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Solutions for optimizing renewable power generation systems at Kyung-Hee University's Global Campus, South Korea ☆

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ABSTRACT

Owing to the heavy fossil fuel dependence of South Korean energy-supply systems, the South Korean government has advised educational facilities, including universities, which have high electricity consumption, to use more renewable energy facilities. The present study uses the HOMER software to explore possible solutions for providing various energy resources among diesel generator, solar energy, wind energy, batteries, and the grid system to satisfy the load demand at Kyung-Hee University's Global Campus. The renewable fraction, cost of energy (COE), and total net present cost (NPC) of various scenarios for renewable power generation systems are calculated. The simulation results indicate that the suggested systems achieve a COE value in the range from $0.509 to $0.515 (on-grid) and from $0.525 to $0.531 (off-grid). Recommendations and limitations are discussed.

Contents

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1. Introduction

With the increased interest in using renewable energy sources and systems to address depleting fossil fuels and rising greenhouse gas emissions, developed countries, such as the US, Japan, and Europe, have executed government-driven policies for the distribution and development of renewable and alternative energy systems [23,35]. South Korea, with few natural resources and facing some difficulties owing to its high energy dependency on foreign nations, has spurred the development of renewable and alternative energy systems in order to retain energy security and supply reliable energy services [34]. One of the main policies implemented by the South Korean government is the installation of renewable energy facilities in buildings belonging to public and education and research organizations. However, only a few studies have been conducted to investigate the efficient utilization of renewable energy sources.

High energy consumption by universities is considered one of the most important social issues in South Korea. The Korea Energy Management Corporation [25] indicated that universities represent about 13% of the top 100 most energy-consuming organizations in South Korea [33]. In addition, the energy consumption of universities has rapidly increased. An estimated 360,000 t of oil equivalent (TOE) was consumed by all South Korean universities in 2012, compared to 130,058 TOE in 2000 and 240,437 TOE in 2007 [41]. The annual rate of increase in energy consumption in South Korea is 2.83% [16]; thus, the annual rate of increase in energy consumption for South Korean universities (about 8.86%) is over three times the average rate.

The current energy consumption in South Korean universities is mainly distributed between electricity (more than 50%), gas, and fuel. Because most educational facilities and buildings are operated by electricity-oriented products, the dependence on electricity could be intensified in the future [18,33]. Thus, many universities have manifested their desire to reduce the price of electricity for educational services, as is the case for industrial services. However, this appears to be very difficult, according to the management conditions of the Korea Electric Power Corporation, one of South Korea's public enterprises and the company responsible for domestic electricity supply and control [24]. Therefore, establishing sustainable renewable energy facilities is essential for maintaining the competitiveness of universities.

This study explores different possibilities for providing the electricity demand of Kyung-Hee University's Global Campus, one of the biggest campuses in South Korea. This campus is mostly operated using the main electricity grid. Following the introduction of a new set of policies, this campus has consistently attempted to use a renewable power generation system to serve as an alternative to the current grid-electricity system. This study uses the Hybrid Optimization of Multiple Energy Resources (HOMER) model developed by the National Renewable Energy Laboratory, one of the most widely used optimization tools, to explore potential renewable energy configurations using two key parameters: cost of energy (COE) and net present cost (NPC).

2. Review of economic feasibility simulations

Several software tools are consistently used to propose and investigate possible hybrid electricity generation systems for responding to the demand of particular areas [39,9]. Among the tools, HOMER, which was introduced by the National Renewable Energy Laboratory, is used to propose the optimal configurations of renewable electricity generation systems and provide the information general designs, and energy flows of the components in the systems.

Because HOMER can be used to manage various energy sources (fossil fuels, natural resources: solar, hydropower, wind and geothermal heat), technologies (boilers, wind turbines, diesel turbines, photovoltaic and fuel cells), energy loads (thermal, hydrogen loads, and AC–DC) and economic sensitivities (real interest rate, and project lifetime), it is used to propose the possible configuration of renewable electricity generation systems [7].

With these advantages, HOMER has been used in many economic feasibility studies for both developed and developing countries (Table 1). In developed countries, renewable energy generation or advanced technology-oriented energy systems are applied to cope with the energy demand of a particular area. Because the energy demand in developed countries is generally heavy, the simulations in the prior studies were conducted for islands or isolated sites. Moreover, the proposed configurations are used to support the current grid connections.

In developing nations, the simulations are conducted for proposing a stand-alone electricity generation system to provide energy in relatively small villages or locations. Givler and Lilienthal [13] proposed PV/battery and PV/diesel/battery systems with 305 Wh daily load demand for Sri Lanka. The systems achieved COE of $0.85 per kWh. Dorji et al. [11] conducted several options for off-grid electrification in Bhutan. Considering PV–battery or wind–battery systems, alternating the current grid connections were simulated. Himri et al. [15] proposed a wind–diesel hybrid system for a remote village located in Algeria. The system simulated by HOMER achieved COE of $0.114 per kWh when investing total NPC of $2,982,825 with a project lifetime of 25 years. Nfah et al. [31] conducted a simulation on several remote villages in Cameroon. With the simulated hybrid hydropower–diesel generator-battery system, the results achieved COE of 0.296 EURO per kWh with a renewable fraction of 0.821.

However, most of these prior studies focused on remote villages or islands which cannot easily be connected to the grid [15]. Therefore, the main purpose of the studies was to use renewable energy generation facilities for fully covering the energy demand at limited locations. As shown in Table 2, most economic feasible tests have been conducted for independent locations including islands. In the case of South Korea, no research has been conducted to simulate renewable energy generation facilities for responding to and reducing the current energy demand of educational institutes. Therefore, the current study investigates the potential of renewable energy generation facilities at one large university in South Korea.