SIZING AND PRELIMINARY EVALUATION OF THE DYNAMICS OF A PHOTOVOLTAIC SOLAR ENERGY GENERATION, CONDITIONING, AND STORAGE SUBSYSTEM DEDICATED TO GREEN HYDROGEN PRODUCTION

Summary

The sizing of a photovoltaic solar energy generation, conditioning, and storage subsystem arose from the need to partially meet the energy demand of a bench-scale green hydrogen production system via effluent electrolysis. This subsystem was designed based on technical standards and specialized literature, including photovoltaic solar panels, lithium batteries, a hybrid inverter, appropriate cabling, and electrical protection devices. The results show that the sizing of the photovoltaic solar subsystem was successfully carried out, ensuring operational functionality, safety, and efficiency, while the preliminary evaluation enabled an understanding of the operational dynamics of photovoltaic generation, energy conditioning, and storage equipment.

Keywords: Photovoltaic solar energy, green hydrogen production, effluent electrolysis.

1. Introduction

The energy transition is becoming increasingly urgent in light of a global electricity matrix still largely dependent on fossil fuels (71% in 2022), while Brazil stands out with a 44.8% share of renewable sources (IEA, 2022; EPE, 2022). In this context, green hydrogen, produced by water electrolysis using renewable energy, emerges as a promising alternative for industrial decarbonization (IRENA, 2021). However, the high water consumption in these processes — between 9 and 18 kg per kg of H_2 (Mehmeti et al., 2018) — imposes limitations, especially in water-scarce regions.

The use of industrial effluents as feedstock for electrolysis emerges as a sustainable solution, promoting a circular economy and reducing pressure on water resources (Elgarahy et al., 2022; Germscheidt et al., 2021). Although technologies such as alkaline electrolysis and PEM are already at a commercial stage (TRL 9), few studies integrate these technologies with other subsystems, such as energy systems, especially using effluents (Gomes et al., 2025).

In this context, this study presents the sizing and preliminary analysis of a photovoltaic solar generation, conditioning, and storage subsystem designed to partially supply energy to a bench-scale effluent electrolysis system (SPH2V off-grid), as described by Gomes et al. (2025).

2. Methodology

The sizing of the photovoltaic subsystem equipment was based on Hankins (2010), considering the system loads, such as the PEM electrolyzer (450 mL/min) and the gas analyzer, as well as the inherent losses of solar generation and other components (inverter, battery). The system was designed to operate for up to 1 hour with voltages of 24 V (storage) and 220 V (consumption). Correction factors of 20% were applied to account for system losses, and the inverter sizing included an additional 25% margin for greater durability. The lithium battery was estimated to use 80% of its nominal capacity, and the recharge time was determined assuming a charging current equivalent to that provided by the photovoltaic solar generation.

On the other hand, the electrical cabling was dimensioned according to the NBR 5410 standard (ABNT, 2004), using current-carrying capacity and voltage drop criteria. The segments between panels, battery, inverter, and loads were analyzed, taking into account temperature, conductor grouping, insulation, and type of electrical line. The cable cross-section was defined based on the more demanding of the two criteria. Circuit breakers were sized based on currents lower than the cables' supported capacity, in accordance with the same standard.

The system also includes surge protection devices (SPD) for both direct and alternating current, installed in distribution panels. The selection of SPDs also followed NBR 5410 criteria, considering environmental characteristics, grounding scheme, voltage parameters, and impulse withstand capability, based on manufacturer specifications.

Finally, an experimental test was conducted to evaluate the dynamics of the photovoltaic subsystem, both in solar power generation and battery storage, as well as in consumption by the loads, verifying the performance of the components against their technical specifications.

3. Results and Discussion

The total energy demand of the subsystem was estimated at 626.4 Wh, including 20% losses. Although the consumption required an inverter of approximately 650 W, a 3 kW model was chosen to allow future expansion of the subsystem (Figure 1a). The 100 Ah lithium battery, with 80% usable charge, allows up to 3 hours of continuous operation, and full recharge is estimated at 11 hours under a 2.37 A current supplied by the solar panels. These panels, although undersized due to acquisition limitations, provide up to 378 W under ideal conditions.

The selection of cable cross-sections strictly followed the NBR 5410 standard. 4 mm² and 10 mm² cables were used to connect the solar panels to the inverter and the battery to the inverter, respectively, and 1.5 mm² cables were used to connect the inverter to the loads and grounding. The circuit breakers used on the generation side were TOMZN TOB7Z-63 (20A, 6kA, 1000V) and SOPRANO SHB2 (32A, 500V, 6kA), while on the load side the Schneider Easy9 C10 EZ9F56210 (10A, 230V, 3kA, Curve C) was used. The SPDs adopted on the generation side were Clamper Solar 150 40kA (class 2) using Metal Oxide Varistor (MOV) technology [Maximum Discharge Current (Imax) of 40 kA, Nominal Discharge Current (In) of 18 kA, Maximum Continuous Operating Voltage (Uc) of 150 VDC, and Protection Level or Residual Voltage (Up) < 1 kV]. On the load side, the WEG SPW02 275-20 SPDs (Class 2) were used, with Imax of 20 kA, In of 10 kA, Uc of 275 VAC, and Up of 1 kVAC.

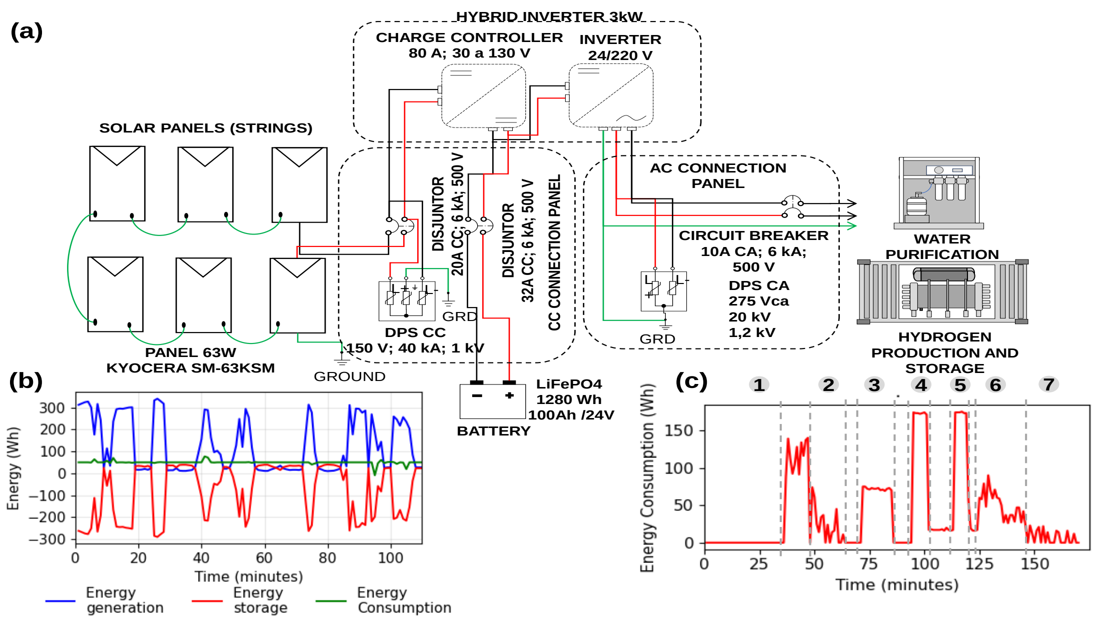

Fig. 1: (a) Multifilar Diagram and (c and d) Energy Dynamics (Wh) of the photovoltaic solar power generation, conditioning, and storage subsystem dedicated to the SPH2V Off-grid.

Experimental tests allowed for the evaluation of the dynamics of generation, storage, and consumption, both with and without connected equipment. In the absence of load, solar generation reached peak values of 340 Wh and averages close to 97 Wh, while the inverter's internal consumption recorded peaks of 77 Wh (Figure 1b). With active loads, the system's behavior was monitored at seven different points. The electrolyzer showed a maximum consumption of 174 Wh, and the gas analyzer 23 Wh (Figure 1c). The observed variations confirm the system's ability to operate stably and in accordance with the specifications of the connected equipment.

4. Conclusions

The study successfully presented the design of the photovoltaic solar energy subsystem for green hydrogen production via effluent electrolysis, highlighting the safety and efficiency ensured by NBR 5410 standards. The dynamic analysis showed that, despite the limitations of the small-scale solar plant, the system met the energy demand through battery support. The intermittent operation revealed operational challenges and validated the technological choices adopted. The results contribute to future optimizations of the SPH2V Off-grid and provided valuable technical training to the project participants, strengthening practical knowledge in renewable energy and applied electrolysis.

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