Renewables, Energy Storage, and Power Markets: Optimization of plant design and operation to maximize net present value and minimize emissions

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Abstract

Existing work in optimizing renewable energy systems has generally focused on minimizing the levelized cost of power or green hydrogen. In contrast, we present a bi-level optimization framework for the design and operation of renewable energy systems to maximize net present value (NPV) and minimize emissions. The framework uses a user-specified location to acquire historical weather and power market data. Design considerations include the type and relative generation capacity of implemented renewable generation and energy storage technologies. Operational considerations include power storage and dispatch decisions during the lifetime of the system. Sensitivity analysis consider the impact of technological, weather, market, and policy uncertainties on the NPV and emissions of the system. The code to reproduce and extend the results presented in this work is available at .

Keywords:

1. Introduction

Advances in technology have made renewable energy sources increasingly competitive with traditional fossil fuels–an important step in the overarching energy transition. While renewable energy sources such as wind and solar

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power have low marginal generation costs, increased penetration of renewables is associated with a cannibalistic effect on the price of energy. The levelized cost of renewable energy is largely dominated by capital costs .

1.1. Related Literature

- **?**] integrate waste heat from a PEM electrolyzer to desalinate and deionize water before electrolysis. This heat integration allows cost parity with SMR at an average electricity price of $0.03 /kWh.

2. Modeling Approach

2.1. Objective Function

2.1.1. Net Present Value Calculations

2.1.2. Emissions Calculations

2.2. Data Acquisition

2.2.1. Climate and Weather Data

2.2.2. Market Data

2.3. Renewable Generation

2.3.1. Photovoltaic Power Generation

2.3.2. Concentrated Solar Generation

2.3.3. Wind Power Generation

2.4. Energy Storage

2.4.1. Battery Storage

2.4.2. Thermal Energy Storage

2.4.3. Electrolysis and Fuel Cells

2.5. External Integration

2.6. Final Problem Statement

3. Results

3.1. Sensitivity Analysis

3.2. Discussion

4. Conclusions

References