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Interface Engineering in Hybrid Energy Systems: A Case Study of Enhance the Efficiency of PEM Fuel Cell and Gas Turbine Integration

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INTRODUCTION & AIM

Integrating electrochemical fuel cells and internal combustion units can enhance energy power systems' total efficiency and sustainability. This study presents a promising solution by integrating a Proton Exchange Membrane Fuel Cell (PEMFC) with a mini gas turbine system, forming a hybrid system named the "Oya System." This approach aims to mitigate the efficiency losses of gas turbines during high ambient temperatures.

The hybrid model was designed using Aspen Plus for modelling and the EES simulation program for solving mathematical equations. The primary objective of this research is to enhance the efficiency of gas turbine systems, particularly under elevated ambient temperatures. The results demonstrate a notable increase in efficiency, rising from 37.97% to 43.06% at an ambient temperature of 10°C (winter) and from 31.98% to 40.33% at an ambient temperature of 40°C (summer). This improvement, ranging from 5.09% in winter to 8.35% in summer, represents a significant achievement aligned with the goals of the Oya System. Furthermore, integrating PEMFC contributes to environmental sustainability by utilizing hydrogen, a clean energy source, and reducing greenhouse gas emissions. The system also enhances efficiency through waste heat recovery, further optimizing performance and reducing energy losses. This research highlights the critical role of interface engineering in the hybrid system, particularly the interaction between the PEMFC and the gas turbine. Integrating these two systems involves complex interfaces that facilitate the transfer of electrochemistry, energy, and materials, optimizing the overall performance. This aligns with the conference session's focus on green technologies and resource efficiency. The Oya System exemplifies how innovative hybrid systems can enhance performance while promoting environmentally friendly processes.

METHOD

1. Designed a hybrid gas turbine PEM fuel cell system.
2. Used Aspen Plus for process simulation.
3. Applied EES for thermodynamic and mathematical analysis.
4. Recovered exhaust heat to produce hydrogen via steam methane reforming (SMR).
5. Fed hydrogen into the PEM fuel cell to generate extra power.
6. Validated models using published performance data.

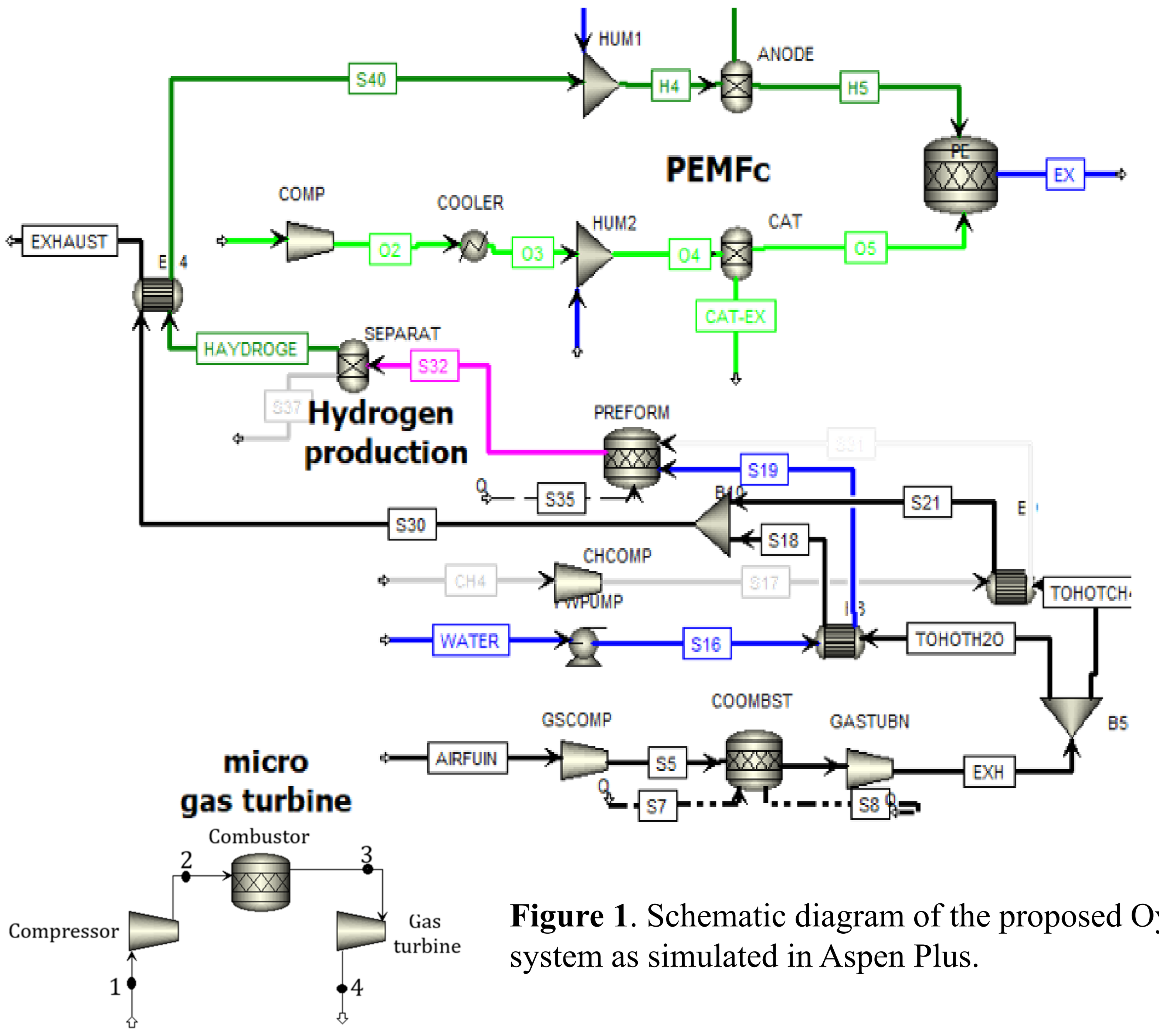


Figure 1. Schematic diagram of the proposed Oya system as simulated in Aspen Plus.

RESULTS & DISCUSSION

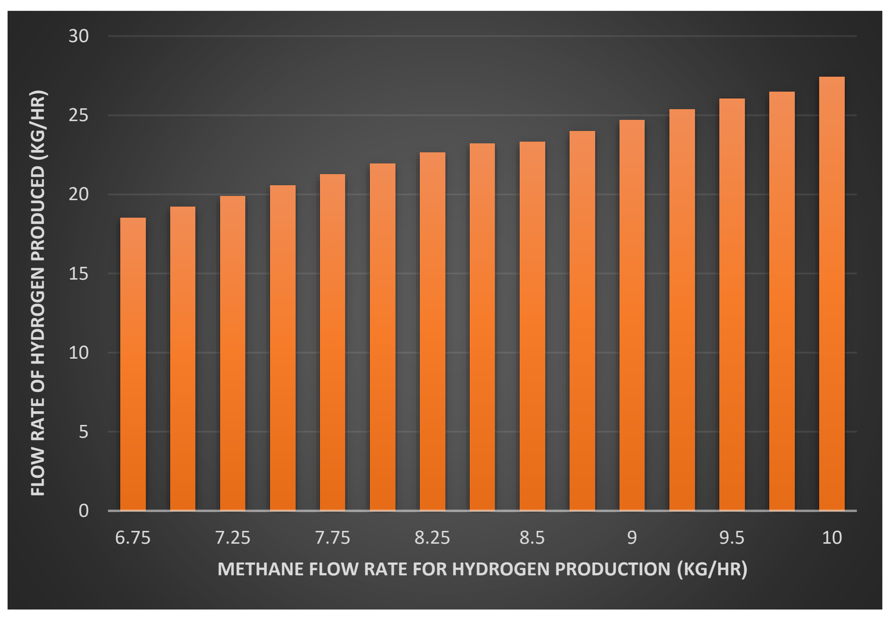


Figure 2. The relationship between methane flow rate to the steam reformer and the rate of hydrogen production

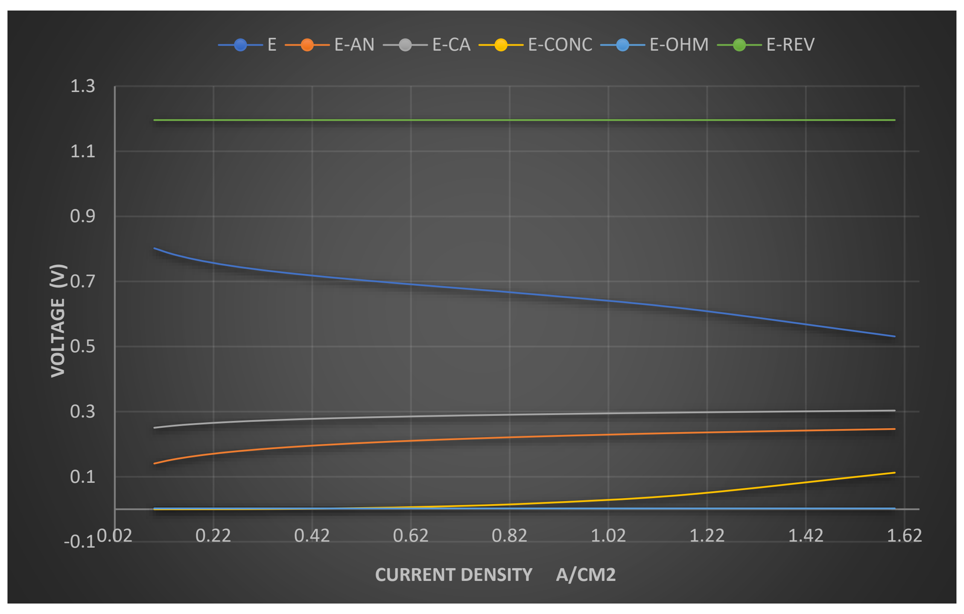


Figure 5. Types of voltage and voltage losses in the PEM fuel cell.

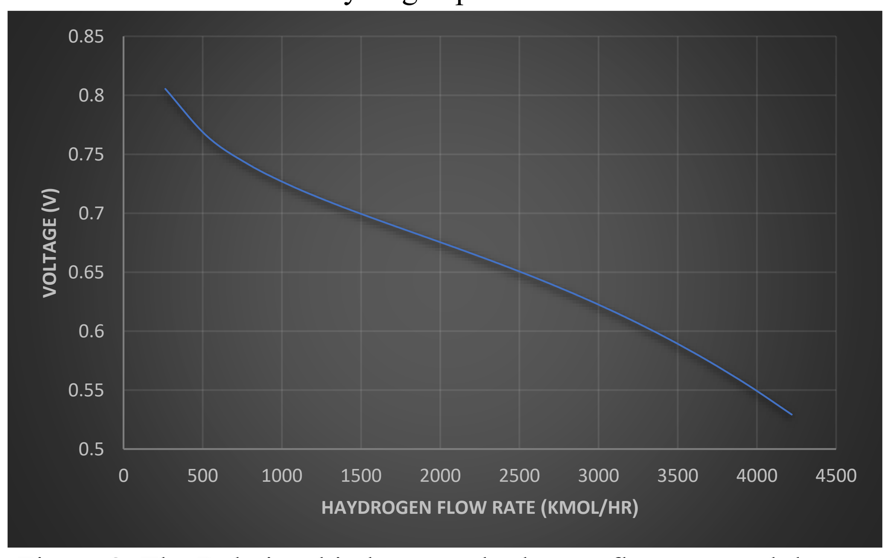


Figure 3. The Relationship between hydrogen flow rate and the useful voltage output from the PEM fuel cell.

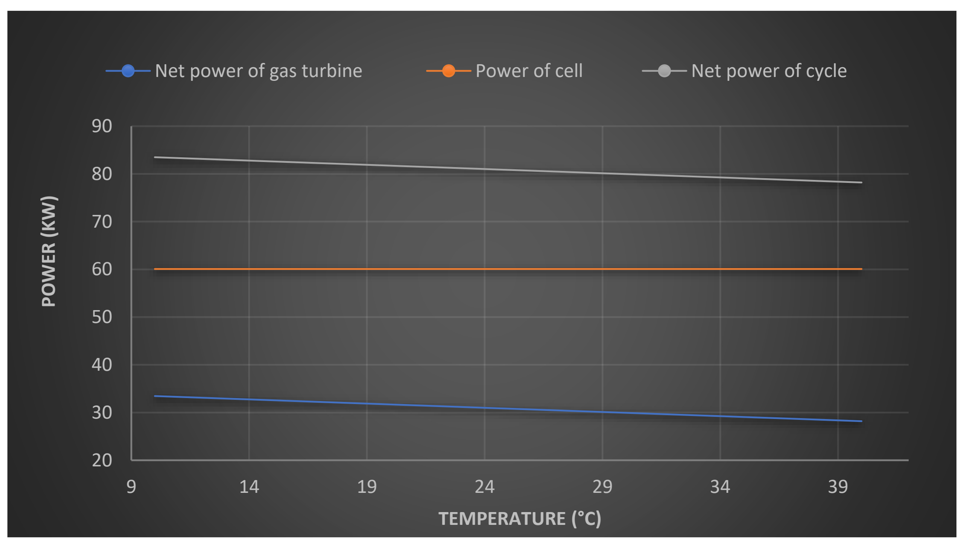


Figure 6. Net power output of the Oya hybrid system components versus ambient temperature.

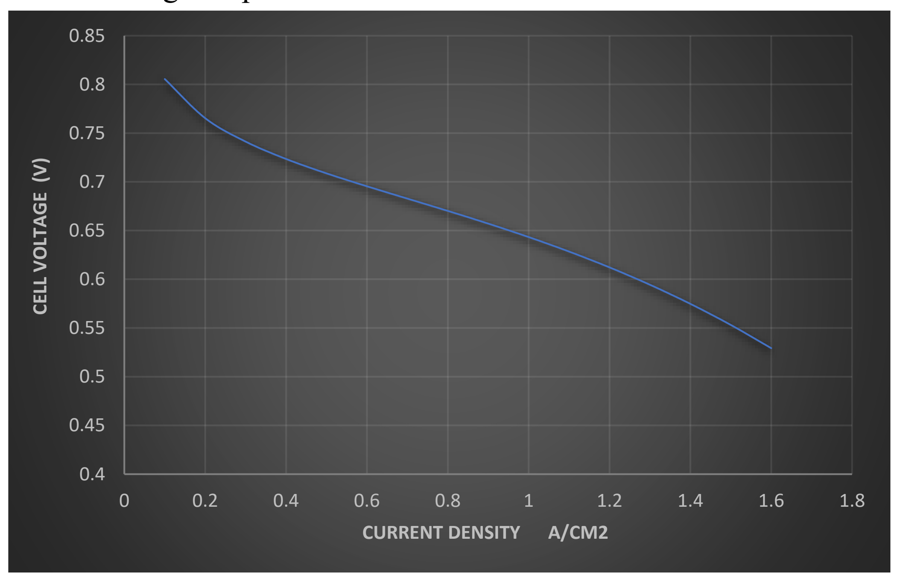
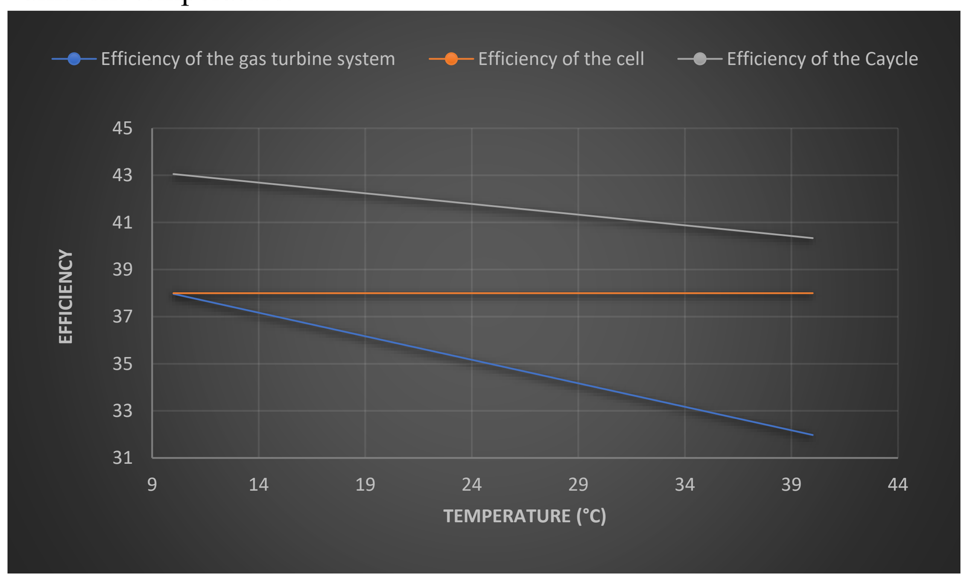


Figure 4. Relationship between cell current density and cell voltage (Polarization Curve).



Efficiency curve of the Oya hybrid system.This illustrates how the efficiency of the gas turbine alone and the combined Oya hybrid system (gas turbine + PEM fuel cell) changes with temperature

CONCLUSION

This study introduces the "Oya Cycle“ a hybrid energy system that combines a gas turbine with a Proton Exchange Membrane Fuel Cell (PEMFC) to enhance efficiency, especially in hot climates. By utilising the turbine's exhaust heat to produce hydrogen for the fuel cell, the system significantly boosts performance. The Simulation results show that while the efficiency of a standalone gas turbine drops with rising temperatures, the hybrid system maintains high efficiency, reaching up to 43.06% in winter and 40.33% in summer. This marks an improvement of up to 8.35%, making it a strong candidate for energy systems in warm regions. The PEMFC's stable output, regardless of ambient conditions, and the on-site hydrogen production make the system both efficient and sustainable. Overall, the Oya Cycle offers an innovative, eco-friendly solution to modern energy challenges, combining reliability with cleaner power generation.

FUTURE WORK / REFERENCES

FUTURE WORK

1. Validate the hybrid system experimentally.
2. Optimize heat exchanger and dynamic reformer design.
3. Explore renewable-based hydrogen production.
4. Develop advanced control strategies.

REFERENCES

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