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Feasibility study of using renewable energy sources for Technical and Vocational University of Guilan Using Homer software

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Extended Abstract

1. Introduction

The resurgence of greenhouse gas emissions to 2019 levels in 2021, driven by post-pandemic economic recovery, underscores the urgent need for cleaner energy solutions. Renewable energy adoption is accelerating globally to mitigate environmental pollution, reduce greenhouse gas emissions, and conserve fossil fuels. The share of renewables in global electricity generation has seen significant growth in recent years, surpassing the combined growth of coal and natural gas. This trend highlights the importance of assessing the potential for renewable energy integration in various sectors, including educational institutions. Previous studies have utilized HOMER software for feasibility analyses of hybrid renewable systems in diverse contexts, such as rural schools in Iraq, off-grid villages in Iran, and optimized hybrid systems integrating biomass, solar, and fuel cells. Building upon this research, the present study conducts a techno-economic feasibility analysis for implementing hybrid renewable energy systems at a university campus in Rasht, Iran.

2. Methodology

The feasibility assessment was performed using HOMER Pro software, a tool designed for optimizing microgrid design across on-grid and off-grid applications. HOMER facilitates the simulation, optimization, and sensitivity analysis of various system configurations by evaluating technical and economic performance over 8,760 annual hours.

2.1. Site Description and Meteorological Data

The study site is the Technical and Vocational University (Shahid Chamran Campus) in Rasht, Guilan Province, located at 37.13° N, 49.35° E. Meteorological data, including solar radiation, wind speed, and ambient temperature, were obtained from NASA's database integrated within HOMER. Key annual averages include a wind speed of 6.54 m/s, daily solar radiation of 4.42 kWh/m², and an ambient temperature of 12.59°C.

2.2. Electrical Load Profile

The university's electrical load was modeled as a commercial profile, with peak consumption occurring between 8:00 AM and 4:00 PM. The annual primary AC load was 956,300 kWh, with no significant DC load.

2.3. System Configurations

Three hybrid system configurations were modeled and compared:

1. **Grid-Wind Hybrid System:** Comprising a generic 10 kW wind turbine connected to the main grid.
2. **Grid-PV Hybrid System:** Comprising a 7,863 kW flat-plate PV array, a 1,974 kW converter, and connection to the main grid.
3. **Grid-Wind-PV Hybrid System:** Comprising a 3 kW wind turbine, a 7,863 kW PV array, a 490 kW generator, 13,092 units of generic 1 kWh lead-acid batteries, a 1,974 kW converter, and grid connection.

2.4. Economic and Environmental Parameters

The economic analysis considered a project lifetime of 25 years, discount rates of 8% and 18%, and a 45% inflation rate. Key metrics included Net Present Cost (NPC), Levelized Cost of Electricity (LCOE), and Net

Present Value (NPV). Environmental impact was assessed based on annual emissions of carbon dioxide (CO_2), carbon monoxide (CO), unburned hydrocarbons, particulate matter, sulfur dioxide (SO_2), and nitrogen oxides (NOx).

3. Results and Discussion

3.1. Grid-Wind Hybrid System Performance

The system generated 14,769,712 kWh annually, meeting 98.9% of the simulated load from the wind turbine and purchasing the remaining 1.14% from the grid. A significant surplus of 13,984,090 kWh was available for sale to the grid. The maximum output power was 7,890 kW with a capacity factor of 21.4%. However, the economic analysis yielded a negative NPV, rendering this configuration financially unfavorable despite its low LCOE of -$0.568/kWh (indicating net revenue from electricity sales under the modeled tariffs).

3.2. Grid-PV Hybrid System Performance

The PV-grid system generated 363,102 kWh annually, with the PV array contributing 86.9% and a backup generator supplying 13.1%. It successfully met the entire AC load (62,050 kWh). The maximum output power was 263 kW, and the calculated LCOE was $0.00812/kWh. Crucially, this system demonstrated a positive NPV, identifying it as the most economically viable option among the three configurations.

3.3. Grid-Wind-PV Hybrid System Performance

This comprehensive hybrid system generated 24,644,290 kWh annually, with contributions of 46.6% from PV, 53.2% from wind, and 0.195% from the grid. It met the entire load and had a 96.1% surplus for grid sales. While technically robust and effective, its complex configuration resulted in a high initial capital cost and a negative NPV, making it economically unattractive under the given financial assumptions.

3.4. Emissions Analysis

The annual pollutant emissions for each system are summarized in Table 10. The Grid-PV system produced the highest CO_2 emissions (48,234 kg/yr), primarily due to the backup generator's operation. The Grid-Wind system produced the least CO_2 (29,738 kg/yr). The triple-hybrid system showed zero emissions for CO, unburned hydrocarbons, and particulates, but higher SO_2 emissions, highlighting the trade-offs between different system designs and their pollution profiles.

3.5. Economic Viability (NPV Analysis)

The NPV analysis was decisive. Only the **Grid-PV Hybrid System** showed a positive total NPC (Net Present Cost, the inverse of a positive NPV in the context of cost minimization), confirming its economic feasibility. Both the Grid-Wind and the comprehensive Grid-Wind-PV systems resulted in negative NPCs (positive costs outweighing revenues), leading to their rejection based on the applied financial criteria.

4. Conclusion

This study conducted a techno-economic feasibility analysis for integrating renewable energy sources at a university campus in Rasht, Iran, using HOMER software. The key conclusions are:

1. The **Grid-Wind Hybrid System**, while capable of producing 14.77 GWh annually and reducing emissions, was deemed economically unfeasible due to its high initial cost and negative NPV.
2. The **Grid-PV Hybrid System** was identified as the optimal solution. It is economically viable (positive NPV), has a low LCOE ($0.00812/kWh), a maximum output of 263 kW, and reduces environmental impact compared to conventional supply, despite the highest CO_2 emissions among the three due to backup generation.
3. The comprehensive **Grid-Wind-PV Hybrid System**, though technically efficient with an annual generation of 24.64 GWh and significant emission reductions for several pollutants, was economically prohibitive due to its high capital cost and negative NPV.

Therefore, for the specific site conditions and economic parameters defined in this study, a hybrid system integrating photovoltaic panels with the existing electrical grid represents the most practical and economically justified pathway for adopting renewable energy at the university.

Key words: Feasibility, renewable energy, energy of wind, energy solar, HOMER software.
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