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A study on planning for interconnected renewable energy facilities in Hokkaido, Japan

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HIGHLIGHTS

- Stabilizing power distribution by linking renewable energy facilities was investigated.
- Algorithm for interconnection of renewable energy over a large area was developed.
- Optimum layout and capacity of distributed renewable energy were clarified.
- Power linking and supplementing renewable energy over a large area were examined.

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ABSTRACT

In this paper, to optimize the kind and capacity of renewable energy installed in each area, an optimization program was developed using a simple genetic algorithm (GA). In the proposed algorithm, the kind and capacity of renewable energy was expressed using a chromosome model. The most efficient and economical system could be identified by applying the model in a random computer search. A case study was developed to test the proposed algorithm. In the case study, a solar power station was installed near 14 cities in Hokkaido, Japan, and a wind power station was installed seven areas. Using the algorithm, the system planning requirements for the interconnection of these renewable energy facilities over a large area were optimized. On the basis of these results, the kind and capacity of renewable energy considered to be the most economically advantageous to the region were identified and evaluated. Using the proposed optimization algorithm for planning and design, an efficient, economical, and interconnected system of electrical power could be realized from renewable energy over a large area.

1. Introduction

To expand controls on the discharge of greenhouse gases and the use of safe power sources, it is necessary to encourage the interconnection of a large quantity of renewable energy in commercial electric power networks. However, the cost of equipment for backup power supply and energy storage for stabilizing fluctuations in power output is a vital concern in the renewable energy industry. Many studies have reported on techniques for controlling and stabilizing power fluctuations in renewable energy [1–9] along with methods for backup power supply [10–15]. Furthermore, new technologies for optimizing energy management and operational planning [16–19], and microgrid based on extensive introduction of renewable energy [20–22] have also been investigated. In general, a change in the power output of several minutes or less is defined as a cyclic fluctuation, e.g., a change in weather. A change in power output from several minutes to about 20 min is defined as a fringe fluctuation, e.g., a change in the relative position of the sun. Finally, a change in power output exceeding 20 min is defined as a sustained fluctuation, e.g., seasonal changes in weather patterns that affect the output of solar or wind energy facilities. In the case of wind power, a cyclic fluctuation may be a change in wind speed, a fringe fluctuation may include changes in wind direction from morning to evening, and a sustained fluctuation may include seasonal changes in the direction and speed of prevailing winds [23–28].

When solar and wind power generation facilities are interconnected over a large area, fluctuations in the power output of one facility may be offset by the sustained output of another [29,30]. For example, when two or more solar power stations that are located several kilometers apart are interconnected, the cyclic

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fluctuation of each power station can be smoothed [29]. Moreover, when wind power stations located in areas with different wind speed characteristics are interconnected, fringe and cyclic fluctuations can be smoothed [30]. Therefore, when solar and wind power stations are installed in a large area and interconnected at a suitable rate, a wide range of potential power fluctuations (cyclic to sustained) can be smoothed. Moreover, when power output is smoothed by interconnecting renewable energy facilities over a large area, the cost to stabilize the supply of electricity can decrease significantly. However, to achieve this goal, it is necessary to clarify the type and rated capacity of the renewable energy facilities. Therefore, the objective of this study was to develop a computer algorithm that identifies the most economically advantageous power source when solar and wind power stations are interconnected over a large area. In the proposed genetic algorithm (GA), many power sources with nonlinear characteristics and variables can be managed [31–34]. The GA offers a method of conducting random computerized searches with high efficiency. It can identify solutions for optimizing power output in which industrial applications are possible. When the algorithm optimizes the configuration of renewable energy facilities based on economical efficiency, it reflects the characteristics of climatic conditions and demand for electricity in each area. As a result, the findings of this study can contribute toward the planning and designing of renewable energy power generating systems that are interconnected over large areas.

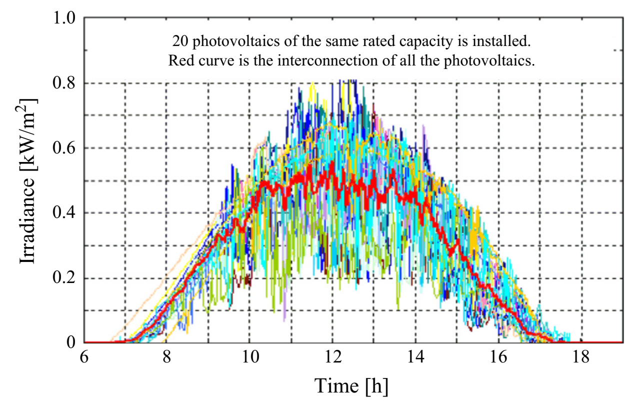

Fig. 2. The amount of global solar radiation received by 20 global solar radiation meters [29].

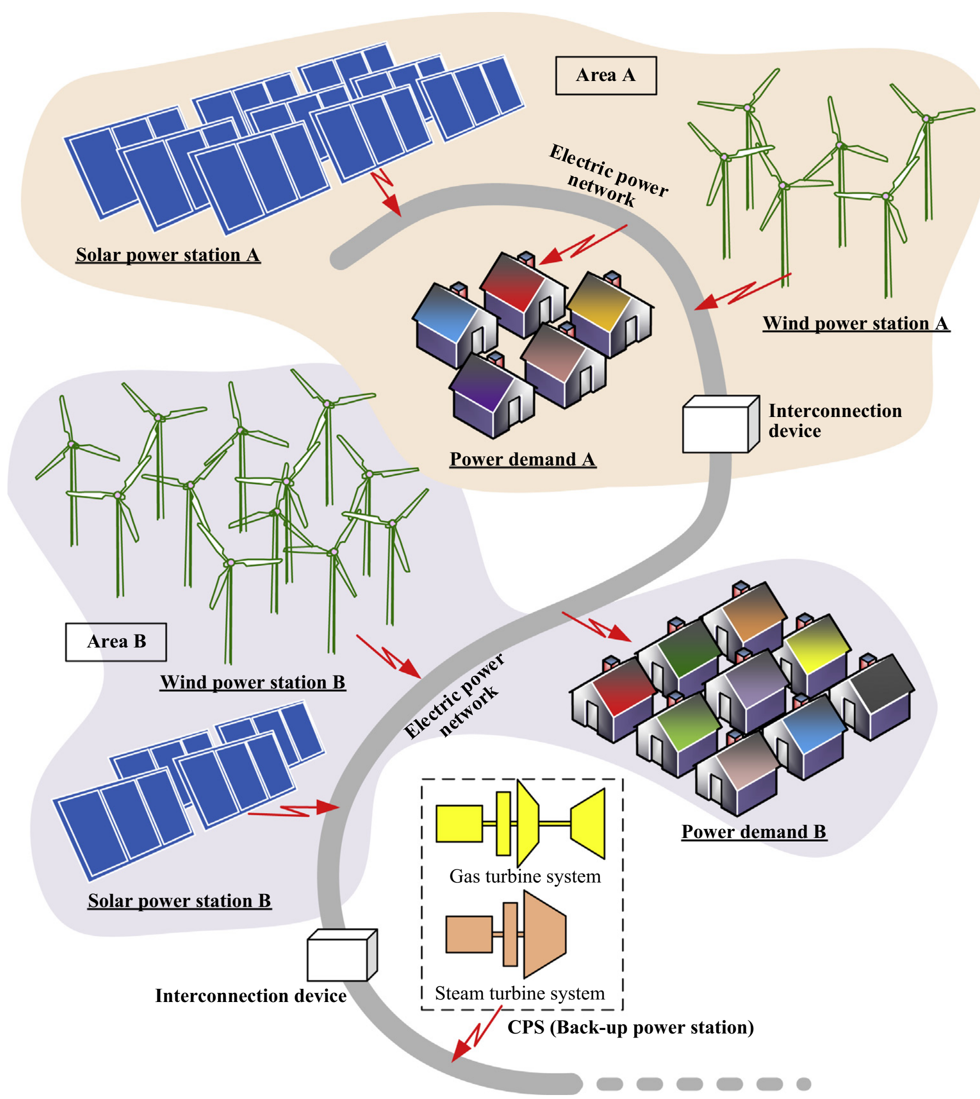

Fig. 1. The proposed power supply network for the interconnection of renewable energy facilities over a large geographical area.