Integrating Standalone solar system with hydrogen fuel cell battery storage for emergency lighting

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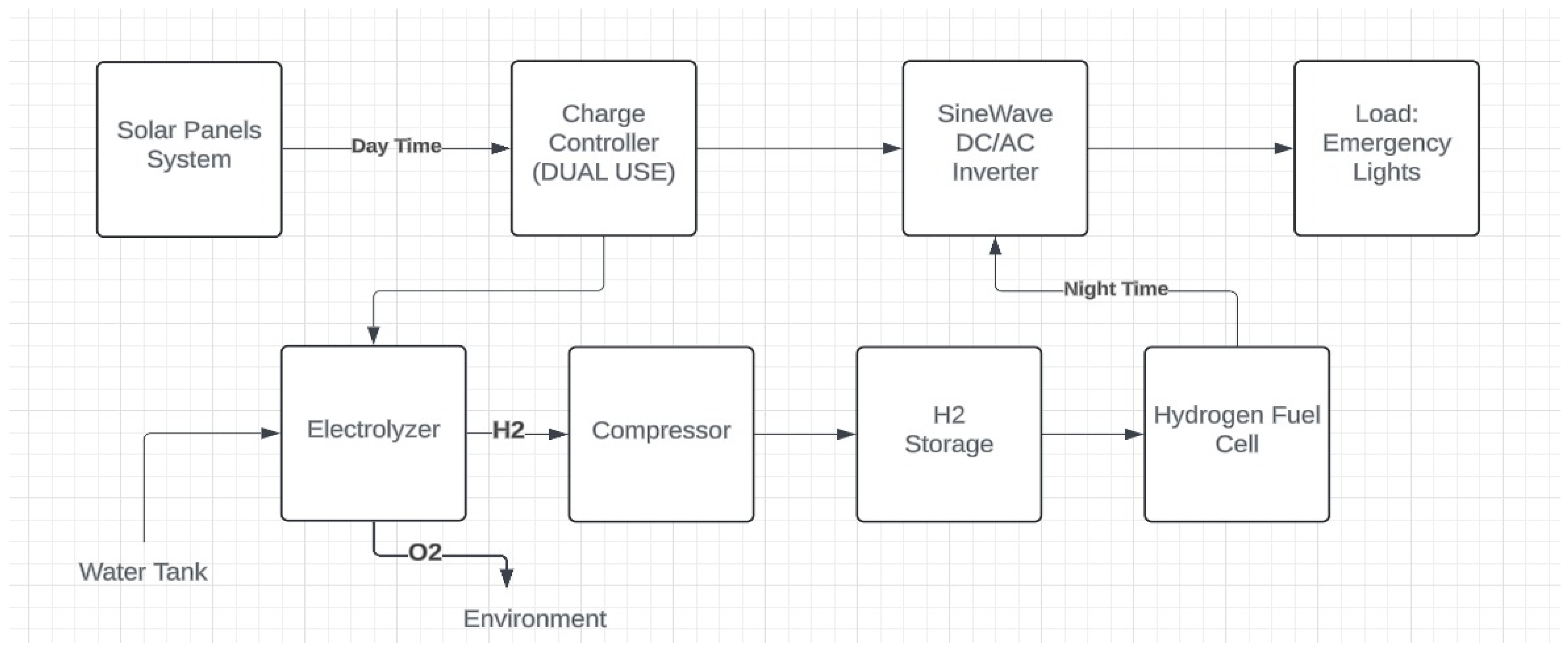
Introduction/Background

- **<u>Problem Statement:</u>** Traditional emergency lighting systems rely on fossil fuels or unstable power grids, causing environmental harm and risking failure during outages. There is a growing need for a clean, reliable, and cost-effective solution. Integrating solar panels and hydrogen fuel cells can provide sustainable backup power, supporting goals of Saudi Vision 2030 and reducing reliance on non-renewable energy.
- **<u>Project Objective</u>:** This project aims to integrate a standalone solar system with hydrogen fuel cell battery storage to supply emergency lighting during electricity outages. It focuses on creating a reliable, efficient, and scalable green energy source, while ensuring high output, safety, ease of use, and affordability.
- **<u>Constrains:</u>**
  1. **Safety:** Hydrogen is a flammable compound, that is why we need a special lab to deal with it and temperature ranges from -10 to 40.
  2. **Economical:** The system should be cost effective. For prototype: Cost ≤ 6000 SAR.
  3. **Environmental:** This project must use environmentally friendly materials, with at least 80% of the materials being eco-friendly.
- **<u>Specifications:</u>**
  1. **Output voltage from the hydrogen fuel stack:**12 volts
  2. **Number of hydrogen cells:** 12
  3. **Amount of H_2O in the input:** 85.5 mL
  4. **Electrolysis efficiency:** 52%
  5. **Hydrogen fuel cell efficiency:** 60%
  6. **Solar panel volt output:** 12 volts
  7. **Solar panel watt output:** 200 watts
  8. **Light luminosity:** 800 lumens

Prototype Design



Calculations

Load: Emergency Lights:

$$P_1 = P_2 = 9\,W$$

I have chosen parallel connection:

$$I = \frac{P}{V} = \frac{P_1 + P_2}{V} = \frac{9\,W + 9\,W}{220} = 0.082\,A$$

Unlike in series which would require up to $P = 36\,W$,

Also, the lights would dampen each other due to its connection.

SineWave DC/AC Inverter:

It will take the Input either from Solar Panels, or from Hydrogen Fuel Cells.

Its Input:

$V_{DC} = 12\,V$

$P_{in} = 25\,W$ *to maintain* $85\% - 95\%$ *efficiency due to losses*

$$I = \frac{25\,W}{12\,V} = 2.083\,A$$

Its Output:

$$V_{AC} = 220\,V$$

$P_{out} = 25\,W$ *to maintain* $85\% - 95\%$ *efficiency due to losses*

Charge Controller:

The type of Charge Controller we will use Maximum Power Point Tracking, which should withstand the following:

$$P_{In} = 200\,W$$

$$V_{in} = 12\,V_{DC}$$

The output should match the input to maximize the efficiency of Solar Panels and to manage power flow during daytime and nighttime.

Solar Panels:

$$V_{out} = 12\,V$$

$P_{out} = 200\,W$ *to maintain both operations during daytime, which are producing power for inverter and load, also the operation of the "Electrolyzer":*

The Electrolyzer requires:

$$V_{in} = 12\,V_{DC}$$

$$P_{in} = 100\,W$$

The Electrolyzer consumes from $50 - 100\,W$, so we chose the maximum due to losses

Electrolysis Reaction:

$2H_2O(l) \rightarrow 2H_2(g) + O_2(g)$

Moles of $H_2 = \frac{9.5\ grams}{2g/mol} = 4.7\ moles\ of\ H_2$

Mass of $H_2O = 4.75\ mol \times 18\frac{g}{mol} = 85.5\ grams\ of\ water$

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Testing / Validation

Metric	Ideal Value	Tested value
Output voltage from the hydrogen fuel stack	12	9.3
Number of Hydrogen cells	12	12
Amount of H2O in the input	85.5	85.5
Electrolysis Efficiency	52	52
hydrogen fuel cell Efficiency	60%	60%
Solar panel volt output	12	18
Solar panel Watt output	200	200
Light luminosity	800	800

Conclusion

This project successfully demonstrates the development of an efficient, environmentally friendly emergency lighting system by integrating solar energy and hydrogen fuel cells. The system addresses the growing demand for sustainable energy solutions by providing a reliable, clean, and cost-effective alternative to traditional power sources. It aligns with global sustainability goals, such as reducing carbon emissions and dependency on fossil fuels. Future improvements can focus on enhancing system efficiency, scalability, and broader applications in various emergency scenarios.

Recommendations

Future improvements to this model could include automating the system. For instance, automating the hydrogen storage valve to initiate the process at night and optimizing the solar panel tilt to maximize energy capture from the sun.

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