

Operational Strategy and Control of a Renewable-Energy-Powered Hydrogen Production Plant with Flexible Electrolyzer Management

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This paper presents the design and operational strategy of a green hydrogen production plant powered by photovoltaic (PV) solar and wind energy. The facility integrates four electrolyzers, a hydrogen compressor, and a storage tank, all managed by a centralized control system. The plant operates continuously with a guaranteed supply of electricity secured through a base Power Purchase Agreement (PPA), which always provides the base level of power required for core operations. One of the electrolyzers operates as a "sacrifice" unit, providing flexibility to maximize renewable energy utilization. The plant manager dynamically allocates power, controls electrolyzer operation, manages grid interaction, and accounts for auxiliary plant consumptions, such as the hydrogen compressor. The integrated control system ensures efficient, safe, and economically optimized hydrogen production, demonstrating the economic and technical viability of flexible, renewable-powered hydrogen generation. This simulation have been performed using Ecosimpro and we have developed all the libraries involved.

Introduction

Integrating renewable energy into green hydrogen production is a critical step toward decarbonizing industrial and energy sectors. Hydrogen produced by electrolysis, especially when powered by variable renewable sources, faces the challenge of fluctuating resource availability. This paper describes a plant design and operational strategy that addresses these challenges through flexible electrolyzer management and comprehensive control of both primary and auxiliary energy consumptions, all underpinned by a base PPA that always guarantees a minimum, stable electricity supply. [1].

Ecosimpro and H2ENERGY

This work has been carried out using EcosimPro, specifically the H2ENERGY workspace, a dynamic simulation program designed for modeling and analyzing green hydrogen processes. The tool enables the management and design of hydrogen production systems by integrating renewable energy sources, electrolysis technologies, and fluid network configurations. Its dynamic nature makes it particularly suitable for studying transient behaviors, which are critical in the operation and stability of these systems. Through this approach, process performance can be analyzed under different renewable supply and PPA scenarios.

Operational Strategy

The plant's operational strategy is built around the dynamic allocation of available power, with the base PPA always forming the foundation of the electricity supply. The manager prioritizes PV generation, ensuring it always operates at its maximum potential. Wind generation is then adjusted to supply any additional demand not met by PV, maintaining a balance between renewable supply and plant requirements. The three base electrolyzers are guaranteed continuous operation at or above 40% capacity, thanks to the base PPA. The sacrifice electrolyzer is used only when all base units have reached full capacity and there is still surplus renewable energy. The manager also takes into account the power required by all auxiliary systems, ensuring that total plant consumption does not exceed the sum of available renewable generation and the base PPA.

When the plant produces more electricity than is needed for hydrogen production and auxiliary loads, the excess can be sold to the grid, providing an additional revenue stream. Conversely, if renewable generation plus the base PPA is not sufficient to meet the plant's needs, the plant can procure additional electricity through a variable PPA, thus maintaining uninterrupted hydrogen production. The integrated control

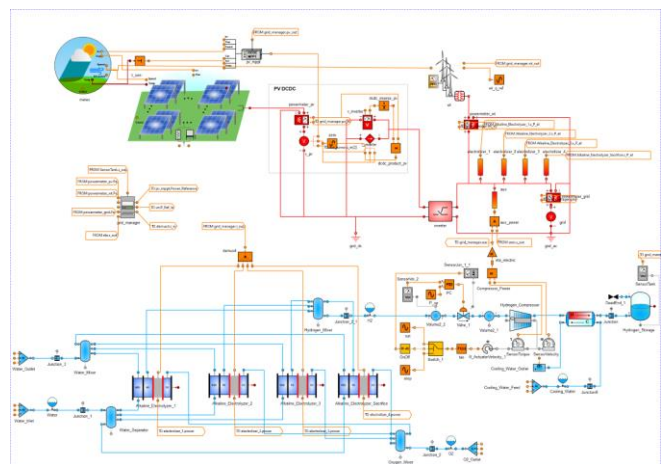


Figure 1- Schematic of the model

system continuously monitors the pressure in the hydrogen storage tank and will automatically shut down the electrolyzers and compressor if the tank reaches its maximum pressure threshold, ensuring operational safety. [1]

Control System Architecture

The facility's centralized plant manager is responsible for real-time management of all major operations. This includes distributing electrical currents to each electrolyzer, setting operational targets for PV and wind generation, and monitoring hydrogen storage pressure. The manager also oversees the activation and deactivation of both electrolyzers and the compressor, making decisions based on available power, storage constraints, and auxiliary consumption.

Optimization

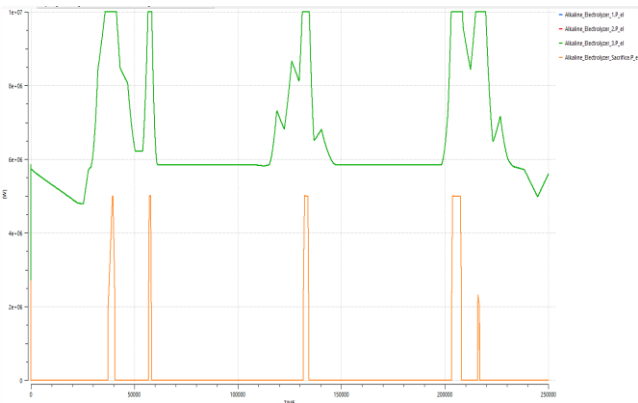


Figure 2 - Electrolyzers Power Consumption

In this study, we present an optimization framework to determine the optimal operation in a green hydrogen plant powered by solar photovoltaic, wind energy, and a Power Purchase Agreement (PPA). The model minimizes the total system cost, which includes capital expenditures for hydrogen storage and electricity costs associated with energy consumption from the PPA. Hourly profiles of renewable energy generation are used to simulate the operation of the electrolyzer and storage system, considering conversion efficiency and accumulative storage dynamics. The optimization problem is implemented in EcosimPro using the OPTIMIZATION library, with the storage capacity as the main decision variable, subject to energy availability and technical constraints. [2]

Results and discussion

The described operational approach allows the plant to maximize renewable energy utilization by flexibly operating the sacrifice electrolyzer and accounting for all auxiliary loads, while always relying on the stability provided by the base PPA. The base PPA ensures a stable supply of hydrogen, which is crucial for meeting contractual obligations and market demand. Through careful energy management, the plant can participate in electricity markets, selling excess power during periods of high renewable output and purchasing electricity when needed. The integrated control system's ability to monitor and respond to storage pressure further enhances operational safety and reliability. By including auxiliary consumption in the control logic, the plant achieves realistic and dependable performance, making it well-suited for regions with high renewable penetration and variable electricity prices.

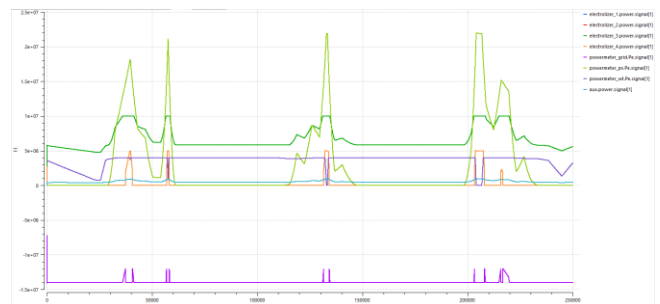


Figure 3 - Total Energy Management

Conclusion

This paper has described a robust approach to renewable-powered green hydrogen production, emphasizing the importance of flexible electrolyzer management and comprehensive control of both primary and auxiliary energy consumptions, with the base PPA as a constant foundation. The integration of a sacrifice electrolyzer into the plant's control logic allows for efficient, safe, and economically viable operation. The proposed model offers a scalable blueprint for future hydrogen facilities aiming to maximize renewable energy utilization and support the global transition to sustainable energy systems. All of this has been developed using Ecosimpro libraries and has served to validate these components with the expected process values.

References

- [1] IRENA (2020), Green Hydrogen Cost Reduction: Scaling up Electrolyzers to meet the 1.5°C Climate Goal, International Renewable Energy Agency, Abu Dhabi.
- [2] Clean Hydrogen Partnership. Levelised Cost of Hydrogen (LCOH) Calculator Manual. European Hydrogen Observatory (2024, June).