Techno Economic Optimum Sizing of Hybrid Renewable Energy System

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Abstract— This Project advancements in the techno-economic optimization of hybrid renewable energy systems (HRES), focusing on the sizing and configuration of these systems. It discusses various methodologies and models used to determine the optimal mix of renewable energy technologies, storage systems, and auxiliary components. Key parameters influencing the process include renewable resource availability, energy demand profiles, component costs, and financing mechanisms. The paper also analyzes case studies from diverse geographical regions and applications, including off-grid, grid-connected, and microgrid systems. It also discusses emerging trends like machine learning, artificial intelligence, and blockchain technology for HRES optimization and their potential impacts on system performance, reliability, and cost-effectiveness. The review concludes with recommendations for future research, emphasizing the need for interdisciplinary collaboration among engineers, economists, policymakers, and stakeholders to address the complex challenges associated with HRES deployment.

Index Terms—Hybrid Renewable Energy Systems (HRES), Techno-Economic Analysis (TEA), Renewable Energy Resources.

I. INTRODUCTION

Techno-economic optimum sizing of hybrid renewable energy systems presents a promising solution at the intersection of sustainability and efficiency in energy production. As the global demand for clean energy continues to surge, the integration of renewable sources like solar, wind, and hydroelectric power is becoming increasingly vital. However, the variability of these sources necessitates innovative approaches to ensure reliability and cost-effectiveness. In this context, the techno-economic optimization of hybrid renewable energy systems emerges as a pivotal strategy. By leveraging advanced computational algorithms and economic models, this approach seeks to determine the optimal configuration and sizing of renewable energy components, such as solar panels, wind turbines, and energy storage systems. Through meticulous analysis of techno-economic parameters, including capital costs, operating expenses, energy yields, and environmental benefits, stakeholders can make informed decisions to maximize energy output while minimizing overall costs. This paradigm not only facilitates the transition towards a sustainable energy landscape but also fosters economic competitiveness and resilience. In essence, the pursuit of techno-economic optimum sizing represents a harmonious blend of technological innovation and financial prudence, driving us closer to a future powered by clean, affordable, and reliable energy.

II. LITERATURE SURVEY

Smruti Ranjan Pradhan et al [1], have defined global environmental concerns for the production of electrical power generation and utilization, it is very necessary to use renewable energy sources. By use of hybrid systems we can implement renewable energy sources which are very economical for remote villages, homes etc. In particular, rapid advances in wind-turbine generator, biomass generator and photovoltaic technologies have brought opportunities for the utilization of wind and solar resources for electric power generation world-wide .So by the use of hybrid systems consisting of Biomass ,PV and also wind for production of electrical energy in these remote areas can be more economical

Samson Gebre T.* and Tore M. [2], have presented an idea of optimal load sharing strategy for a PV/FC/battery/super- capacitor hybrid power system that optimizes the system performance. The fuel cell is used to complement the intermittent output of the PV source while the battery storage is used to compensate for part of the temporary peak demand which the PV and fuel cell can't meet thus avoiding oversizing of fuel cell. Super-capacitor energy storage is employed to relieve the battery of narrow and repeated transient charging and discharging ensuring longer battery life. Both the battery and the super-capacitor cover the slow power response of the fuel cell. A power flow control strategy is developed and simulation results are presented to demonstrate its effectiveness.

MengLiu; Wei-Jen Lee;Lee, L.K. [3] have examined that, the Increasing electricity demand reveals the challenges presented by limited resources and environment impacts. As an alternative to conventional plants, renewable resources suchas wind power and PVs account for an increasing percentage of electricity generation in recent years. Although renewable resources have many advantages, their intermittent nature must addressed before large scale application. Unlike wind power, which usually has higher power output at night and in the early morning, solar power only exists during daytime. This paper proposes the idea of combining wind turbines and PVs at different capacity ratios to match the hybrid system output to the system load profile. With an optimal capacity ratio, feasibility studies are also made by adding battery storage to the hybrid system to dispatch total hybrid output.

III. OBJECTIVE

- Cost Minimization
- Energy Reliability and Availability
- Environmental Impact
- Technological Feasibility
- Scalability and Flexibility
- Regulatory Compliance

IV. METHODOLOGY

Optimizing the sizing of a hybrid renewable energy system involves balancing various factors such as energy demand, available renewable resources, equipment costs, and operational constraints. Here are some working principles typically employed in techno-economic optimum sizing:

Load Analysis: Understand the energy demand profile of the system or site. This includes analyzing both the magnitude and timing of energy consumption.

Resource Assessment: Evaluate the availability of renewable energy resources such as solar irradiation, wind speed, or hydro potential at the site. Historical data or simulation tools can be used for this purpose.

Technology Selection: Choose appropriate renewable energy technologies based on the resource availability, site characteristics, and energy demand profile. For example, a combination of solar PV, wind turbines, and battery storage might be suitable for some locations.

System Modeling: Develop mathematical models or use specialized software to simulate the performance of the hybrid system under various configurations and operating conditions. This helps in understanding the interactions between different components and optimizing their sizes.

Optimization Algorithms: Utilize optimization techniques such as linear programming, genetic algorithms, or particle swarm optimization to find the optimum sizes of each component (e.g., PV array size, wind turbine capacity, battery capacity) that minimize the total cost of the system over its lifetime while meeting the energy demand.

Cost Analysis: Estimate the capital costs, operation and maintenance (O&M) costs, and fuel costs (if applicable) associated with each renewable energy technology and energy storage option. Consider factors such as equipment costs, installation costs, maintenance requirements, and expected lifespan.

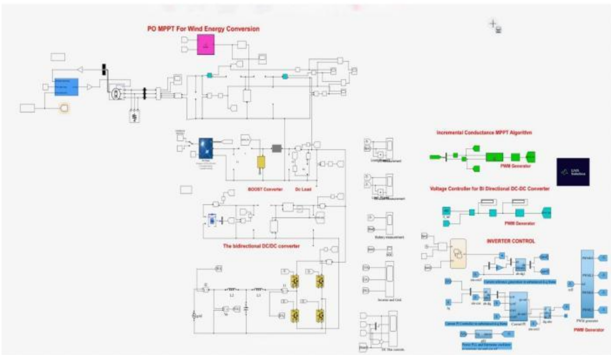
Financial Analysis: Perform a financial assessment to determine the economic feasibility of the proposed hybrid system. Calculate metrics such as levelized cost of energy (LCOE), net present value (NPV), and internal rate of return (IRR) to compare different sizing scenarios and financing options.

Sensitivity Analysis: Evaluate the sensitivity of the optimization results to changes in key parameters such as energy demand, fuel prices, equipment costs, and discount rate. This helps in identifying robust sizing solutions that are resilient to uncertainties.

Operational Constraints: Consider operational constraints such as system reliability, grid integration requirements, and environmental regulations during the sizing process. Ensure that the proposed system design meets the desired performance standards and compliance criteria.

Lifecycle Assessment: Assess the environmental impacts of the hybrid renewable energy system throughout its lifecycle, including manufacturing, operation, and decommissioning phases. Aim for designs that minimize greenhouse gas emissions and other environmental footprints.

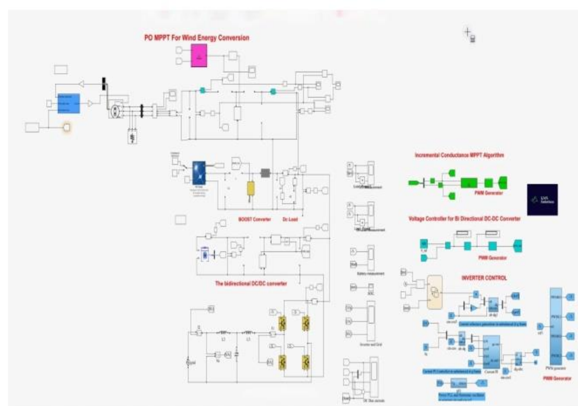
V. CIRCUIT DIAGRAM



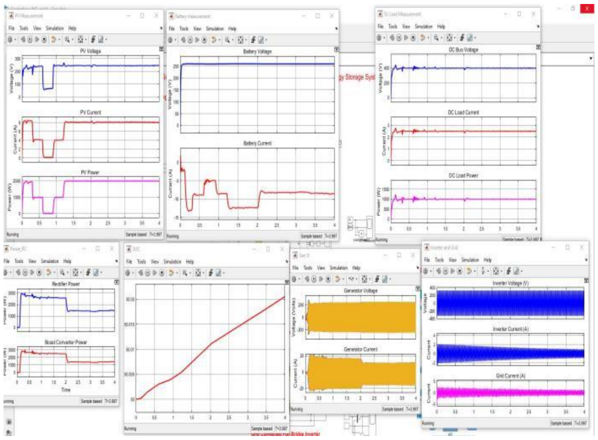
In the techno-economic optimum sizing of a hybrid renewable energy system, the circuit diagram represents the interconnected components that work together to generate, store, and distribute energy efficiently. At its core, this diagram typically includes renewable energy sources like solar panels, wind turbines, and possibly other sources such as biomass or hydroelectric generators. These sources are connected to power electronics components like inverters and charge controllers, which regulate the flow of electricity and ensure compatibility with the energy storage system. Speaking of which, energy storage is a crucial part of the system. Batteries or other storage technologies store excess energy generated during peak production periods for later use during periods of low renewable energy availability or high demand. The load, or energy demand, is also part of the circuit diagram. It represents the electrical appliances, machinery, or systems that consume electricity. This load is connected to the renewable energy system through an energy management system, which optimizes the allocation of energy from different sources to meet the demand efficiently. Furthermore, the circuit diagram may include auxiliary components such as backup generators or grid connections. These serve as fallback options during extended periods of low renewable energy generation or when the energy storage capacity is depleted. Overall, the circuit diagram illustrates the complex interplay between various components in a hybrid renewable energy system, highlighting how they collaborate to ensure reliable power supply while maximizing cost-effectiveness and sustainability. accuracy of the same. The fault occurring at a particular distance and the respective phase is displayed on a LCD interfaced to the Arduino board.

VI. RESULT AND MODEL

The Techno-Economic Optimum Sizing of Hybrid Renewable Energy Systems aims to find the most efficient and cost-effective combination of renewable energy sources to meet specific energy demands. Through thorough resource and load assessments, coupled with modeling and optimization techniques, it determines the optimal mix of technologies such as solar PV, wind turbines, and energy storage to minimize overall system costs while meeting performance requirements. Economic analysis, sensitivity analysis, and risk assessment are key components to ensure the financial viability and reliability of the proposed solution. Ultimately, this approach facilitates informed decision-making for the design, implementation, and operation of hybrid renewable energy systems, contributing to sustainable and affordable energy solutions.



Simulink model



Results

CONCLUSION

In conclusion, the techno-economic optimum sizing of hybrid renewable energy systems represents a crucial endeavor in the transition towards sustainable energy solutions. By integrating various renewable sources like solar, wind, and hydro, alongside efficient energy storage options, this approach strives to meet energy demands effectively while minimizing costs. Through meticulous resource and load assessments, coupled with sophisticated modeling and optimization techniques, such systems can be tailored to suit specific requirements, ensuring both technical feasibility and economic viability. Ultimately, this methodology offers a pathway towards resilient, environmentally friendly energy infrastructure, fostering a more sustainable and prosperous future.

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