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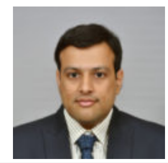
Optimal configuration of solar and wind-based hybrid renewable energy system with and without energy storage including environmental and social criteria: A case study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ABSTRACT

The Hybrid renewable energy system (HRES) has the potential to better match the demand load profile with power by using the complementary nature of the variable renewables. The sizing of the HRES should be done carefully to better match with demand load without oversizing and under-sizing. This study presents the use of the Generalized Reduced Gradient Method to optimize the size of components of HRES. The case study is performed to demonstrate the HRES for a remote rural region. Cases of both the standalone and grid-connected modes are explored. The standalone system with reliability from 100% up to 70% is investigated. A grid-connected system is studied with and without payment of power supplied to the grid to explore the feasibility of HRES for different price regimes. The methodology used is validated using HOMER software by comparing its results with HOMER results for the cases considered. Higher renewable share in the standalone systems leads to more need for employments at every stage of the lifecycle of components. In addition to that, the negative environmental impact of the HRES system in comparison to the conventional system is significantly less. It can be concluded that the standalone system proves to be better in terms of job creation and carbon emission. In contrast, grid-connected comes out to be better in terms of reliability and economics.

1. Introduction

The search for viable alternates to conventional energy extraction methods has become imperative. The technological advances in the manufacturing of solar photovoltaic panels and a large amount of production quantity have been decreasing their capital cost steadily for many years [1]. The issue of the intermittent supply of solar and wind energy, because of their dependence on the non-steady natural phenomenon has been the cause of concern. This issue has gained increased significance in the wake of the Paris agreement in 2015 [2], where member countries, including India, have agreed to substantially increase the share of renewables in their energy mix [3].

Putting together more than one energy resource with some energy storage facility can be the way forward to synchronize the demand and supply curves [4]. The combination of two or more renewable sources with or without conventional source and storage is called a hybrid renewable energy system (HRES), as shown in Fig. 1, where the complementarity of resources is harnessed to decrease the mismatch between the supply of individual energy sources and demand load [5]. The optimization technique should be able to handle the mathematical model of power production and other parameters of the HRES system. If the power production is not linearly correlated with renewable resource availability e.g., wind speed [6], then our optimization technique can't be linear programming. The optimization method ought to be capable of computing equations of cost and power production of HRES, as shown in the flow diagram of the general optimization process of HRES in Fig. 2.

The optimization techniques used for HRES are many [7] and can be categorized into conventional, modern, and hybrid techniques [8]. Classical optimization techniques try to find the global optimum of the set of the equations using mathematical formulations like nonlinear programming (NLP), Iterative techniques, etc. The advantage of these methods is that they provide definite answers, but the demerit is that they cannot handle a large number of variables. Criteria like negative environmental impact and social parameters like job creation are gaining the attention of researchers in addition to economic and reliability criteria. This adds complexity and subjectivity to the modeling of HRES. Artificial techniques like genetic algorithm (GA), Particle Swarm Optimization (PSO), and other evolutionary algorithms are needed to handle multi-criteria decision-making effectively. Many researchers have tried

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