OPTIMIZATION OF ECONOMIC PARAMETERS FOR HYBRID RENEWABLE ENERGY SYSTEM- A REVIEW

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ABSTRACT

The rapid advancement of renewable energy markets has significantly increased the interest in integrating multiple power sources into Hybrid Renewable Energy Systems (HRES). These systems can address the limitations of individual energy generation technologies by enhancing fuel efficiency, economics, reliability, and flexibility. A key challenge, however, is the stochastic nature of solar (photovoltaic, PV) and wind energy resources. Wind energy does not always align with load patterns and can be wasted during periods of excess, while solar energy is only available during daylight hours. A hybrid energy system that incorporates energy storage, renewable, and nonrenewable generation sources can mitigate the challenges posed by renewable resource uncertainties and fluctuations. The optimization of a large set of random variables and system parameters is essential to determine the most efficient sizing of the hybrid system components, ensuring the achievement of economic, technical, and design objectives. This chapter provides an overview of optimal sizing and the various optimization algorithms used for designing HRES, along with the objective functions typically considered in such systems.

Keywords: Hybrid Energy System; Optimization; Renewable Energy; Sizing, Economic Analysis.

1. INTRODUCTION

The use of solar and wind energy has steadily grown in significance due to its declining cost and its importance since the oil crises of the 1970s. Despite the need to transition to renewable energy sources, the intermittent nature of these resources presents a major challenge. Both solar and wind energy depend on variable environmental factors like solar irradiance and wind speed, which make it difficult for these individual energy sources to supply consistent power to the grid. To overcome this, hybrid systems that combine renewable sources with other dispatchable energy resources, such as biogas and fuel cells, along with energy storage systems, provide a reliable solution. Hybrid Renewable Energy Systems (HRES) typically consist of multiple power generation sources (e.g., wind turbines, solar panels, diesel generators), a battery storage system, and a power management system that optimally coordinates energy production from each source. A widely-used example of such systems is the microgrid, an integrated energy system comprising energy resources, storage, and loads. Microgrids, particularly those incorporating PV, wind, and battery storage, have gained popularity due to the increasing demand for distributed energy generation and their ability to provide high power quality, improved energy efficiency, reduced carbon emissions, and lower costs. Additionally, microgrids can operate in "islanding" mode, which allows them to disconnect from the utility grid in the event of upstream disturbances or voltage fluctuations. For HRES to function effectively, their design must optimize performance while adhering to physical and technical constraints. As such, optimization tools and techniques have become central to achieving the best system configurations.

2. OPTIMAL SIZING FOR HYBRID RENEWABLE ENERGY SYSTEMS

To meet the objectives of cost-efficiency, reliability, and performance, HRES require optimal design and sizing of system components. Table 1 highlights various studies that have explored optimization parameters in HRES, including hybrid system components, load characteristics, and sizing specifications.

Table 1: Optimized Parameters for Hybrid Energy Systems

References	Hybrid System	Load Specifications	Optimized Parameters
[4]	Wind/PV/Battery	225kW peak, 25kW base	Size, NPC, LCOE
[5]	Wind/PV/Micro Turbine/Battery	1.5kW constant	Size, NPC, LCOE
[6]	Wind/PV/Diesel/Battery	26kW peak, 5kW base	Size, NPC, LCOE, Emission Factor
[7]	Wind/PV/Battery	1500W	Size, NPC, LCOE

References	Hybrid System	Load Specifications	Optimized Parameters
[8]	Wind/Diesel/Battery	3.5kW peak, 0.25kW base	NPC, LCOE, Emission Factor
[9]	Wind/PV/Energy Storage	1MW peak, 0.4MW base	Size, NPC, LCOE
[10]	Wind/PV/Energy Storage	1MW constant	Size, NPC, LCOE

Optimization Objectives for HRES

The design and component sizing of HRES often take into account a variety of optimization criteria, which can be classified into economic and technical categories.

1. **Economic Criteria**: These focus on minimizing the cost of HRESs, including energy cost, Net Present Cost (NPC), and other system costs.
2. **Technical Criteria**: These criteria aim to maximize reliability, efficiency, and environmental benefits. They ensure the hybrid system meets load demands with optimal efficiency while minimizing greenhouse gas emissions.

   While HRES generally incur high capital costs and low operation and maintenance (O&M) costs, optimizing these parameters is crucial to strike a balance between upfront investments and long-term operational savings.

a. Minimization of Energy Cost

One of the primary objectives in HRES optimization is the minimization of the Levelized Cost of Energy (LCOE). LCOE represents the total cost of a system divided by the energy it generates over its lifetime, providing a measure of energy cost efficiency. Many studies have focused on minimizing LCOE to ensure that the system delivers cost-effective energy.

b. Minimization of Net Present Cost (NPC)

The NPC of an HRES accounts for the total present value of the system, which includes not only the initial installation cost but also the replacement and maintenance costs over the system's operational lifetime. The objective is to minimize the NPC to achieve a cost-effective hybrid system.

c. Minimization of Other Costs

In addition to LCOE and NPC, several other cost-related optimization objectives include minimizing Life Cycle Cost (LCC), Levelized Unit Electricity Cost (LUEC), Annualized Cost of the System (ACS), Capital Cost (CC), Total Cost of the System (TCS), and Average Generation Cost (AGC). Each of these cost factors plays a role in determining the financial viability and long-term sustainability of HRES.

3. CONCLUSION

This study examines various HRES configurations and evaluates the optimization parameters that are critical for their design and operation. Key factors such as system sizing, NPC, LCOE, and emission reduction are considered to optimize hybrid systems. Based on site-specific surveys, proposed hybrid systems can be optimized using software tools like HOMER Pro to evaluate their feasibility in meeting electricity demand in a cost-effective and reliable manner.

4. REFRENCES

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