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Article

Optimization of solar and battery-based hybrid renewable energy system augmented with bioenergy and hydro energy-based dispatchable source

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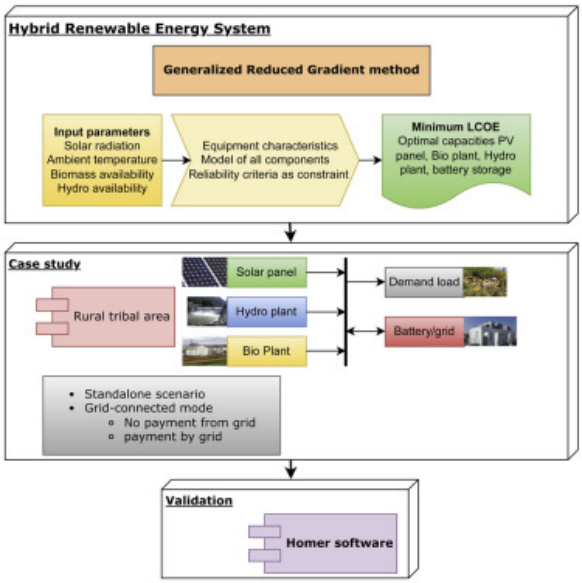
Highlights

- The battery system is not needed at more than 10 LPSP in PV, bio, and hydro-based HRES
- Biomass energy source adds dispatchable green source in the HRES energy portfolio
- Hydro energy enhances the economics and reliability of HRES substantially
- GRG can successfully optimize the HRES with different energy resources and storage

Summary

The hybrid renewable energy system (HRES) can overcome the problem of the mismatch of supply of variable renewable energies and demand. The optimal sizing of the HRES methodology is implemented by employing the generalized reduced gradient (GRG) method. A case study of HRES with solar, bio, and hydro sources for tribal areas in a hilly region of India is demonstrated. Both the grid-connected scenario and the standalone scenario in island mode are simulated. The optimal LCOE of 0.106–0.053 $/kWh is achieved in standalone mode for 100%–70% reliability. The grid-connected scenario is simulated with two different rates of payment for the electric energy delivered to the grid and a range of grid purchase prices. The LCOE results to around 0.06 $/kWh for the prospective grid-connected mode cases. The sensitivity analysis and validation of the work are also performed.

Graphical abstract



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Subject areas

Environmental science; Energy resources; Energy systems

Introduction

A combination of different renewable energy and/or some energy storage system in the form of a hybrid renewable energy system[1] (HRES) can temporally harmonize electricity demand with the resource availability of renewable energy.[2] The interest of researchers in HRES has grown tremendously over the last two decades.[3] The main problem statement has been the optimal arrangement of HRES constituent systems in terms of sizing and energy management,[4] because of temporal mismatch between supply and demand of electricity.[5]

The survey of the publications on the optimal sizing of HRES shows the wide variety of optimization techniques used by the researchers.[6,7] The earlier research was mainly based on classical optimization techniques with the predominant use of linear programming for simplified models and a variety of non-linear programming methods[8] for the detailed models of HRES. The use of artificial intelligence-based modern optimization techniques like the genetic algorithm,[9] particle swarm optimization,[10] and gray wolf optimizer[11] has increased lately because of their inherent capability to search in larger space with population-based variable values.[12,13] The hybrid techniques with a combination of more than one optimization technique are also gaining currency to exploit the advantages of two different optimization techniques.[14] The researchers have envisaged the energy need fulfillment of off-grid communities in isolated areas[15] and developing nations.[16]

The need for a simple yet effective and robust optimization methodology was felt, which can optimize the hybrid renewable energy system with multiple resources and storage systems in standalone and grid-connected mode. Generalized reduced gradient (GRG) method is seldom used in the literature and provides an avenue to explore the optimization of HRES. In addition, the need for HRES system studies with biomass utilization was felt. A wide range of reliability from 0 to 30 loss of power supply probability (LPSP) is investigated for a detailed idea of the feasibility of the system, which is very important in the socio-economic realities of the developing world. The method presented here also evaluates the reliability of the system for diurnal cycles in addition to widely used annual reliability evaluation parameters like loss of power supply probability. This assures that minuscule LPSP does not result in a continuous power outage in a concentrated period of time in a year. The diurnal power loss calculated in this study also enables the designer to plan the HRES as per the tolerance level of a specific consumer set needed in terms of LPSP-denoted reliability level. The breakaway points in the graph of daily reliability vs LPSP indicate the minimum LPSP level needed for that. It is the contribution of this study, where the daily reliability and annual reliability (i.e. LPSP) are correlated to get a clear idea about the acceptability of a particular HRES