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Climate-adaptive battery solutions for renewable microgrids: A case study in Indian coastal and inland regions

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ABSTRACT

The utilization of renewable energy has the potential to alleviate global warming, reduce carbon emissions in the environment, and offer sustainable energy solutions to remote regions. Presently, 13 % of the worldwide population resides in isolated inland and coastal areas where electricity remains inaccessible. Consequently, implementing microgrids powered by renewable energy sources becomes essential to enhance electricity accessibility in these remote locations. This study aims to identify efficient and cost-effective renewable energy technologies suitable for deployment inland and coastal areas. The techno-economic feasibility of renewable energy systems is being evaluated in two distinct locations: Yadavole (inland) and Uppada (coastal) villages in the Indian state of Andhra Pradesh. The energy analysis encompasses various sources, including photovoltaic, diesel generators, wind turbines, flywheels, and batteries (Li-ion and lead-acid). The HOMER software conducts all necessary modeling and simulations for economic analysis and optimal system sizing. According to the simulation results, the most viable microgrid configurations for the inland region, Yadavole, are photovoltaic/diesel and generator/Li-ion. In contrast, for the coastal region, Uppada, photovoltaic/diesel, and generator/lead-acid configurations prove to be the most promising configurations. Moreover, a MATLAB model of the proposed system is created to analyze energy quality. Given the superior performance of Li-ion batteries in elevated temperatures typically found inland, this study recommends a diversified range of battery solutions. Specifically, Li-ion batteries are recommended for inland areas, while lead-acid batteries are recommended for coastal regions. This approach aims to efficiently store renewable power by the specific climatic conditions of each area. It is crucial to systematically analyze region-specific renewable energy technologies to provide valuable insight to stakeholders involved in investment and energy policy decisions.

1. Introduction

The persistent rise in population, economic expansion, and reliance on conventional power sources has accelerated the accumulation of greenhouse gases (GHGs) in the atmosphere. Moreover, the extensive use of fossil fuels results in substantial GHG emissions, contributing to elevated surface temperatures. This escalation intensifies the frequency and severity of extreme weather events, impacting both human populations and other living species [1,2]. Hence, prioritizing decarbonization initiatives, tackling challenges posed by climate change, and adopting sustainable energy practices are of paramount importance to both global society and the electrical industry. In the last decade, there has been a significant increase in the adoption of renewable energy sources (RES) as a means to transition towards a low-carbon environment and mitigate GHG emissions [3,4].

Despite the significant impact of the COVID-19 pandemic on global energy demand, which declined by 6 % according to the 2020 report from the International Energy Agency (IEA), renewable energy capacity increased by 45 % (280 GW) as indicated in the 2021 IEA report [5]. Over the past decade (2010–2020), solar and wind energy systems, among other RES, have made significant advancements in creating a low-carbon emission environment and generating the necessary electricity to fulfill primary energy demands. According to the 2022 Statistical Review of World Energy, global renewable energy generation

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