Resilient Energy Generation for Hybrid Floating Photovoltaic-Hydropower Systems

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Abstract

Hybrid Floating Photovoltaic-Hydropower (HFPVH) systems offer a promising solution for climate-resilient energy generation by integrating hydropower and solar energy to enhance grid reliability. Such systems aim to utilize the water reservoir surface's natural cooling ability to enhance solar panel efficiency [2, 3]. This research aims to develop a robust optimization framework that combines hydrological modeling, machine learning-based forecasting, and adaptive decision-making to optimize HFPVH system operations under uncertain climate conditions [4, 6].

Several critical challenges motivate the development of such a framework. First, rapid population growth and urbanization have reduced the availability of land area for photovoltaic cell placement thus increasing the need for alternative siting solutions [1]. Second, overheating of photovoltaic cells can cause malfunctions and efficiency losses, requiring effective cooling strategies to maintain performance [2]. Third, climate change is expected to increase reservoir evaporation rates, reducing water availability for hydropower generation [6]. Lastly, future climate conditions remain uncertain, necessitating continuous monitoring and adaptation to ensure system resilience [5].

The research proposes floating photovoltaic (FPV) solar panels as a solution to multiple challenges. Deploying FPV panels on reservoir surfaces not only conserves land but also enhances energy efficiency through the water's cooling effect, mitigating the thermal degradation of solar panels [2]. Additionally, FPV panels reduce reservoir evaporation rates, helping to preserve water levels for hydropower generation [3]. Different climate scenarios will be analyzed to assess the long-term viability of these hybrid systems.

This study focuses on the Amistad Reservoir, utilizing data from active gaging stations (IBWC, USIBWC) to model hydrological flows and energy generation potential. Historical data feeds into machine learning models, employing Recurrent Neural Networks (RNNs) and Long Short-Term Memory (LSTM) networks to predict inflows, energy demand fluctuations, and generation patterns [8, 7]. LSTMs are particularly useful for capturing long-term dependencies in reservoir behavior and climate trends, improving predictive accuracy [4]. A dynamic feedback mechanism

is incorporated to address forecasting uncertainties, enabling real-time parameter adjustments based on observed deviations [4].

In this presentation, we will go over the current progress of our approach to automating water releases from the Amistad Reservoir using machine-learning techniques. By leveraging models such as Recurrent Neural Networks (RNNs), Long Short-Term Memory (LSTM) networks, Bidirectional RNNs, and Dense Networks, we aim to accurately predict water releases in response to varying factors such as inflows, energy demand fluctuations, and environmental conditions. Our machine learning models are trained using historical data from active gaging stations (IBWC and USIBWC), which allows us to capture both short-term and long-term dependencies in the reservoir's behavior. Through this methodology, we aim to generate data that will allow us not only to optimize energy production but also to manage the reservoir's water resources more efficiently, reducing waste and enhancing the sustainability of the system.

Keywords: Hybrid Energy Systems, Robust Optimization, Machine Learning, Climate Resilience, Renewable Energy, Grid Integration.

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