

Title: Planning off-grid hybrid energy system using techno-economic optimization and wins in league theory-based multi-criteria decision-making method in the wetland areas of developing countries

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Abstract: The unique geographical features of wetlands pose challenges to the conventional energy infrastructure. To address these challenges, this study proposes the establishment of off-grid hybrid energy systems (HES) that integrate photovoltaic (PV), wind turbine (WT), diesel generator (DG), and hydrokinetic turbine (HKT) units, along with batteries for energy storage. Initially, a list of criteria was determined for analysis. The Hybrid Optimization of Multiple Energy Resources (HOMER) tool was utilized for techno-economic optimization and to identify optimal off-grid HES designs for powering three villages in the wetland (Haor) region of Bangladesh. Subsequently, the Linear Bounded Weighted Average (LBWA) method was used to calculate the weights of the criteria. Then, a wins in league (WIL) theory-based Multi-Criteria Decision Making (MCDM) method, known as the Combined Compromise Solution (CoCoSo), was introduced to rank the identified optimal off-grid HES alternatives. The results favor an integrated system comprising 388 kW PV, 39 kW WT, 150 kW DG, 160 kW HKT, and 893 kWh Li-Ion BT for optimal load demand fulfillment, providing benefits to nearby communities. This study underscores that a fixed panel-based optimal hybrid system consumes 5 %, 8 %, and 9 % less fuel, emits minimal CO₂, requires fewer water resources, and creates more job opportunities than other tracking technologies. Compared with a DG-only system, the optimal off-grid HES proved to be 59 % more cost-effective and reduced CO₂ emissions by 96 %. In contrast, compared with a stand-alone PV system, the optimal off-grid HES is 35.5 % more cost-effective and reduces excess energy by 62 %. The proposed off-grid HES is highlighted as cost-effective, and environmentally sustainable, without any damage to the PV system during flood. Furthermore, the optimal hybrid system can reduce energy costs and excess energy by 2 % and 9 %, respectively, in future load demand scenarios while also generating 6 % more employment. The effectiveness of the analysis and the proposed approach was demonstrated through sensitivity analyses. The proposed WIL-CoCoSo approach effectively addresses the problem of rank reversal in decision making. The findings of this study also provide a foundational model for designing flood-resilient and sustainable off-grid HES in wetland areas of developing countries.

Keywords: Photovoltaic (PV), Wind turbine (WT), Diesel generator (DG), Hydrokinetic turbine (HKT), HOMER optimization Multi-Criteria Decision Making (MCDM)

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