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OPERATIONAL PLANNING METHOD AND ECONOMIC ANALYSIS OF MICROGRID WITH INTERMITTENT RENEWABLE ENERGY AND BATTERY STORAGE

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Introduction

The electrical power industry worldwide is increasing non-conventional renewable sources of energy to generate electricity to reduce environmental load. The total amount of installed capacity of wind power and photovoltaic (PV) in Japan is approximately 1.2 GW as of the end of 2005, and 1.1GW as of the end of March 2005. The targets for wind power and PV in 2010 are 3 GW and 4.8 GW, respectively. The fluctuating power of these renewable energy sources, however, might degrade power quality such as voltage and frequency. To achieve large penetration goal of renewable sources, one solution is to take a system approach that views distributed generation (DG) and associated load as a subsystem or a microgrid. Microgrids can be connected to the main power network or be operated islanded, and switched seamlessly. Benefits of microgrids include energy efficiency, environmental impact and improved service quality. Here, a microgrid is proposed that utilizes controllable prime movers such as gas engine-powered CHP (combined heat & power) to compensate fluctuating demand and output of renewable energy sources. The battery capacity can be reduced if a gas engine can follow to the output change of renewable energy and the load change to some degree. A gas engine can use wood biomass and biogas from sewage disposal plants as well as city gas. These renewable technologies are expected to reduce imported fuel and activate local economy.

Methods

(1) Analysis of PV output and building load fluctuations

Market for PV is growing fast in Japan, and a lot of PV systems may be installed intensively in residential areas. It will be difficult to control distribution voltage in regulated range when significant capacity of PV is interconnected to the grid. To reduce these negative impact of PV output fluctuations on voltage of distribution lines, it is necessary to coordinate with battery storage and/or controllable DG. We here analyze characteristics of PV output fluctuations and show the necessary capacity of inverter in a battery storage system.

(2) Optimal economic operational planning

We formulate a problem to minimize a cost to supply electricity to load in a microgrid. Cost variations by scale of PV and capacity and the efficiency of a battery will suggest appropriate design of microgrid.

Results

(1) Inverter capacity based on PV output fluctuation analysis

In order to separate the measured load data into the load that the gas engine can follow and the load change that corresponds with the battery, we calculated maximum width of load fluctuation. The fluctuation width is expected to be depended on the insolation condition of every day. The fluctuation width when the time window frame (N second) is set in arbitrary time is examined, and the maximum width is plotted in that over $0.1< N<50$(s) shown in Fig. 1. This figure suggests 50 to 60 kW of inverter capacity of battery to compensate PV output fluctuation.

(2) Load fluctuation analysis and load following capability of gas engine

We divided measured load (sampled in 100 msec) into load followed by gas engine-CHP and residual load supplied by battery, based on load fluctuation analysis. Fig.2 shows an example of maximum width of load fluctuation in November 2005. Three straight lines in Fig.2 show load following capability of 350 kW of gas engine-CHP. The area at the left of the intersection of Fig.2 cannot be followed by gas engine. Output change speed (a dashed line in Fig.2) that a gas engine can follow is approximately 2%kW/s. Green line shows the most responsive engine (ramp rate is 7 kW/sec). A change in the left side of this line should be supported by battery storage in islanded operation or purchased power from the utility grid in interconnected operation.

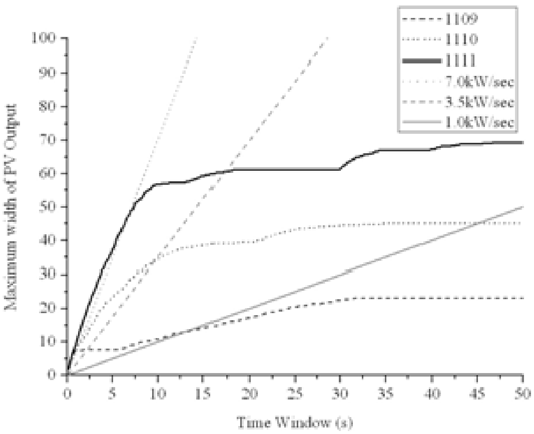

Fig.1. Maximum width of PV output(100kW)

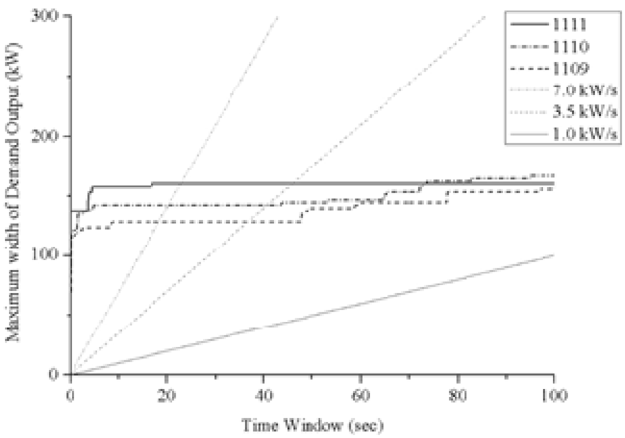

Fig.2. Maximum width of load fluctuation: office building with 700 kW peak demand

(3) Impact of PV output fluctuations on operational schedule of gas engines

The operation plan of the system that consists of PV and gas-engine CHP is obtained by operation cost minimization here for a building complex consisting of an office building and apartment buildings. We compare operation schedule of gas engines in three cases of PV capacity; 100 kW, 200 kW, and 300kW. Fig.3 shows the optimal supply operation schedule in case of 300 kW PV. Three engine CHP supplies electricity and thermal demand to minimize costs and battery storage helps balancing of demand and supply. The incremental cost reduction rate is 2.8% from 100 kW PV to 200 kW PV. On the other hand, the incremental cost reduction rate is 1.4% from 200 kW PV to 300 kW PV. This cost includes demand charge of electricity and city gas.

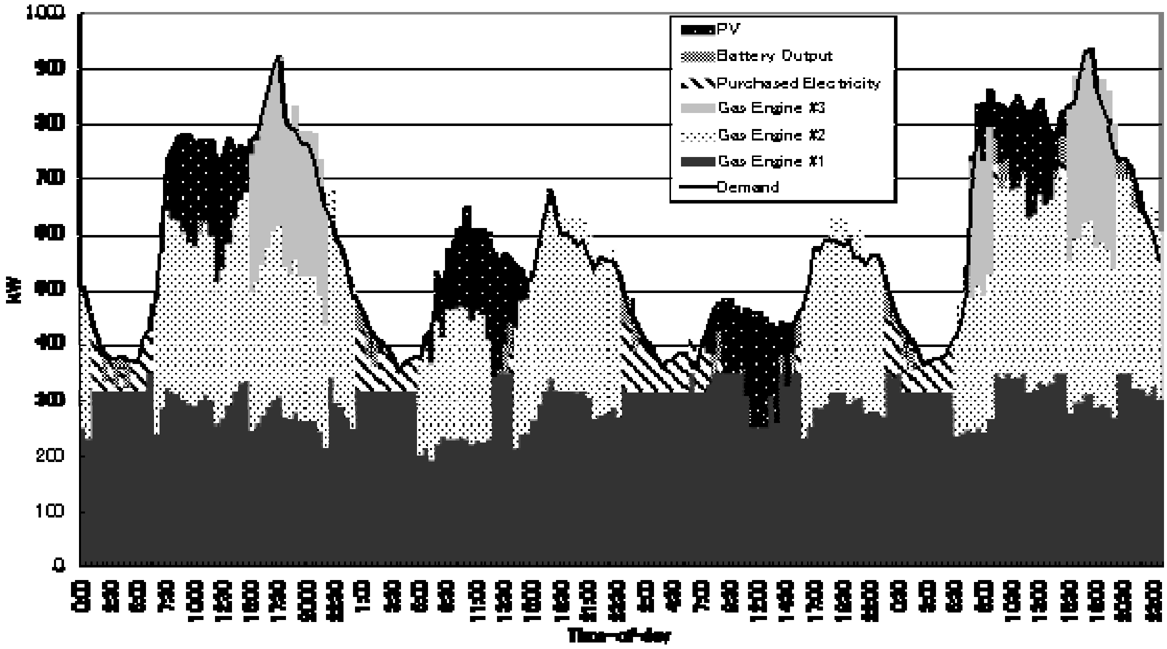

Fig.3 Optimal electricity supply based on 30-minute demand data: Friday to Monday, 300kW of PV case

Concluding Remarks

We conduct economic analyses of the microgrid which can support the introduction of intermittent renewable energy. The use of renewable energy is expected as means to supply energy in emergency such as disasters, in particular, at public facilities. The central government and local governments are actively demonstrating regional power grids with renewable energy and battery storage in Japan.