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Using Green Hydrogen Energy Storage for Robot Charging Station

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***Abstract*—This article describes a solar-powered robot charging station that uses green hydrogen as a long-duration energy storage medium. Surplus photovoltaic energy is converted into hydrogen by a PEM electrolyser, stored in metal hydride canisters, and later converted back to electricity through a 300 W fuel cell to support nighttime robot charging. The system stores 1.2 Nm³ of hydrogen and delivers approximately 1.54 kWh of usable electrical energy, with a full refill requiring about 9.33 kWh of input. The resulting round-trip efficiency of ~16.5% reflects the real-world performance of small PEM systems. Despite the modest efficiency, the architecture provides reliable off-grid operation, scalable storage capacity, and flexible autonomous charging for diverse robot fleets.**

Keywords*—*fuel cells, charge station, service robots

I. INTRODUCTION

Green hydrogen is produced by splitting water using renewable electricity [1]. When the solar resource is plentiful during the day but robot operations extend into evening and night, a hydrogen loop offers an elegant way to shift energy in time: solar electricity is converted to hydrogen by an electrolyser; hydrogen is stored in safe, compact metal-hydride canisters, and a fuel cell regenerates electricity for a low-voltage DC bus that feeds robot chargers after sundown. Unlike a battery bank, the power a station can deliver and the energy it can store are mainly independent. Power comes from the electrolyser and fuel cell ratings, while energy scales with the number of canisters. This separation is attractive when robots have sporadic but energy-intensive charging needs, or when the site is remote and unattended for long periods [2]. The goal of this article is to describe the general structure of such a station and to quantify the energy available to robots and the chain efficiency from electricity into hydrogen and back .

II. SOLAR CHARGER STRUCTURE

The charger is best understood as three cooperating subsystems connected by a common DC bus. A photovoltaic (PV) array supplies a DC bus through maximum power point tracking (MPPT). The bus may include a modest buffer battery to absorb transients and support the bus during brief cloud passages. When the electrolyser must be fed with AC, a sine-wave inverter converts it from the DC bus; otherwise, a DC-input electrolyser can be used (Fig. 1). The robot side presents one or more isolated DC/DC chargers set to the fleet's nominal pack voltages (e.g., 24 V, 36 V, 48 V), with interlocks and contactors to ensure safe connection before energizing a port. Hydrogen generation and storage - during the day, surplus PV power is routed to a PEM electrolyser that splits deionized water into H2 and O2. Hydrogen is stored in metal hydride canisters that absorb gas into a solid lattice at comparatively low pressures and ambient temperatures. For the use case here, two MHS 800 canisters are installed in parallel so that the station can build a meaningful night reserve while staying compact and

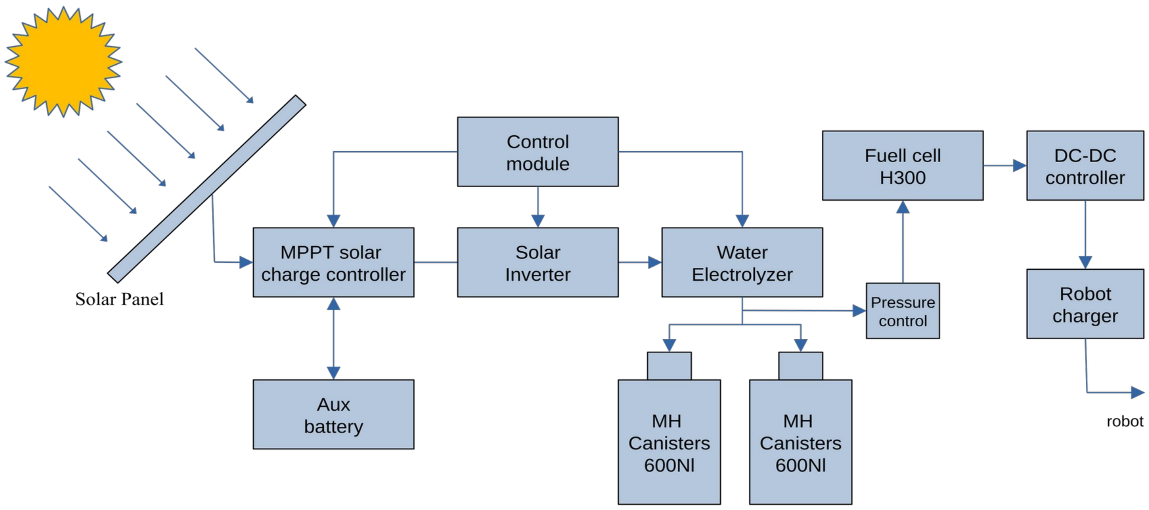

Fig.1 Charge station diagram

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serviceable. Electricity regeneration for night charging - when the sun fades or the load exceeds the PV output, a PEM fuel cell feeds the DC bus. The fuel cell runs steadily in its efficient region while the small buffer battery handles sudden plug-in spikes and short surges from fast chargers [3]. Supervision software coordinates when to start/stop the electrolyser, how to hold the bus setpoint, and when to request more or less fuel cell power.

III. Energy calculation

This section uses manufacturer data to quantify the hydrogen produced, the electrical energy recovered for charging, and the implied round-trip efficiency. The hydrogen system's specific components are:

• H300 PEM fuel cell, rated 300 W with a hydrogen consumption of 3.9 l/min at full output and a listed system efficiency of 40 % at the rated voltage (Fig. 2) [4].

Fig. 2. H300 fuell cell

• On Fig 3 is shown HG72 PEM electrolyser with maximum hydrogen flow 1.2 l/min and installed power 560 W (max) [5].

Fig. 3. HG72 PEM electrolyse

• The required piping, valves, and pressure control systems to ensure safe operation in optimal conditions of the component (fig.4).

Fig. 4. Pressure regulator

• Two MHS 800 metal-hydride canisters, each storing 600 Nl when filled from HG-series generators; nominal discharge 4 Nl/min per canister (Fig. 5) [6].

Fig. 5. MHS800 metal-hydride canisters

Hydrogen inventory from two canisters

The total hydrogen inventory is

$$V_{H_2} = 2 \times 600\, Nl = 1200\, L = 1.2\, Nm^3$$

This inventory meets the fuel cell flow requirement because two canisters in parallel have a nominal combined outflow of ~8 L/min, which exceeds the H300's 3.9 L/min at full output.

Fuel cell runtime and electrical energy recovered.

Assuming the H300 operates at its rated 300 W, the runtime based on hydrogen volume is:

$$t_{run} = \frac{V_{H_2}}{V_{H_2,FC}} = \frac{1200\, l}{3.9\, l/min} \approx 308\, min \approx 5.13\, h$$

The electrical energy available at the DC bus from that run is then:

$$E_{out} = 0.300\, kW \times 5.13\, h \approx 1.54\, kWh$$

This value comes entirely from the two datasheet quantities: fuel cell power and hydrogen flow at full output.

Electrolyser refill time and electrical input.

The time to produce 1200l of hydrogen at the HG72's maximum flow is:

$$t_{fill} = \frac{1200\, l}{1.2\, l/min} = 1000\, min \approx 16.7\, h$$

If the electrolyser draws its installed power while producing at this rate, the electrical input required for two canister fills is:

$$E_{input} = 0.560\, kW \times 16.7\, h \approx 9.33\, kWh$$

That also implies an energy intensity of ~7.8 kWh per 1 cubic meter of hydrogen at the HG72's maximum production rate.

Electric-to-electric roundtrip efficiency.

Using only the two measured endpoints (electrical input to the electrolyser and electrical output from the fuel cell), the station's electric round-trip efficiency for one charge-discharge cycle is:

$$\eta_{rt} = \frac{E_{out}}{E_{input}} \approx 1.54/9.33 \approx 16.5\,\%$$

Because this figure is derived purely from the two manufacturers' flow/power numbers, it is a practical indicator of what robots can expect at the DC bus from a given amount of PV electricity stored as hydrogen.

In Table I are summarized the main technical parameters of hydrogen charging station

TABLE I. CHARGE STATION PARAMETERS

Parameter	***Value***
Electrolyser max. consumption	560W
Electrolyser production rate	1.2l/min
Total hydrogen storage	1200 Nl
Max. working pressure	16 bar
Fuel cell consumption	3.9l/min
Fuel cell output power	300W
Total energy stored	1.54kWh
Overall efficiency	16.5%

IV. DISCUSSION

The general architecture deliberately decouples duty cycles. During the day, PV serves the chargers first; any surplus is used to run the electrolyser until the two canisters are full. At night, the fuel cell sustains the bus for an estimated ~5.1 h of continuous 300 W output, or longer at lower average power. If a field team prefers to treat energy in the language of robot batteries rather than hydrogen volumes, the ~1.54 kWh figure is the most actionable. For instance, three Athena2 [7] robot batteries of ~0.5 kWh each could be charged back-to-back (subject to charger efficiency and charge profiles), or a single large robot 1 kWh pack could be taken from a low to a high state of charge with margin for overheads. The efficiency computed above (~16.5 %), accounts for all intermediate conversions without requiring assumptions about the higher/lower heating values of the fuel. It is also a realistic planning number because it uses the electrolysers' installed power at their maximum flow and the fuel cell's power at its rated hydrogen consumption. In practice, careful dispatch can raise the apparent round-trip slightly: for example, running the electrolyser at part-load when PV is abundant but temperatures are mild, trimming DC/DC losses by matching charger voltages closely to pack voltages, or allowing the fuel cell to operate a little below its peak output to avoid throttling losses. Conversely, cold canisters and aggressive charging may reduce effective hours; scheduling a gentle prewarm of the hydrides before the night window can improve gas delivery without materially changing the energy balance. None of these operational choices alter the core calculation; they help the station deliver that energy when it is most useful.

The structure scales predictably. Adding more MHS 800 canisters increases the night runtime in direct proportion. If autonomy rather than peak power is the limitation, this is the most economical change. If the station must charge several robots simultaneously, a second H300 operating into the same DC bus increases sustained power while leaving the energy inventory unchanged. If refill time is the constraint, additional HG72 units can be operated in parallel; their flows sum, and the required PV energy per fill scales accordingly. The control philosophy remains the same: the bus is served first; surplus energy is stored as hydrogen; and the fuel cell regenerates electricity when the bus needs it.

V. CONCLUSION

A solar-hydrogen robot charger built around a small PEM stack is structurally simple yet operationally flexible. Two MHS 800 canisters hold 1.2 Nm^3 of hydrogen; an H300 running at its rated 300 W then supplies about 1.54 kWh of electricity over ~5.1 h; and refilling both canisters at the HG72's maximum rate requires roughly 9.33 kWh of electrical input and ~16.7 h of production time. The implied electric round-trip efficiency is ~16.5 %. These anchor points make it straightforward to size the PV array, decide how many canisters are needed for a target autonomy window, and budget nighttime charging for a mixed fleet.

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REFERENCES

[1] Ali O M Maka, Mubbashar Mehmood, Green hydrogen energy production: current status and potential, Clean Energy, Volume 8, Issue 2, April 2024, Pages 1–7, https://doi.org/10.1093/ce/zkae012

[2] Zahariev R., Valchkova N.. Collaborative Off-Road Robot with Hydrogen Fuel Cell for Healthcare. Pr. of Int. Conf. "ADP 2025", Sozopol, 2025, Bulgaria, 8, TU-Sofia,, 2025, ISSN:2682-9584, 35-43

[3] Paunski, Y., Angelov, G. Embedded Power Management System for Mobile Service Robots. 31st International Scientific Conference Electronics, ET 2022 - Proceedings, Institute of Electrical and Electronics Engineers Inc., 2022, ISBN:978-166549878-4, DOI:10.1109/ET55967.2022.9920299

[4] Horizon Educational, HSeries Fuel Cell Stacks (H300 datasheet: 300 W at 36 V, 3.9 L/min H2 , 40 % system efficiency).

[5] Heliocentris, HG Rack SeriesHG72 (K001303) (maximum 1.2 L/min, installed power 560 W, 19" rack form).

[6] Heliocentris, MHSMetal Hydride Storage Canisters (MHS 800) (600 Nl per canister with HG units; 4 Nl/min nominal discharge).

[7] SLAMTEC, "Athena 2.0 Robot Chassis Multi-Floor Navigation", 2024, https://www.slamtec.com/en/Athena2.