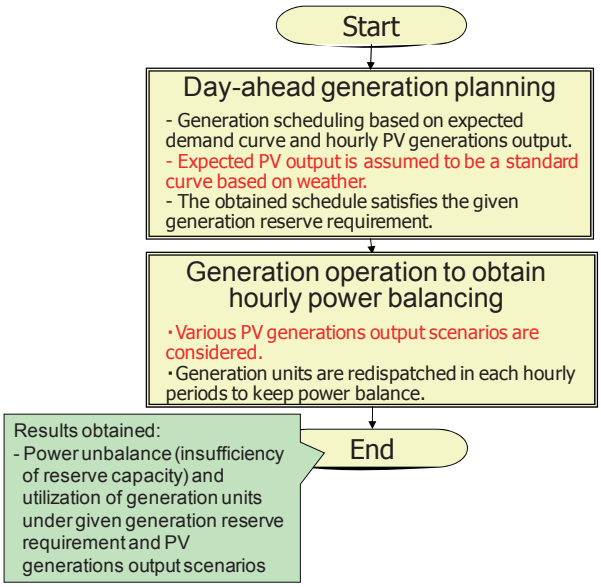
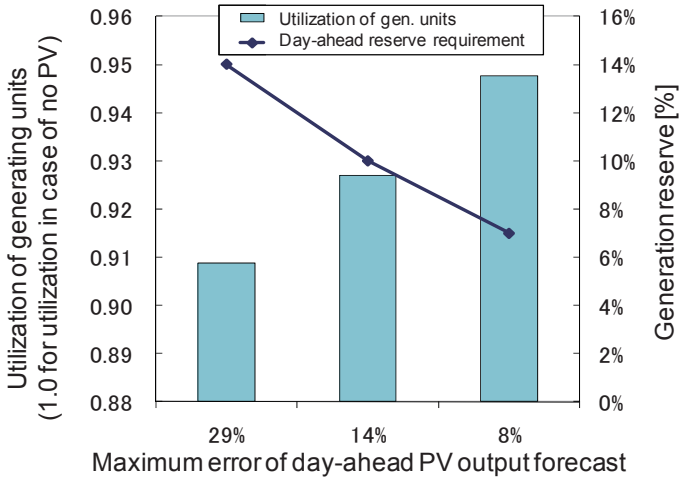


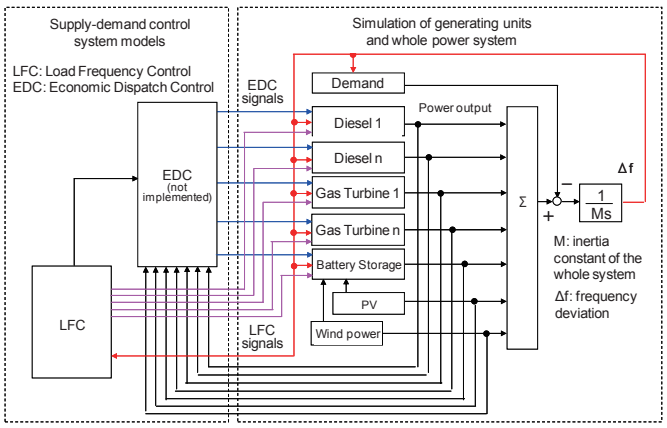
Fig. 2 Flowchart of the developed power balancing assessment tool



＜Assumptions＞
・50GW PV capacity
・Off-peak day (Sunday in May)
・3% generation reserve should be kept In operation.
・Power balancing is obtained by regulating output of thermal units.

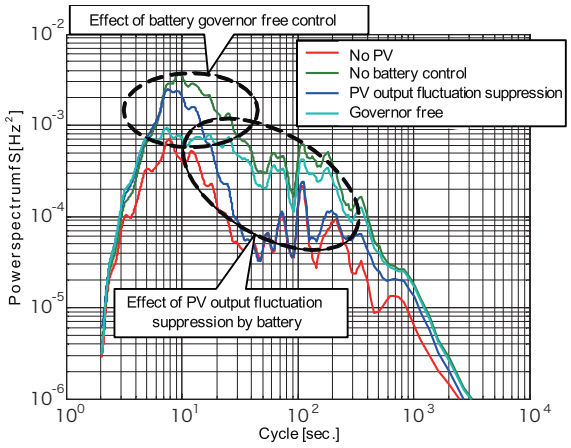
Improvement of PV output forecast error leads to:
(1) reduction of day-ahead reserve requirement
(2) higher utilization of generating units

Fig. 3 Impact of day-ahead PV output forecast error on generation reserve requirement and operation of generations supplying reserve power



(a) Main components of the developed simulation tool

The tool can simulate behaviors of PV generations, wind power generations and battery storage systems as well as diesel and gas turbine generation systems.



(b) Effect of battery storage systems control on frequency fluctuation

The tool can evaluate the effects of various control schemes to suppress frequency fluctuations.

Fig. 4 Developed simulation tool of supply-demand control of small island power systems