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Optimal Hybrid Power System Using Renewables and Hydrogen for an Isolated Island in the UK

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Abstract

A distributed electrical power system using renewable generations (RG) on an island was studied. The original system includes micro hydropower stations, wind turbines and solar PVs with a bank of batteries for storage of the extra power from the renewables; and two diesel generators were used as the back-up units. From the analysis of historic electricity generation and consumption data, it was found that the RG alone could not meet the total demand and the diesel generator(s) needed running occasionally in 8 months in one year. In order to make the electric power supply completely from renewables, one novel solution using hydrogen generated from extra renewable electricity to replace diesel as the fuel for the diesel generators was proposed, i.e. a sub-system of renewable hydrogen generation (RHG), which composed of extra wind turbines, a water electrolyser and a hydrogen storage tank, were added to the renewable system. A technical and economic performance evaluation of the RG system was carried out using HOMER software. The results showed that the RHG sub-system produced and stored enough hydrogen for the diesel generator(s) to generate electricity whenever needed. In this way, the power supply on the island will be completely from renewables and zero CO_2 emission without using diesel. The cost of electricity (COE) of the new system was £0.776 per kilowatt hour.

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Keywords: Distributed power system, hybrid, renewable, hydrogen, HOMER

1. Introduction

Due to the public environmental concern to the global warming and climate change, it is requested to reduce carbon dioxide emissions to the atmosphere significantly by reducing the use of fossil fuels. One

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solution is to increase the utilization of renewable energy. For isolated communities where using grid are impossible or uneconomic, distributed power system is an option [1]. These distributed systems in the past have mostly been designed and powered by diesel engine generators as they are widely available and reliable, and the running cost was affordable. But with the growing concern on the increasing greenhouse gas emissions, these distributed systems are gradually and partly replaced by renewable hybrid systems where renewable energy sources are available and the generators are used as a backup sub-system. Islands are typical cases of these isolated communities. Therefore, researchers paid more attention to the area of renewable energy system for islands. Paska et al [2] described hybrid systems as a good means for islands to increase the availability and flexibility of power supply systems and to have available and flexible sources of electricity from different primary energy carriers. A similar study to that carried out by Senjyu, T., et al [3] and Ashok, S [4]. They analyzed the energy usage and the optimum configuration of a hybrid renewable energy system for a typical farming village of Western Ghats in Kerala, India. The study concluded that the optimal hybrid configuration including a micro-hydro, two wind turbines and battery storage could contribute to 100% of 24-hour energy demand for the communities. Parissis, O. et al [5], carried out a case study for an island using two wind turbines, two diesel generators, a fuel cell, a water electrolyser and a hydrogen storage tank. They found that a remarkable reduction (43%) in the power generation cost and 80% of the electricity needs of the island could be covered by renewable energy. Gokcek, M. [6] investigated the potential of hydrogen generation from small-scale wind-powered electrolysis system, the results showed that both electrical energy and hydrogen production depended on the hub height of wind turbine; and only the grid-integrated system was profitable when the extra electrical energy sold to the grid. Bajpai, P. and Dash, V. [7], reviewed hybrid renewable power generation systems (HRPS) for stand-alone applications, they found that economic viability and grid interconnection were the major challenges to make the HRPS applicable. Ahadi, A. et al [8], investigated the potential of a hybrid renewable energy with storage system to replace diesel generators for an isolated communities. They found that a hybrid PV/wind system with battery storage backup satisfied the load demand with minimized cost. These studies revealed that the hybrid renewable energy power systems (HRES) were possible to provide electricity for isolated areas with relative high cost; but diesel generators were still needed to provide back-up support in case the HRES could not meet the demand due to weather condition varied. In order to find a feasible, sustainable and renewable solution for the island, it is therefore necessary to carry out further research. The aim of this study was to investigate the feasibility of using hydrogen generated from renewable sources to replace diesel for power generation to realize a completely renewable and reliable power supply system for island using a selected case study.

2. The Case Study

The island in this case study is located off the west coast of Scotland. There was not a link to the national grid power supply. Two diesel generators were used to supply electricity for the island. So the islanders set about creating and building their own renewable electricity grid, which would depend as much as possible on renewable sources [9]. In 2008 the electrification project was switched on and the sole use of the noisy diesel generators was no longer on the island. This gave the islanders 24-hour power for the first time. The system consists of wind, hydro and solar natural resources. It is estimated that approximately 95% of the islands energy demand can be generated from the renewable sources, with diesel generators present as back-up.

2.1. Current System