Optimization of Hybrid Renewable Energy System (HRES) for a Remote Area in Bangladesh

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ABSTRACT

This study combines the power of solar, wind and biomass. With a view to providing affordable, reliable and clean electricity, optimal numbers of solar panels, wind turbines, biomass and battieries were found with the help of Hippopotamus Optimization Algorithm, using meteorological and load data. The optimal configuration includes 9980 solar PV modules, 6 wind turbines, 197 kg/h biomass consumption and 14 batteries, generating 27.12 kW for 25-30 households. With only a 2% power loss probability (LPSP) and levelized cost (LCOE) 5.63 BDT/MWh, the scalability and economic feasibility has been proven from this research.

Keywords: Hybrid Renewable Energy System, Hippopotamus Optimization Algorithm, Rural electrification, LCOE

BACKGROUND

In the Chittagong Hill Tracts, the electricity accessibility ranges from only 50-85%. Although grid extension is difficult in that region, an HRES can be easily built to provide the communities with electricity. Readily available resources that can be found in Bangladesh, such as abundant solar radiation (4-6.5 kWh/m²/day), viable wind speed (4 m/sec) and 35 million metric tons annual rice husk production, are enough to build the system.

OBJECTIVES

The research aims to design and optimize an HRES by:

1. **Modeling** PV, wind, biomass and bettery systems.
2. Applying the **Hippopotamus Optimization Algorithm** to minimize cost while ensuring reliability.
3. Determining **optimal** component configuration,
4. Analyzing **cost** and **social** impact of the research outcomes.
5. Creating positive **socio-cultural** impacts for the remote areas.

PROPOSED METHODOLOGY

The mathematical model for the HRES was built in MATLAB. It used actual weather data like solar irradiance, wind speed, and temperature. The hourly load profiles were collected from from the Dohazari Grid Substation. That covered a full year, all 8760 hours. The system parts included solar PV, wind turbines, biomass generators, and batteries. All the technical specifications and configurations were set up. To find the most optimal configuration for the sizing and numbers of module used in the system, Hippopotamus Optimization Algorithm was used. It is a nature-inspired metaheuristic optimization algorithm, that mimics the behaviour of hippos in their natural environment. Working in three main phases, the algorithm finds out the most optimal configurations that contribute to both the cost-saving and the reliability-improvement. The goal was to cut down the Cost of Energy and the Loss of Power Supply Probability. All while meeting constraints like minimum state of charge, covering the load, and depth of discharge. With around 500-1000 iterations, finally the expected outcome was achieved.

EXPERIMENTAL DESIGN

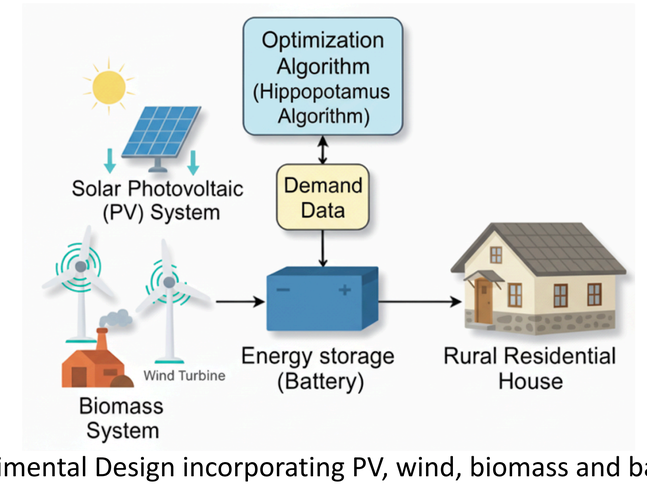

Figure: Experimental Design incorporating PV, wind, biomass and battery storage

KEY OUTCOMES/RESULTS

The study resulted in an optimal configuration, consisting of **14 batteries**, **6 wind turbines**, **197 kg/h of biomass** and **9980 PV modules**. It ensured a Levelized Cost of Energy **(LCOE) of 5.63 BDT/MWh** and reduced power loss probability **(LPSP) to just 2%**. The approach offers a cost-efficient, sustainable solution for the remote areas, while lowering the dependence on fossil fuels and national grid, with a renewable energy contribution of over 95%.

NOVELTY/SIGNIFICANT CONTRIBUTIONS

The novelty of this study:

1. **Lower LCOE**: 5.63 BDT/MWh beats most hybrid systems.
2. **Higher Reliability**: 2% LPSP is lower than non-optimized LPSP (5%).
3. **Real Data**: The hourly load demand used was collected from Dohazari Powerplant, providing real world load scenario.

COMMERCIAL VIABILITY

The system reaches an LCOE of 5.63 BDT per MWh. That shows its economic viability against diesel options for rural electrification. An initial investment of 1.15 billion BDT is needed to establish the whole Hybrid Renewable Energy System as a one-time cost. It delivers affordable, reliable and sustainable power to 25 or 30 households. Operational costs stay moderately minimal after that. Long-term economic viability is proven with obtained results.

OBE ATTRIBUTES

POs		Ks		Ps		As	
PO1	✓	K3	✓	P1	✓	A1	✓
PO2	✓	K4		P2	✓	A2	✓
PO3	✓	K5	✓	P3	✓	A3	
PO4	✓	K6	✓	P4		A4	✓
PO5	✓	K7	✓	P5		A5	
PO6	✓	K8	✓	P6			
PO7	✓			P7			
PO8	✓						
PO9	✓						
PO10	✓						
PO11							
PO12							

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