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Short communication

Towards a Sustainable Island: Independent optimal renewable power generation systems at Gadeokdo Island in South Korea

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ABSTRACT

Because of its high dependence on fossil fuels, the South Korean government has consistently endeavored to use renewable energy sources to operate power generation systems. The South Korean government has advised local communities and governments of the islands to establish independent renewable power generation systems, particularly since the installation, operation, and management of power generation systems to connect the islands to the electricity grids amount to large costs. As such, this study explores potential solutions for establishing independent renewable power generation systems in Gadeokdo Island, one of the largest islands in South Korea, by using the HOMER software. The simulation results show that wind turbines, PV panels, converters, and batteries can be used to operate the power generation systems for Gadeokdo Island. The current study presents an optimal renewable power generation system within the framework of the cost of energy (COE), renewable fraction, and total net present cost (NPC). The system achieves $0.326 per kWh of COE and 1.00 of renewable fraction. Both implications and limitations of the proposed system are discussed.

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1. Introduction

With increasing interest in using alternative energy sources for producing electricity, the majority of developed countries have put in place policies and supporting plans for distributing alternative energy systems (Güler, Akdağ, & Dinçsoy, 2013). Following this global trend, the South Korean government actively supports the renewable energy industry and systems so as to reduce reliance on fossil fuels and increase national energy security (Hong, Bradshaw, & Brook, 2013; Huh & Lee, 2014; Kim, Baek, Park, & Chang, 2014; Park & Ohm, 2014).

As such, the government offers financial assistance for the installation of solar and wind energy facilities when a local autonomous entity and a particular island aim at setting the facilities to become an energy-independent region (Huh & Lee, 2014; Hwang, 2013; Lewis, 2011). For example, Jeju Island, one of the biggest islands in South Korea, has attempted to develop an energy-independent system (Shin et al., 2013). However, because the local government of Jeju Island only aims at distributing and establishing renewable energy systems to lower the financial costs of energy consumption, there are no adequate studies presenting an optimal renewable energy solution for the island.

South Korea is bounded by the Pacific Ocean on the east, west, and south, and includes more than 4000 islands. Therefore, developing independent renewable energy systems for these islands and minimizing the operation and management costs of the electricity grid are two of the most important issues while providing electricity to the islands (Hwang, 2013).

The current study explores potential solutions for independent optimal renewable energy systems for one of the islands in South Korea. The study suggests solutions for *Gadeokdo* Island of Busan Metropolitan City, in the southeastern part of South Korea. This island mostly consumes electricity from the electricity grid connected to the grid system of Busan Metropolitan City. Based on the supporting plans and policies proposed by the South Korean central government, Busan local government has been building renewable power generation facilities to achieve an independent electricity system for the island. The current study employs the Hybrid Optimization of Multiple Energy Resources (HOMER) software introduced by the National Renewable Energy Laboratory, in order to find potential solutions for renewable energy systems and investigates several economic parameters including the net present cost (NPC) and cost of energy (COE).

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Fig. 1. Map showing the geographic location of Gadeokdo Island.

1.1. Location and population

Several prior studies were conducted to propose optimal renewable energy generation systems for islands in South Korea. Park, Yoo, Ohm, and Kwon (2016) proposed the optimal renewable electricity generation system for Geoje Island, one of the largest islands in South Korea. With the combination of wind turbines and photovoltaic (PV) arrays, the suggested system can sell the electricity through the currently used grid connection ($465,945) and achieve $0.472 per kWh COE.

Yoo et al. (2014) attempted to the independent renewable electricity generation system for Ulleungdo island, one of the most eastern islands in South Korea. With two currently operated diesel generators, the system achieved 97.3% of renewable fraction with $0.334 per kWh COE. Moreover, because two diesel generators only produced the 3% amount of total electricity production, the possibility for the independent renewable electricity generation system was introduced.

Chae, Lee, Won, Park and Kim (2015) proposed an inverted remote micro grid system for Gasado Island, one of the western islands in South Korea. The optimal configuration organized by PV arrays, wind turbines, diesel generators and batteries showed 94% of renewable fraction and $1.284 per kWh COE.

Although there are several investigations in South Korea, only few studies were conducted to present economic feasibility tests of renewable electricity generation systems for the southern islands in South Korea. Therefore, the current study aims to present renewable electricity generation systems for Gadeokdo Island, one of the southern islands in South Korea.

2. Status of Gadeokdo Island

2.1. Location and population

Gadeokdo Island is located in Busan Metropolitan city, in the southeastern area of South Korea, with coordinates 35.04 latitude and 128.83 longitude (Fig. 1), and an area of 20.78 km^2. The island has about 1300 households and 3800 residents.

2.2. Load information

The current energy demand of Gadeokdo Island is supplied mainly by the electricity grid. Based on data collected from the Korea Electric Power Corporation, the scaled annual average energy demand for the island is calculated to be 33,954 kWh/d while the peak energy demand is calculated to be 2049 kW. The load factor of this island is computed as 0.691.

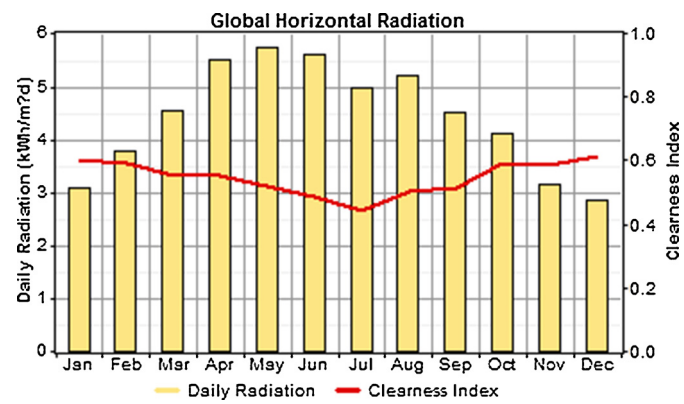

Fig. 2. Average monthly solar radiation and clearness index for Gadeokdo Island.

2.3. Solar energy information

The 2013 data for daily solar radiation and solar clearness collected by the National Aeronautics and Space Administration (NASA) and the Korea Meteorological Administration (KMA) were used. The average annual solar clearness index is computed as 0.531, while the average daily radiation was calculated as 4.422 kWh/m^2/d. Fig. 2 shows the monthly average solar radiation and clearness index.

2.4. Wind energy information

The 2013 data for wind speed collected by the National Renewable Energy Laboratory (2014) were used. The annual average wind speed is calculated to be at 6.175 m/s. Fig. 3 shows the monthly wind speed.

3. Key parameters for the economic analysis

3.1. South Korea's annual real interest rate

The annual real interest rate is one of the most important input variables for a more realistic and accurate economic analysis. Based

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