Hybrid Renewable Energy System Optimization: Combining Complimentary Solar PV, Wind and Battery Storage Integrated with Marine Energy

Abstract

Developing nations like Kenya continue to be faced with the essential task of meeting their people's energy demand gap needs. Often, this challenge is attributed to the extremely high costs associated with grid extension to the remote rural areas. In this study, therefore, a hybrid renewable energy system of Solar Photovoltaic - Wind Turbine - Diesel Generator - Battery Storage Systems - Hydrokinetic Turbine – Converter (PV – WT – DG – BSS – HT – Converter) was presented as a possible solution to the energy inaccessibility challenge in the off-grid rural remote areas.

An analysis was then applied to a real case study of residential load demand for 225 households in a remote rural off-grid area in Kitui County, Kenya. A feasibility study was conducted to determine the actual statistics on meteorological data and local demand load profiles. After that, various hybrid system configurations were modelled and evaluated, and comparisons were made regarding their net present cost (NPC), Levelized cost of energy (LCOE) and environmental aspects using HOMER. Using MATLAB, a control and dispatch strategy algorithm was built and applied to the model in design optimization and control of hybrid renewable energy systems.

The optimal system configuration was PV – WT – BSS - Converter. This system design comprised of 162 kW of PV panels (44.3% solar energy penetration), 18 wind turbines with a rating of 10 kW each (55.7% wind energy penetration), 1,029 batteries with a capacity of 2.71 kWh each, and 123 kW of system converters. The Levelized cost of energy (LCOE) and total net present cost (NPC) from the optimum system configuration were estimated to be US$ 0.227 per kWh and US$ 1.25 million, respectively. Also, the maximum renewable fraction attained by the optimum system

was 100% with no emission of greenhouse gasses. The total electricity generated for the optimal system configuration was 530,532 kWh/yr with an electrical load consumption of 280,129 kWh/yr and an excess electricity surplus of 261,847 kWh/yr. Therefore, it was concluded that the optimum system configuration was the most suitable to generate adequate electricity at a cost-effective price to meet the load demand.

Consequently, this study is important as it sheds light on the hybrid renewable energy system's ability to improve the reliability of power supply by presenting an opportunity on how the impacts of the power grid as a result of the intermittency and randomness of renewable energy technologies can be minimized. It also seeks to showcase renewable energy hybrid system as a perfect solution to meeting the energy demand gap in remote rural areas where the cost of extending grid is too expensive to justify the extension.

Key Words

Hybrid renewable energy system; marine renewables; energy system optimization; levelized cost of energy; net present cost; base case system configuration; optimal configuration system; photovoltaics

Author: Raymond Yogo

Institution Affiliation: University of Strathclyde