Comparative Assessment of Dispatch Strategies for Optimizing Microgrid Operation for Hydrogen Production

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Abstract

Hydrogen produced from renewable sources has been recognized as a key energy vector for the global energy transition. Various alternatives have been investigated to expand the use of green hydrogen and enhance the benefits associated with its production. In this context, Photovoltaic (PV) and battery-based microgrids have emerged as promising solutions for decentralized hydrogen production, where effective coordination of energy sources is essential to maximize renewable utilization, reduce grid dependence, and ensure system viability. Therefore, this paper presents a grid-connected microgrid designed for continuous hydrogen production using a 50 kW electrolyzer, a 350.9 kWp PV system and a 430 kWh battery energy storage system (BESS). Simulations were performed in HOMER Pro, comparing the native Load Following dispatch with a custom strategy implemented via MATLAB Link. Although total hydrogen production remained constant (7,884 kg/year), the custom strategy reduced grid electricity imports by 40% and solar exports by 36%, while enabling active BESS participation to supply stored PV energy. The Net Present Cost (NPC) decreased by 38%, from R$ 11.25 million to R$ 7 million, demonstrating that dispatch control can significantly improve both energy performance and economic viability in renewable-based hydrogen microgrids.

Keywords: photovoltaic system, BESS, microgrid, hydrogen, performance.

1. Introduction

Historically, environmental targets have focused on limiting absolute emissions and reducing greenhouse gas (GHG) concentrations in the atmosphere. However, with the growing recognition of the severity of climate change, the goals to mitigate GHG effects have become increasingly specific, evolving into net-zero emission targets (Fankhauser et al., 2022). Consequently, there has been a growing demand for solutions that enable and enhance decarbonization, in which hydrogen produced from water electrolysis using renewable energy sources (green hydrogen) has been recognized for its ability to maximize the benefits of renewable energy and decarbonize industrial sectors that are difficult to electrify (Incer-Valverde et al., 2023).

Despite this potential, the participation of hydrogen produced from renewable energy sources in meeting global demand remains low. In 2023, while global hydrogen demand reached 97 Mt, only 100 kt were produced using renewable energy. One of the main challenges associated with the large-scale adoption of green hydrogen lies in the infrastructure required to produce, store, and transport efficiently to the point of consumption, considering both technical and economic aspects (IEA, 2024). In this context, microgrids have been evaluated and proposed as a decentralized hydrogen production solution, aiming to bring production closer to the end use and avoid the challenges associated with centralized production (Van et al., 2023).

According to the U.S. Department of Energy (DOE), microgrids are defined as systems composed of multiple loads and coordinated generation units capable of operating either connected to the main grid or in islanded mode, within clearly defined electrical boundaries. These systems can integrate renewable energy sources and, through the use of energy storage systems (ESS), improve the integration of variable renewables (such as wind and solar) into power grids. This allows surplus energy generated during periods of low demand and high renewable production to be stored for later use during high-demand or low-generation periods (Saeed et al., 2021).

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In this context, studies have shown that microgrids based on photovoltaic (PV) systems and Battery Energy Storage Systems (BESS) represent a viable alternative for decentralized green hydrogen production. The electrolyzer operates using power from the PV system whenever its demand is less than or equal to the energy generated by the PV modules. When PV generation is insufficient, the electrolyzer is supplied by the BESS, ensuring continuous operation. (Ouabi et al., 2024). With the integration of PV, BESS, and electrolyzers, the operational complexity of microgrids increases, and computational tools have been used for long-term planning and assessment of operational parameters (Liang et al., 2024).

Among these tools, the HOMER Pro software models renewable energy systems with different equipment combinations and simulates their operation over one year, considering various time steps (Homer Energy LLC, 2025a). HOMER includes native dispatch strategies for energy coordination, one of which is the Load Following strategy. In this configuration, renewable energy sources are used to meet the load first, and any surplus solar energy can be directed to either the grid or the BESS depending on the least-cost operating criterion (Homer Energy LLC, 2025b).

However, this dispatch strategy may not adequately represent the operation of microgrids dedicated to green hydrogen production, since the native algorithm in HOMER may prioritize grid electricity instead of the BESS whenever grid power consumption results in a lower operating cost, thereby reducing the renewable fraction of the hydrogen produced. To allow users to develop their own dispatch strategies, HOMER Pro provides the MATLAB Link module, which enables the creation of custom control algorithms and their direct integration into the simulation environment (Homer Energy LLC, 2025b).

In this regard, several studies have used HOMER Pro with the MATLAB Link feature to develop specific dispatch strategies. Toopshekan et al. (2020) analyzed a hybrid microgrid composed of photovoltaic systems, wind turbines, batteries, diesel generators, and a grid connection, implementing a custom dispatch strategy that achieved up to a 9% reduction in energy cost and an increase in renewable fraction compared to HOMER's Load Following strategy. Uwineza et al. (2022) proposed an algorithm for a hybrid system composed of photovoltaic panels, batteries, and fuel cells, aiming to minimize the Net Present Cost (NPC) and optimize subsystem utilization, resulting in approximately 4% cost savings.

Similarly, Santos et al. (2021) developed a dispatch strategy for a microgrid composed of photovoltaic generation, battery storage, and electric loads representative of a university campus, with a peak demand of about 180 kW. The results showed an 11% reduction in total operating costs compared to HOMER's native strategies. Köprü et al. (2024) applied a custom dispatch strategy to a microgrid comprising solar, wind, biogas generation, and batteries, modeling the real load of a rural community with 53 households. As a result, the Levelized Cost of Energy (LCOE) decreased from \$0.168/kWh to \$0.158/kWh, while the renewable fraction increased from 74.2% to 79.1%, compared to HOMER's native dispatch.

Although these studies demonstrate the potential of using MATLAB Link to improve energy control and management in microgrids, their applications do not focus on hydrogen production and mainly emphasize economic performance analyses. In this context, the present work aims to provide a comparative assessment between HOMER's native dispatch and a custom dispatch logic implemented via MATLAB Link, focused on operational priorities to maximize renewable energy utilization for green hydrogen production, considering the operation of a grid-connected microgrid composed of a photovoltaic system, BESS, and electrolyzer.

Unlike the native dispatch, the logic implemented in this study prioritizes solar energy use for the electrolyzer supplied by the PV system and the BESS, with the electrical grid used only when PV generation or the batteries are insufficient to meet the electrolyzer's demand. The study considers the characteristics of a microgrid installed at SENAI CIMATEC Park, composed of a 350.9 kWp PV system and a 150 kW/430 kWh BESS, connected to a 50 kW electrolyzer stack. In addition, to demonstrate the potential of the proposed algorithm, a comparative analysis is also performed considering the NPC of the system under both dispatch strategies.

2. Methodology

This section presents the methodology adopted in this study, including the description of the system and its components, the simulation software, and the dispatch strategies considered for the development of the analysis.

2.1. HOMER Pro

The system was modeled and simulated using the HOMER Pro software, developed by the National Renewable Energy Laboratory (NREL) to support the design and evaluation of hybrid renewable energy systems. The software allows the simulation of several system types based on climate data, load profiles, the technical and economic characteristics of each component of the system.

In HOMER, each simulation is based on the energy balance of the system, calculated for every time step over a one-year period. For each user-defined interval, the software compares the available generation with the load demand, determining how the energy flows in the system and its devices. Therefore, this process allows the assessment of operational performance indicators such as energy production, storage utilization, grid exchanges, and renewable fraction.

In addition, HOMER can perform techno-economic analyses to determine the most feasible system configuration. However, in this study, the software was employed specifically to evaluate the system's energy balance, aiming to compare the benefits and limitations of different dispatch strategies in the microgrid's operational performance.

Therefore, HOMER's native dispatch algorithm was compared with a custom dispatch strategy implemented through the MATLAB Link module, which allows users to replace the default algorithm and implement their own control logic within the simulation environment, enabling customized energy management strategies that reflect real operational philosophies (Homer Energy LLC, 2025b).

2.2. The System

The evaluated microgrid comprises a PV system and a BESS integrated with a hydrogen production module, as shown in Figure 1.

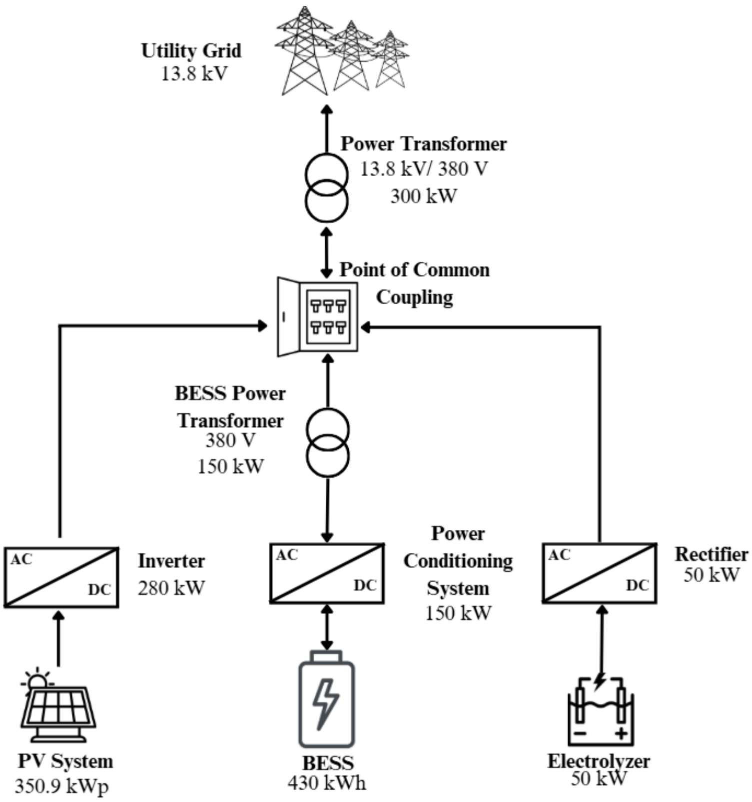

Figure 1: Microgrid schematic representation.

The PV system includes a set of PV modules totaling 350.9 kWp and inverters rated at 280 kWp. The BESS consists of a battery bank with a nominal capacity of 430 kWh and a 150 kW bidirectional power converter (PCS, power conversion system). The electrolyzer features a 50 kW stack dedicated to continuous hydrogen production. The microgrid is connected to a 13.8 kV distribution system and can operate either in grid-connected or islanded mode. Therefore, it is classified as a small-scale, decentralized, alternating current (AC) industrial microgrid with hybrid renewable sources.

2.2.1 PV System

The PV plant was modeled based on the following parameters:

- Environmental parameters: site-specific conditions of the microgrid installation;
- PV module model: WPV 550-555 HMM3;
- Nominal power per module: 550 Wp;
- Lifetime: 25 years;
- Average capital cost: R$ 2,749.95/kWp (GREENER, 2025);
- PV inverter replacement cost: 30% of the acquisition cost (Lazard, 2024);
- Annual operation and maintenance (O&M) cost: 1% of the acquisition cost (EPE, 2024).

The microgrid is installed at SENAI CIMATEC Park, a technological and industrial complex dedicated to research, development, and innovation, located in the Camaçari Industrial Center, Bahia, Brazil (Figure 2). The site has an average annual global horizontal irradiance of 4.91 kWh/m²/day and an average ambient temperature of 25.45 °C.

Figure 2: SENAI CIMATEC Park

2.2.2 BESS

The BESS was modeled using the following parameters:

- Battery technology: lithium-ion;
- Rated power: 150 kW;
- Energy capacity: 430 kWh;
- Minimum state of charge (SoC): 20%;
- Maximum state of charge (SoC): 100%;
- Round-trip efficiency: 92%;
- Battery lifetime: 15 years;
- Capital cost: R$ 6,500/kW (EPE, 2025);
- Replacement cost: 80% of the capital cost (NREL, 2024);
- Annual operation and maintenance (O&M) cost: 2.5% of the capital cost (NREL, 2024).

2.2.3 Electrolyser

In HOMER Pro, the electrolyzer model assumes that a constant amount of electricity produces a constant amount of hydrogen, with no dynamic response. Therefore, to represent the system installed at SENAI CIMATEC Park, the electrolyzer block was configured with a rated power of 50 kW, excluding the auxiliary loads of the balance of plant (BoP). In addition, a constant hydrogen demand profile was defined, corresponding to continuous 24-hour operation of the electrolyzer. This ensures that the model maintains steady operation, allowing the analysis to focus on the effects of different dispatch strategies on energy allocation and the renewable fraction of hydrogen production.

2.2.4 Grid

In HOMER, the electrical grid is modeled based on the electricity consumption costs, which vary according to the tariff structure applied to the consumer. In this study, the A4-Green tariff scheme was adopted, where different electricity prices are applied depending on the time of use throughout the day, and a single demand charge is considered. A contracted demand of 50 kW was considered in the model, corresponding to the maximum power that can be drawn from the grid, with a demand charge of R$ 38.61 per kW, according to the tariff values established by Neoenergia COELBA, the local electricity distribution utility in the state of Bahia.

In addition, the simulation considered the regulatory framework established by Law No. 14,300/2022, which defines Brazil's distributed generation rules. The post-2029 compensation scenario was adopted, representing the most conservative case, where consumers pay 100% of the Distribution System Usage Tariff (TUSD) for all energy exchanged with the grid, and only the Energy Tariff (TE) portion of exported PV energy is compensated. This assumption was applied to reflect the predominant regulatory condition over the project's lifetime and its influence on the economic performance of the microgrid, where grid interactions represent a significant share of operational costs. To accurately represent this regulatory context in HOMER Pro, the grid was modeled with the parameters shown in Table 1.

Table 1: Tariff costs (based on COELBA, 2025).

Tariff	Description	A4-Green Value (R$/kWh)
NetPurchase	Off-peak electricity consumption	0,3639
	On-peak electricity consumption	3,1038
NetExcess	Off-peak electricity compensation	0,26248
	On-peak electricity compensation	0,26248

2.4 NPC Calculation

The economic performance of the microgrid was evaluated through the Net Present Cost (NPC), which represents the total discounted cost of all expenditures and revenues throughout the project lifetime. The NPC aggregates the capital investment (Capex) associated with the installation of each distributed energy resource component and the corresponding operational expenditures (Opex), including operation and maintenance, grid electricity exchanges, and component replacements. The NPC was calculated using the total discounted cash flows over the project horizon, as represented in Equation (1):

$$NPC = -C_0 + \sum_{j=1}^{N} \frac{C_i}{(1 + i_{real})^j} \tag{1}$$

Where C_0 is the initial investment (R$), C_i is the cash flow in year j (R$), i_{real} is the real discount rate (%); N is the project lifetime (years).

For this study, a 25-year project lifetime was considered, along with a nominal discount rate of 8% per year and an average annual inflation rate of 4.5%, resulting in a real discount rate of 3.35% per year. These parameters were selected according to the assumptions commonly adopted in national energy planning studies (EPE, 2024). The same financial assumptions were applied to both dispatch strategies to ensure a consistent basis for comparison[1].

2.3 Dispatch Strategy

The dispatch strategy in HOMER Pro defines how the system components operate at each time step, determining the sequence in which available energy sources are used to meet the electrical load, when the

[1] All monetary values are expressed in Brazilian Reais (BRL). For reference, 1 BRL is approximately equal to 0.177 USD, according to the commercial exchange rate on August 30, 2024 (Central Bank of Brazil).

battery should charge or discharge, and when grid power should be imported. Among the native dispatch algorithms, the Load Following strategy, renewable generation sources are prioritized to meet the load whenever they are available. When PV generation exceeds the instantaneous demand, the algorithm compares the marginal cost of charging the battery with the cost of exporting the surplus to the grid and automatically selects the lowest-cost option. Conversely, during periods when PV production is insufficient to meet the load, HOMER evaluates the cost of discharging the battery relative to the cost of importing electricity from the grid and dispatches the most economical source, as shown in Figure 3 for a time-step interval.

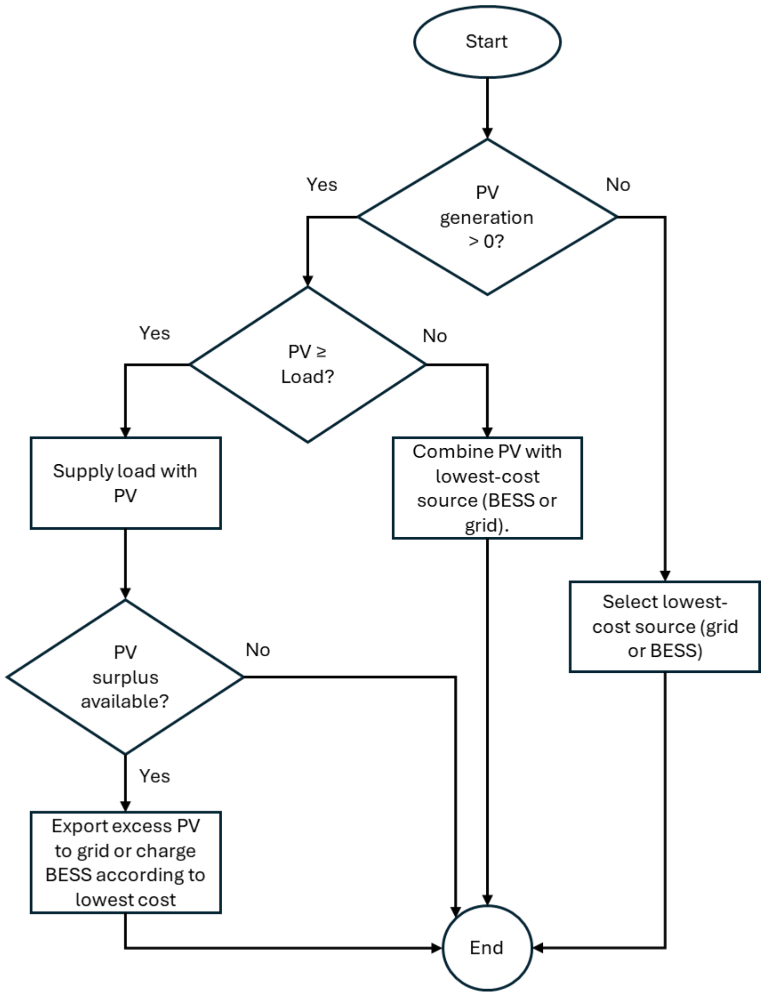

Figure 3: Load following dispatch.

In this framework, the battery state of charge (SoC) acts as an indirect constraint that limits when the BESS can charge or discharge, but it does not influence the dispatch order directly. This means that the algorithm may prioritize grid power over stored renewable energy if grid electricity is cheaper at a given time step. As a result, although the Load Following strategy minimizes operational costs, it often leads to a lower share of renewable utilization in grid-connected systems, especially when grid tariffs are low or when the BESS charging and discharging efficiencies reduce its cost-effectiveness.

To overcome the limitations of the native Load Following algorithm, a custom dispatch strategy was developed using the MATLAB Link interface available in HOMER Pro. This approach enables direct interaction between MATLAB scripts and HOMER's internal simulation engine, allowing users to define specific control rules for component operation at each time step. The custom logic proposed in this study was designed to prioritize renewable energy utilization and reflect the operational philosophy of a hydrogen-oriented microgrid, where the objective is not only to meet the electrolyzer demand at a minimal cost but also the maximization of renewable penetration and energy autonomy.

In the custom dispatch algorithm, the PV system is defined as the primary energy source, supplying the electrolyzer load whenever generation is available. When PV production is insufficient, the algorithm checks the state of charge (SoC) of the BESS. If the SoC is above the minimum discharge threshold, the BESS provides the additional energy required to sustain operation, ensuring continuity of hydrogen production without immediately resorting to grid electricity. The grid connection acts solely as a backup source, supplying power only when both PV generation and the BESS are unable to meet the load. Conversely, during periods of PV surplus, the algorithm verifies whether the SoC is below its maximum limit. If so, the excess PV generation is used to charge the battery; once the battery reaches its maximum SoC, any remaining surplus is exported to the grid, as shown in Figure 4.

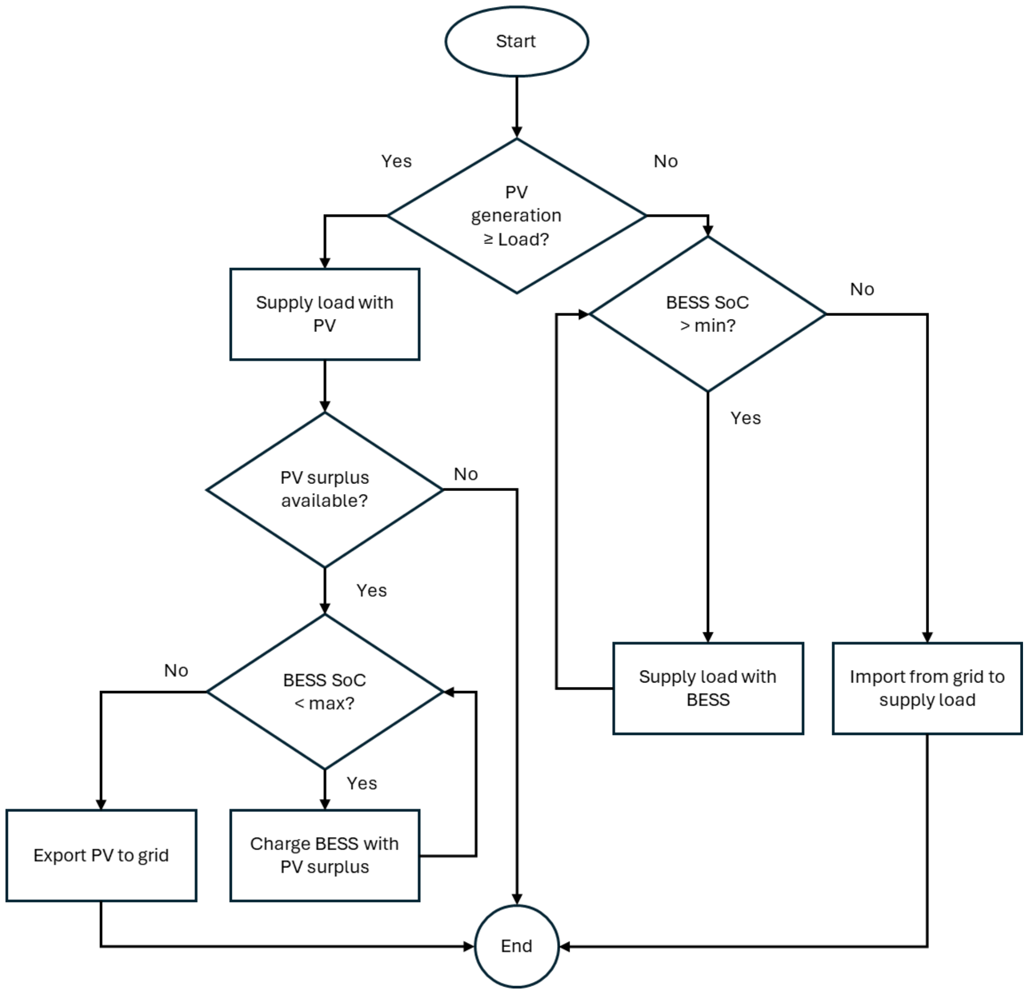

Figure 4: Custom dispatch strategy.

3. Results

Simulations were performed to evaluate the performance of the microgrid under two different dispatch strategies. Therefore, the microgrid was modeled to operate in grid-connected mode, continuously supplying the hydrogen production load. All components, including the electrolyzer, were considered to operate 24 hours per day throughout the 365-day simulation period.

3.1 Load Following

Under the Load Following dispatch, a total of 7,884 kg of hydrogen were produced, with an overall electricity consumption of 437.61 MWh per year. Of this total, 56.7% (248.22 MWh) of the energy was imported from the grid, while 43.3% (189.39 MWh) was supplied by the PV system. Furthermore, it is important to highlight that, in addition to the energy consumed by the electrolyzer, approximately 307.55 MWh of PV generation were exported to the grid instead of being stored or used locally.

Furthermore, despite the inclusion of a BESS in the microgrid configuration, no solar energy was used to charge the battery, and the BESS did not discharge to supply the electrolyzer at any point during the simulation. This behavior results from the Load Following algorithm's cost-minimization logic, which prioritizes importing electricity from the grid whenever it is cheaper than discharging the battery. Consequently, the BESS remained inactive throughout the year, providing neither energy support nor renewable integration benefits, as shown in Figure 5.

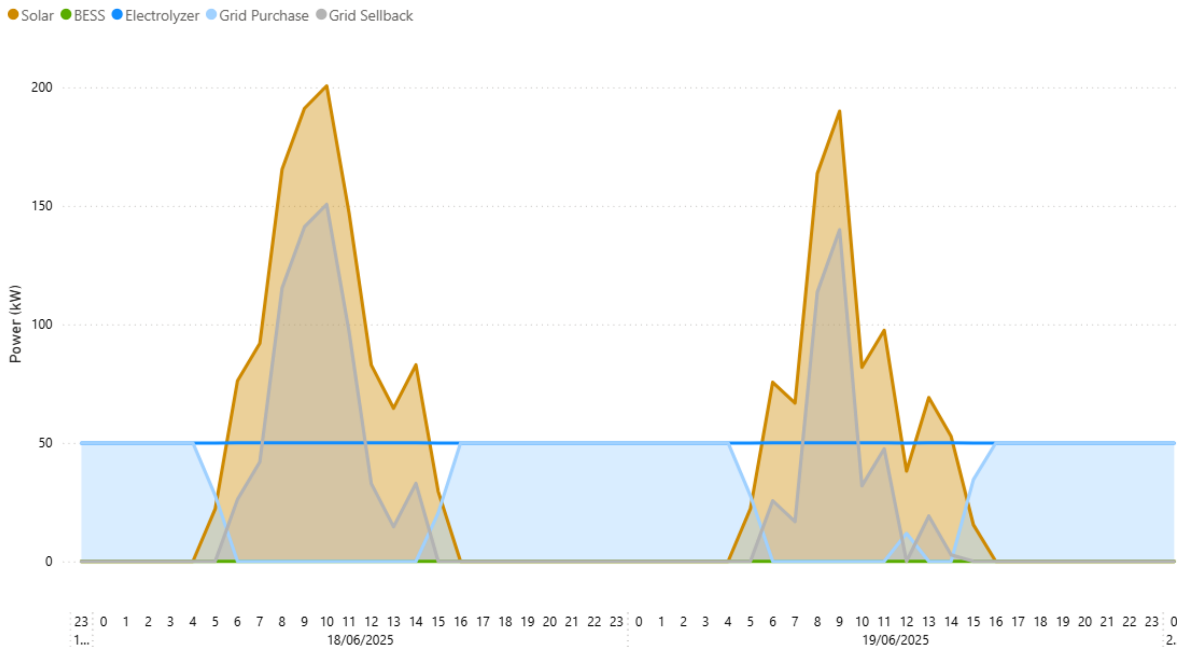

Figure 5: Time Series Plot from the HOMER Pro Load Following Dispatch.

The 48-hour time series of system operation demonstrates that during non-solar periods, the electrolyzer relies entirely on grid electricity, highlighting the system's dependence on external supply. As a result, although hydrogen production targets were achieved, renewable utilization remained limited, resulting in a higher NPC of R$ 11.25 million, primarily driven by the elevated share of grid electricity in the system's energy mix and the underuse of the installed BESS capacity.

3.2 Custom Dispatch Strategy

With the implementation of the custom dispatch strategy through MATLAB Link, the microgrid exhibited a different operational profile compared to the Load Following case. Over the one-year simulation, hydrogen production totaled 7,884 kg, with an overall electricity consumption of 438.00 MWh and the following distribution among sources: 34.2% (149.64 MWh) of the electrolyzer's demand was supplied by the grid, 43.2% (189.09 MWh) by the PV system, and 22.7% (99.27 MWh) by the BESS. For comparison, Figure 6 illustrates the share of each energy source contributing to hydrogen production for both dispatch strategies.

The PV system generated 496.96 MWh, of which 189.09 MWh were consumed directly by the electrolyzer, 110.71 MWh were stored in the BESS, and 197.16 MWh were exported to the grid. Although grid electricity continued to supply part of the electrolyzer's demand, the exported PV surplus effectively offset the imported electricity, resulting in a net annual grid exchange of - 47.5 MWh. This indicates that the microgrid injected more renewable energy into the grid than it imported over the year. When considering Brazil's distributed generation compensation mechanism, this balance translates to a theoretical renewable fraction of 100%, even though instantaneous grid imports still occur due to temporal mismatches between generation and demand.

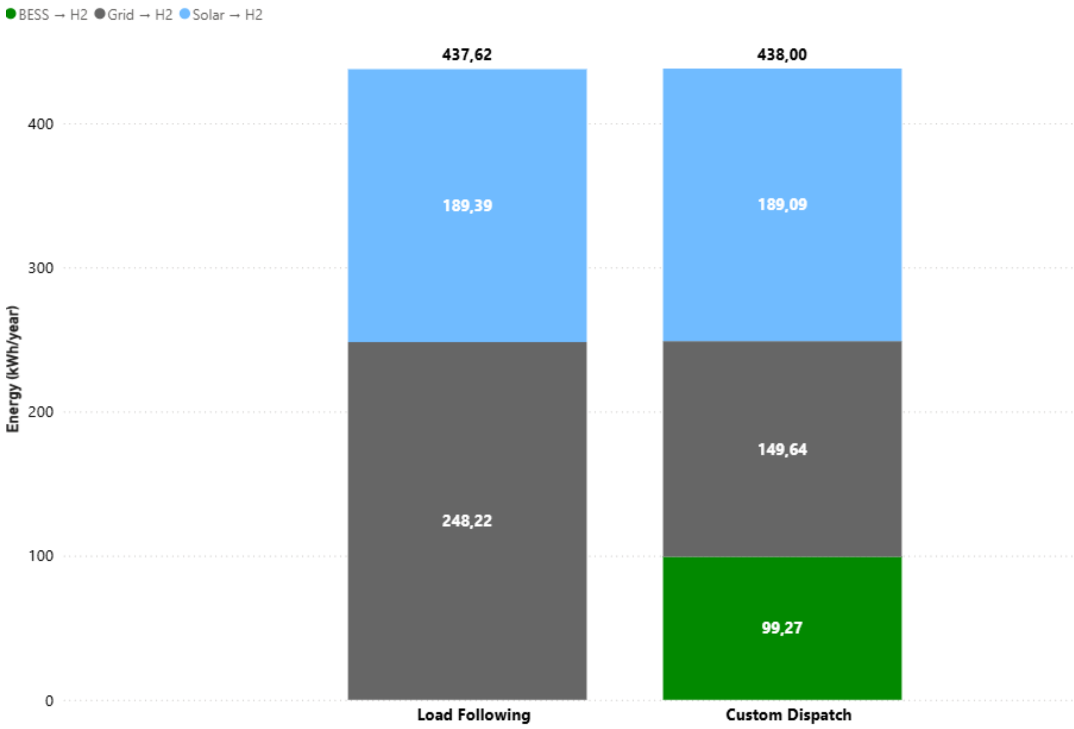

Figure 6: Hydrogen Production Share.

Compared to the Load Following scenario, the custom dispatch reduced grid imports by approximately 99 MWh and PV exports by 110 MWh, evidencing more efficient local use of renewable resources. The greater participation of the BESS ensured continuous hydrogen production during low-irradiance periods, enhancing system reliability and renewable utilization. Figure 7 presents the distribution of PV energy use under both dispatch strategies, showing how the proposed control reduces curtailment and increases on-site consumption.

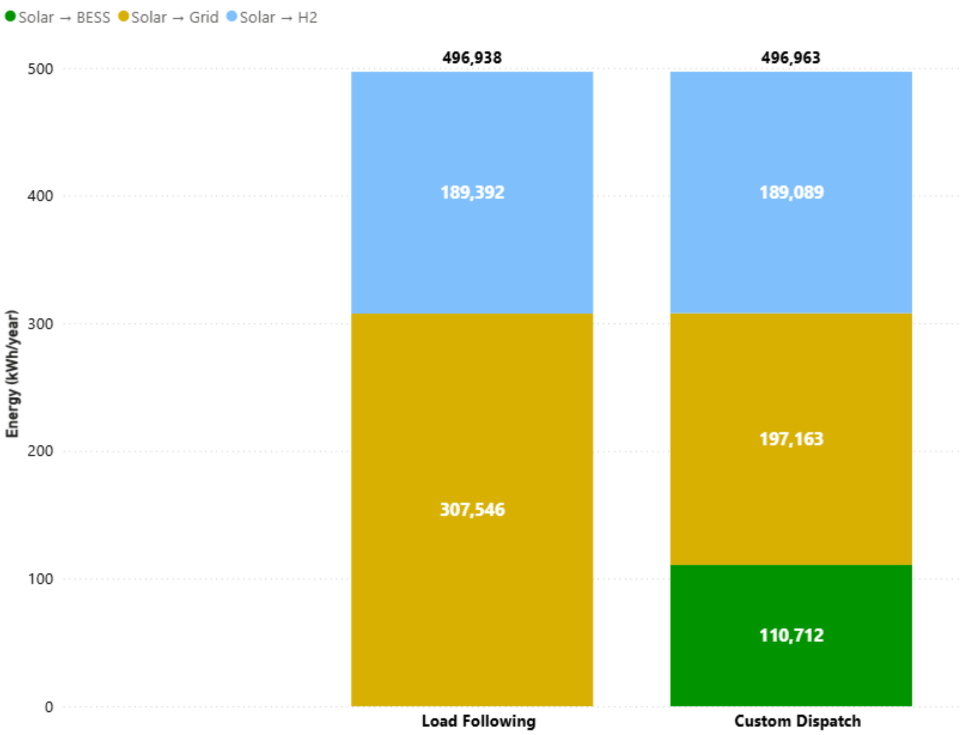

Figure 7: PV Production Share.

The 48-hour time series in Figure 8 illustrates the improved temporal coordination between energy sources. During daylight hours, the electrolyzer operates primarily on direct PV power, while the battery charges from surplus generation. After sunset, the BESS gradually discharges to sustain hydrogen production, minimizing grid reliance during evening and early-night hours. Only when the BESS reaches its minimum state of charge does the system draw power from the grid, ensuring uninterrupted electrolyzer operation.

This dynamic behavior contrasts sharply with the Load Following strategy, where PV surpluses were exported directly and the BESS remained idle. The results confirm that the custom dispatch enables smoother power transitions, higher renewable penetration throughout the day, and better alignment between renewable generation and hydrogen demand. Economically, the approach reduced the NPC by 38%, from R$ 11.25 million (approximately USD 2.0 million) to R$ 7.00 million (approximately USD 1.24 million), demonstrating that optimized dispatch control not only enhances renewable utilization but also improves the cost-effectiveness and operational sustainability of hydrogen production in grid-connected microgrids. Table 2 summarizes the main performance indicators for both dispatch strategies, highlighting the technical and economic improvements achieved with the proposed control logic.

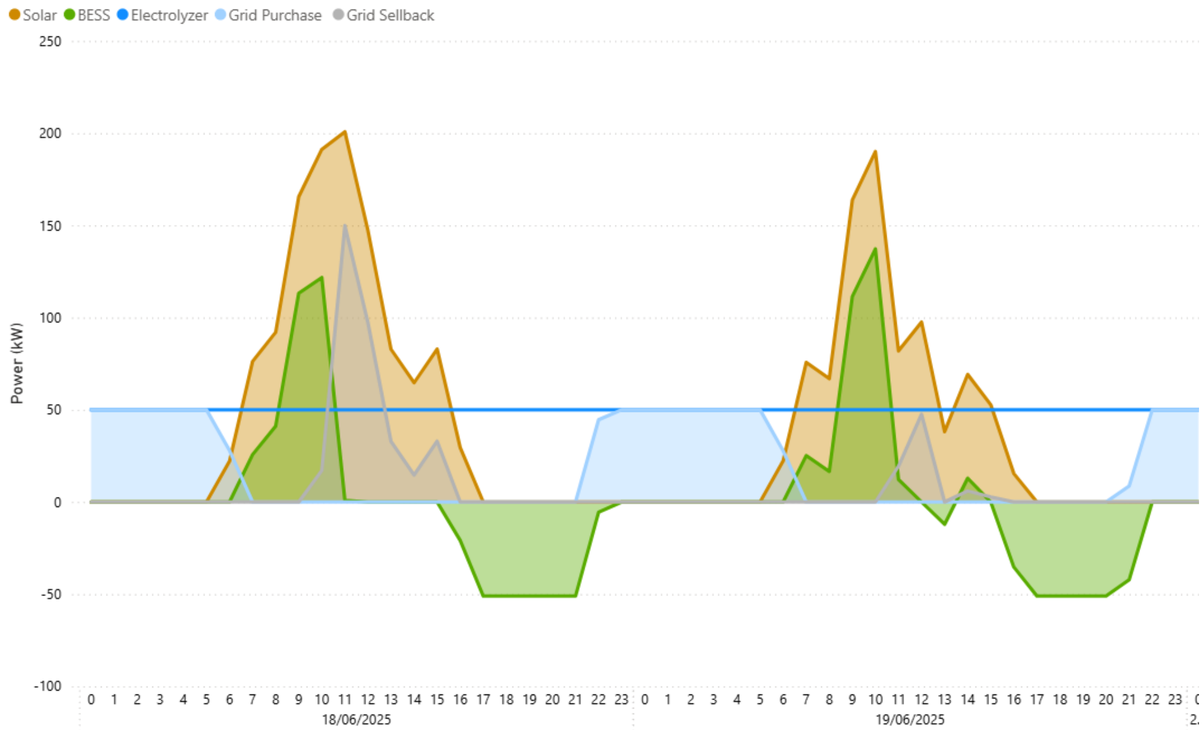

Figure 8: Time Series Plot from the HOMER Pro Custom Dispatch.

Table 2: Comparative performance of dispatch strategies.

Indicator	Load Following	Custom Dispatch	Variation
Hydrogen Production	7.884	7.884	-
Grid used for H_2 (MWh)	284.22	149.64	- 40%
PV used for H_2 (MWh)	189.39	189.09	~ 0%
PV exported to grid	307.55	197.16	- 36%
PV used to charge BESS	0	110.71	+ 100%
BESS used for H_2 (MWh)	0	99.27	+ 100%
NPC (R$ million)	11.25	7	- 38%

4. Conclusion

In this study, the performance of two dispatch strategies for a photovoltaic and battery-based microgrid designed for continuous hydrogen production were compared. The results showed that while both strategies delivered the same annual hydrogen output (7,884 kg), the way energy resources were coordinated led to very different outcomes. The custom dispatch strategy implemented through MATLAB Link enabled better use of local renewable resources, reducing grid electricity imports by about 40% and solar exports by 36%. As a result, the system achieved an annual net-zero grid energy balance and a 38% reduction in the NPC, from R$ from R$ 11.25 million (approximately USD 2.0 million) to R$ 7.00 million (approximately USD 1.24 million).

These results reinforce that the coordination of energy sources in hybrid microgrids should not rely solely on economic optimization criteria. A multi-criteria approach, integrating economic, energetic, and operational indicators, allows a more realistic evaluation of system performance and supports decision-making aligned with sustainability goals and regulatory transitions such as Brazil's distributed generation framework. Therefore, this study highlights the importance of developing intelligent and flexible dispatch strategies capable of balancing technical performance and economic feasibility.

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