Cogénération Stirling, production d'électricité

Free Piston Stirling Engine as a Heat Recovery Option for a Solid Oxide Fuel Cell based Trigeneration Microgrid

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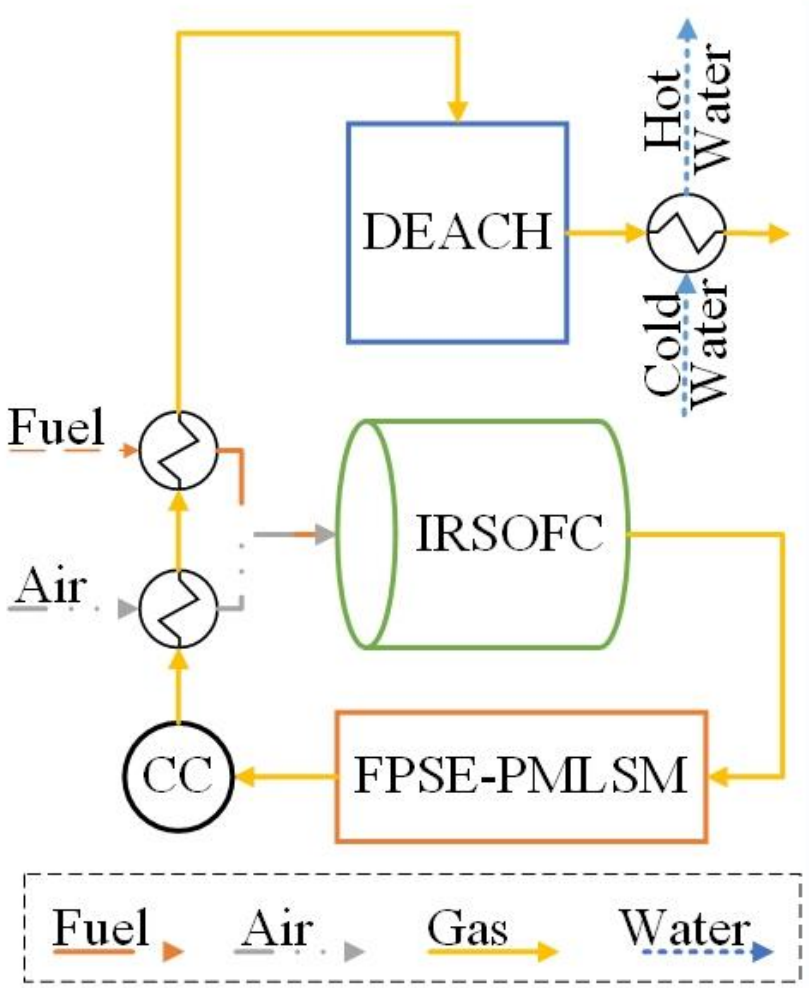
Introduction



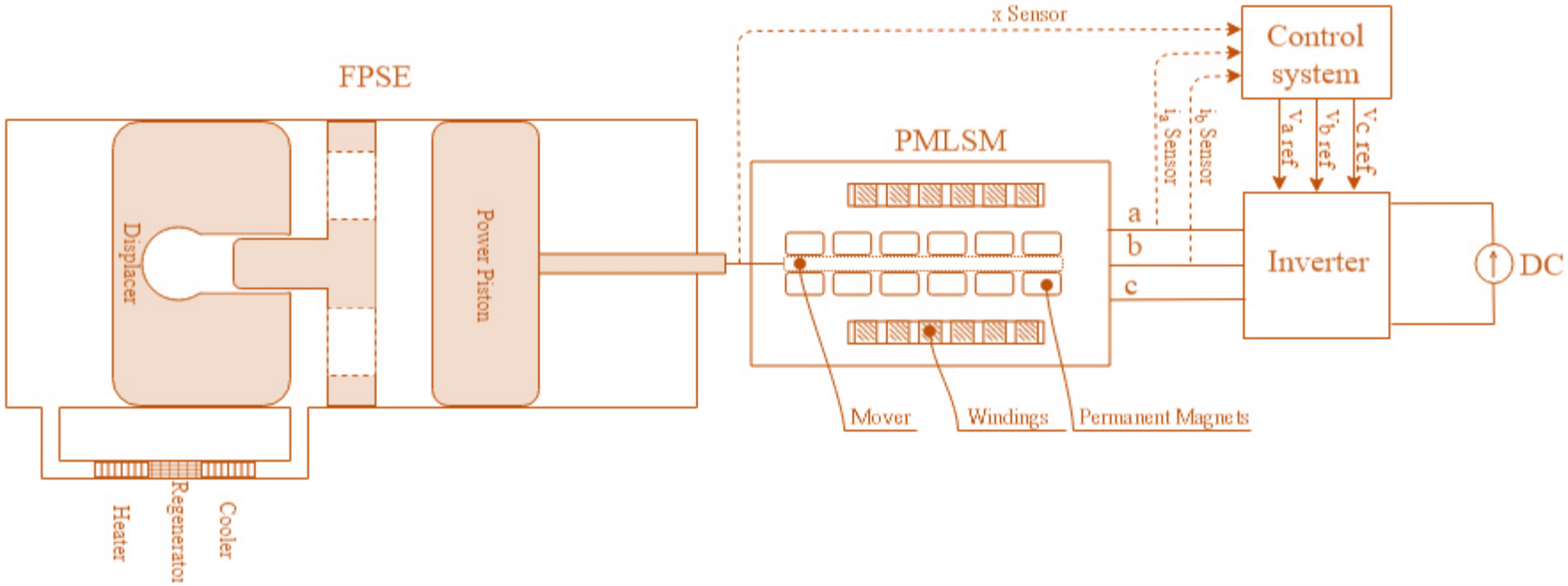
DEACH: Double Effect Absorption Chiller

IRSOFC: Internal Reforming Solid Oxide Fuel Cell

FPSE-PMLSM: Free Piston Stirling Engine - Permanent Magnet Linear Synchronous Machine

CC: Combustion Chamber

Introduction



Compact & Lightweight

Sealed

Reliable

$$\frac{\text{Efficiency}}{\text{Cost}}$$

Methodology
1- Modeling

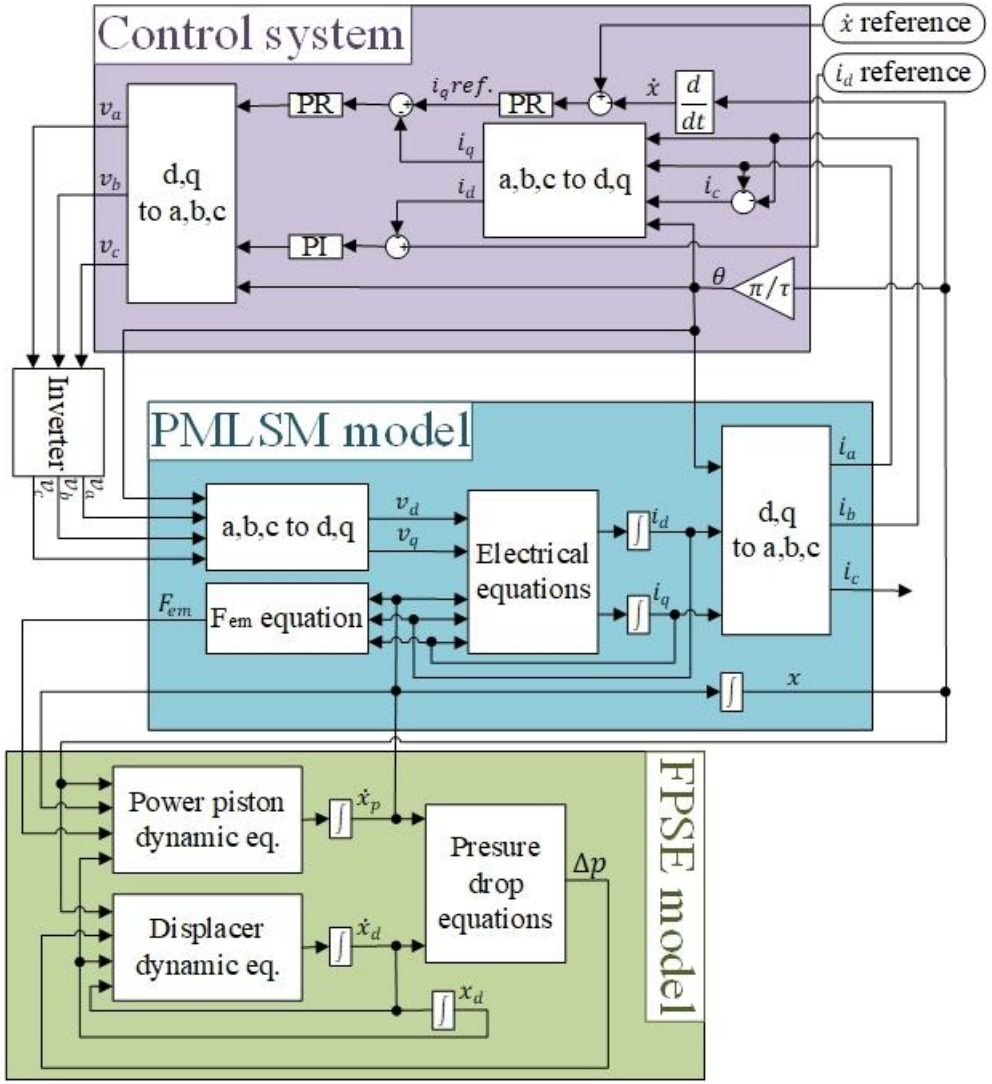
Free Piston Stirling Engine — Dynamic Model, Thermic Model

Permanent Magnet Linear Synchronous Machine — Electric Model

Non-linear Thermo-dynamic Model

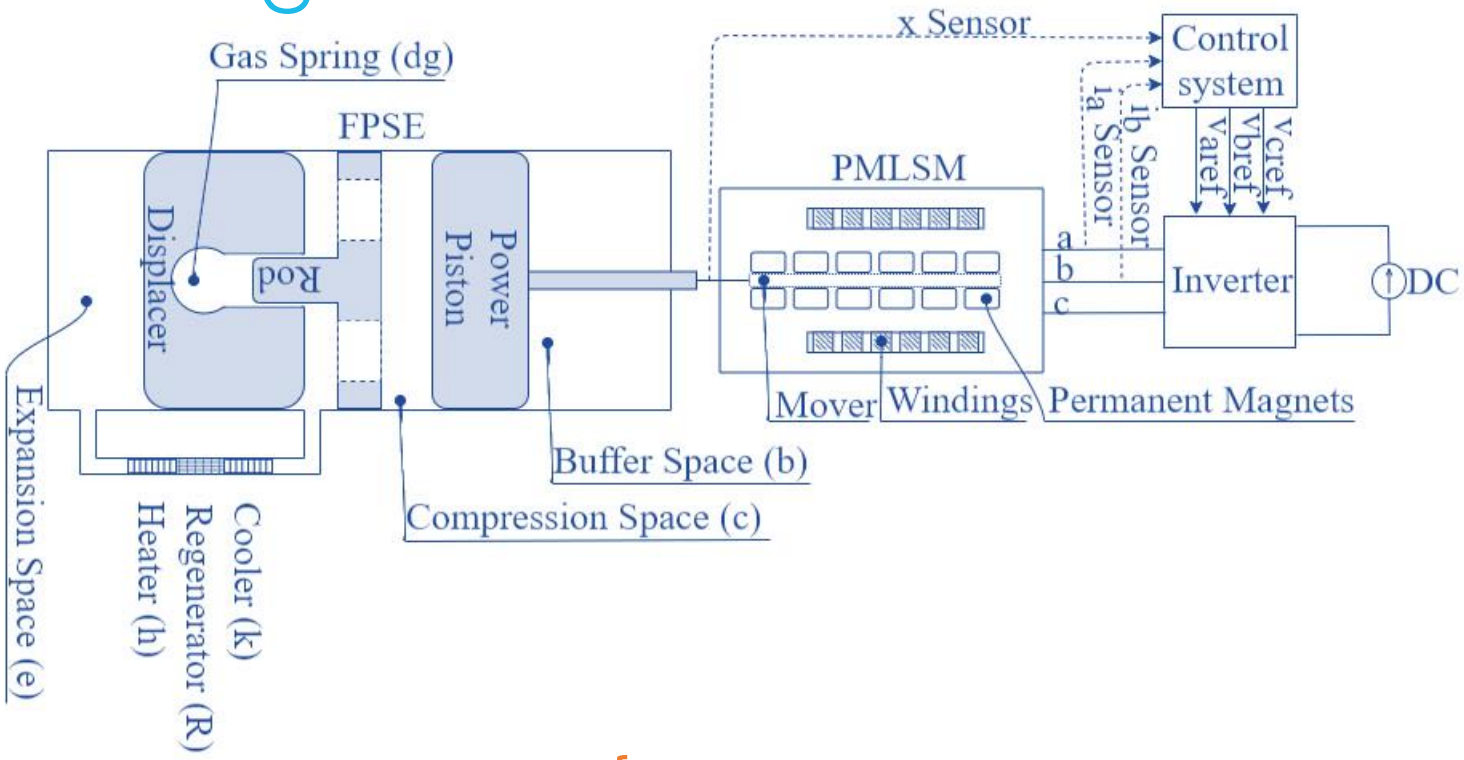
Thermo-electro-dynamic model

Methodology
1- Modeling



Electro-Dynamic model by MATLAB SIMULINK

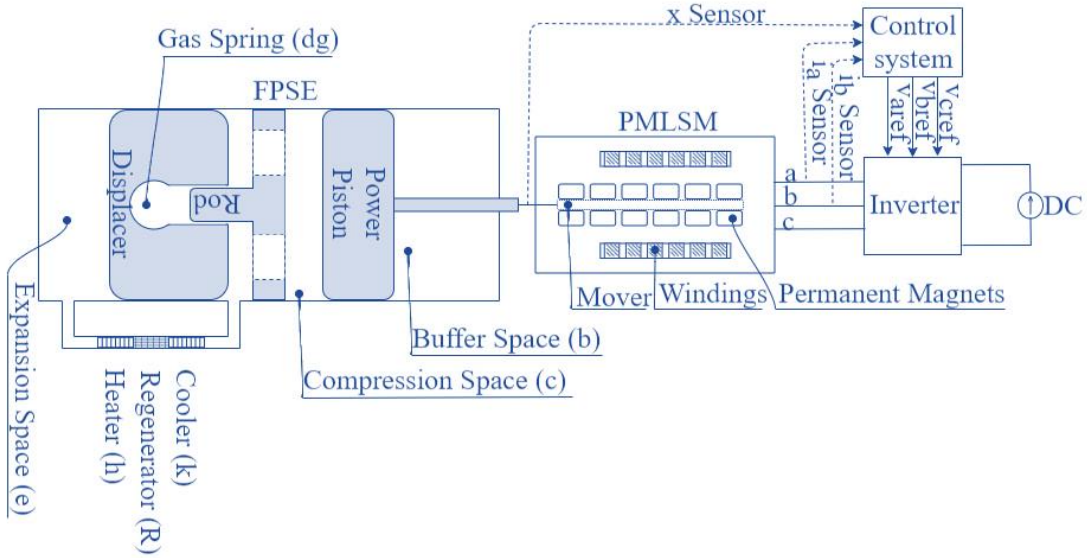
Methodology
2- Optimizing

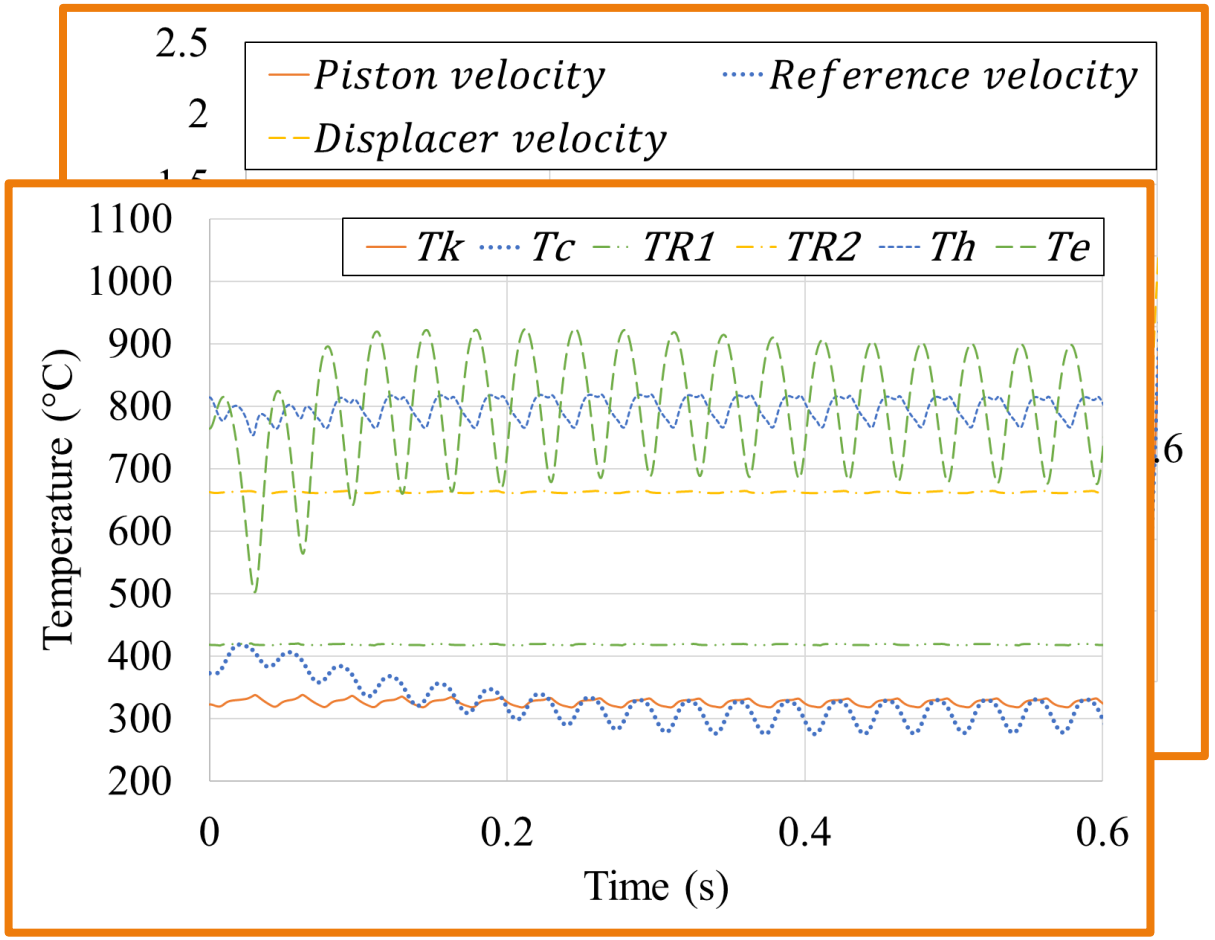


Control Parameters
- Reference velocity amplitude
- Reference velocity frequency

Results and Discussion

1- FPSE-PMLSM (Modeling)



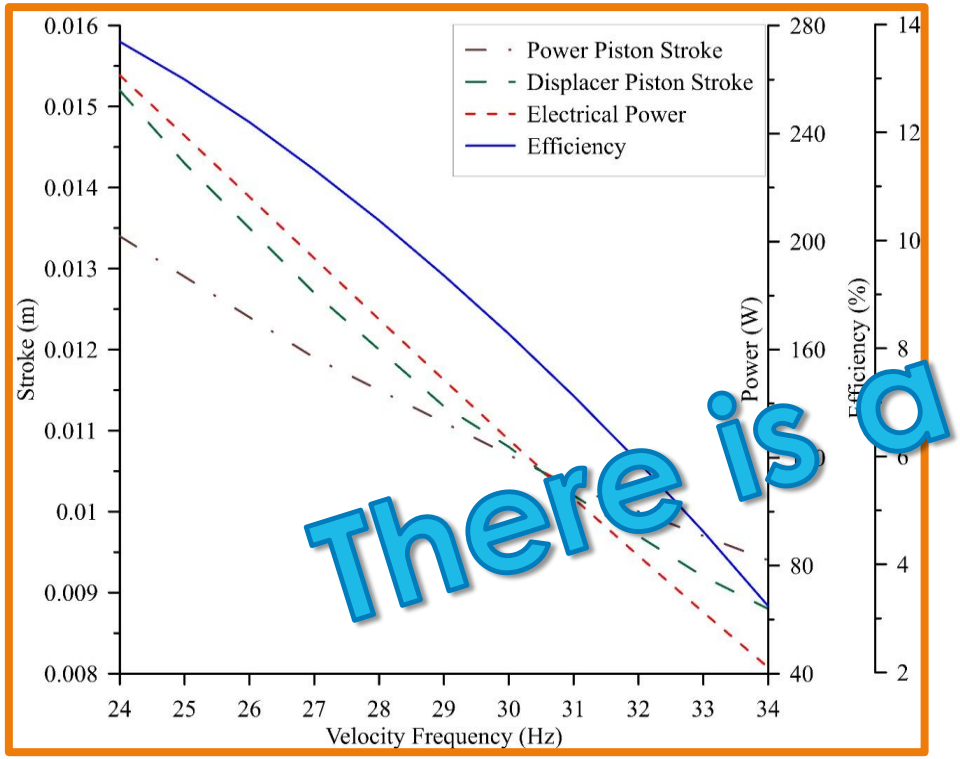


- The system is well controlled

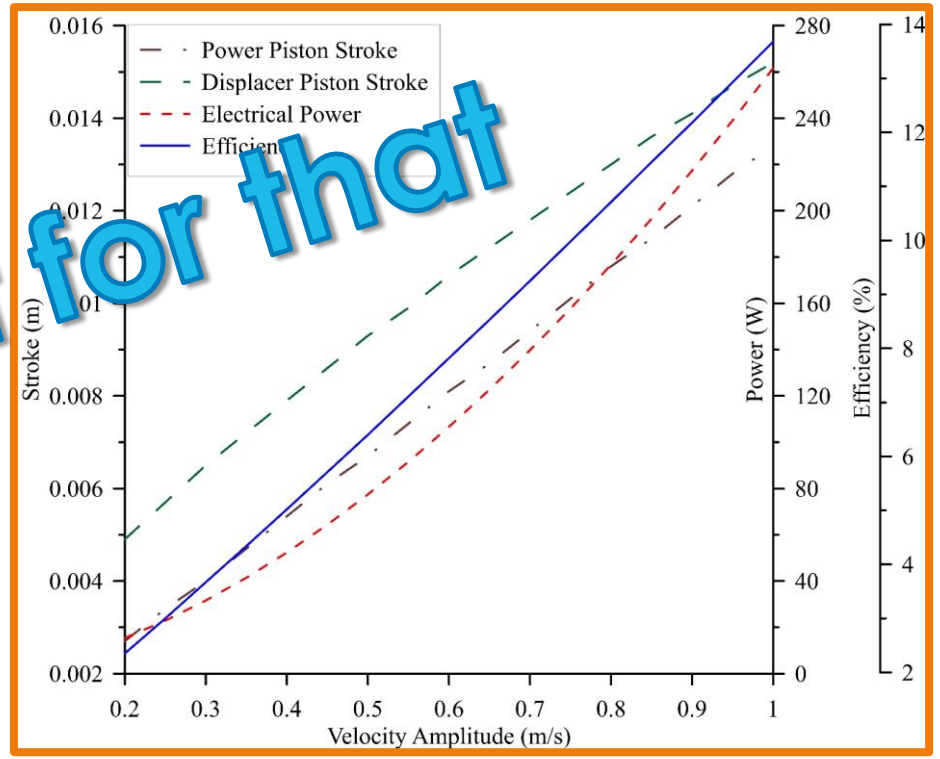
- The variations of temperatures in steady-state are always around a specific value

Results and Discussion

1- FPSE-PMLSM (Optimizing) *by speed Frequency and amplitude*



There is a limit for that

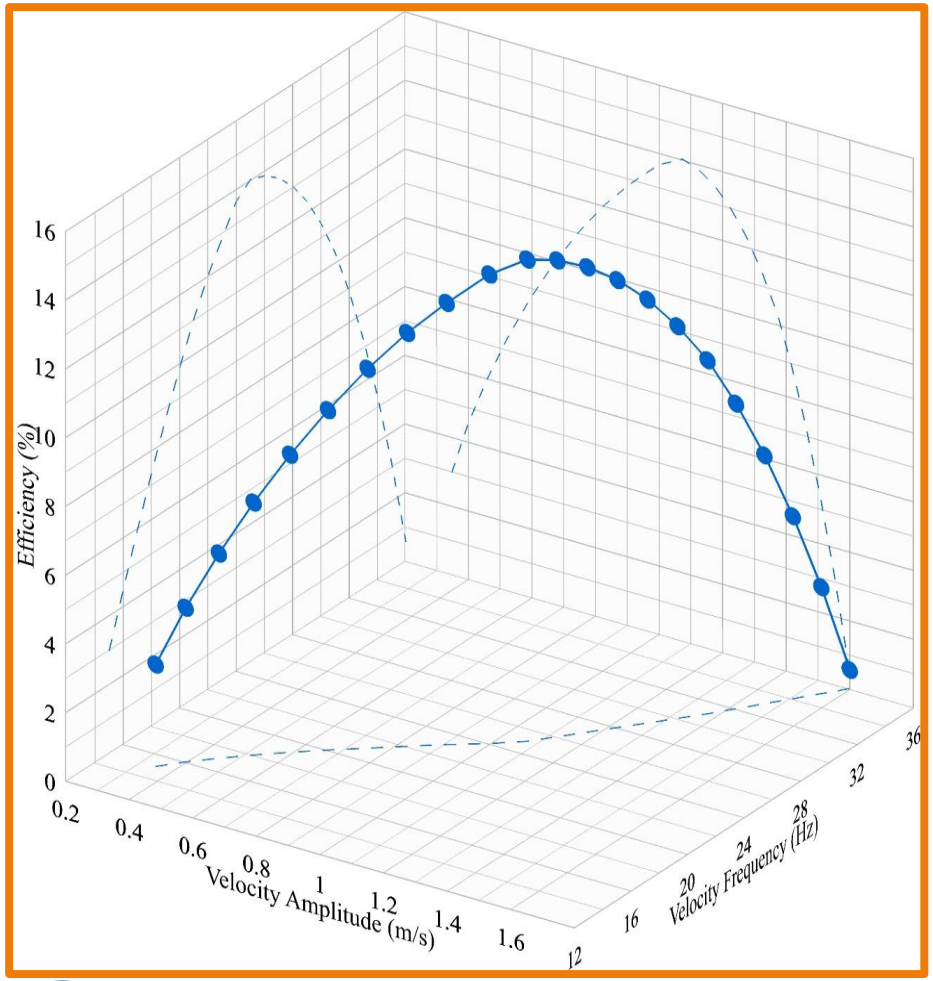


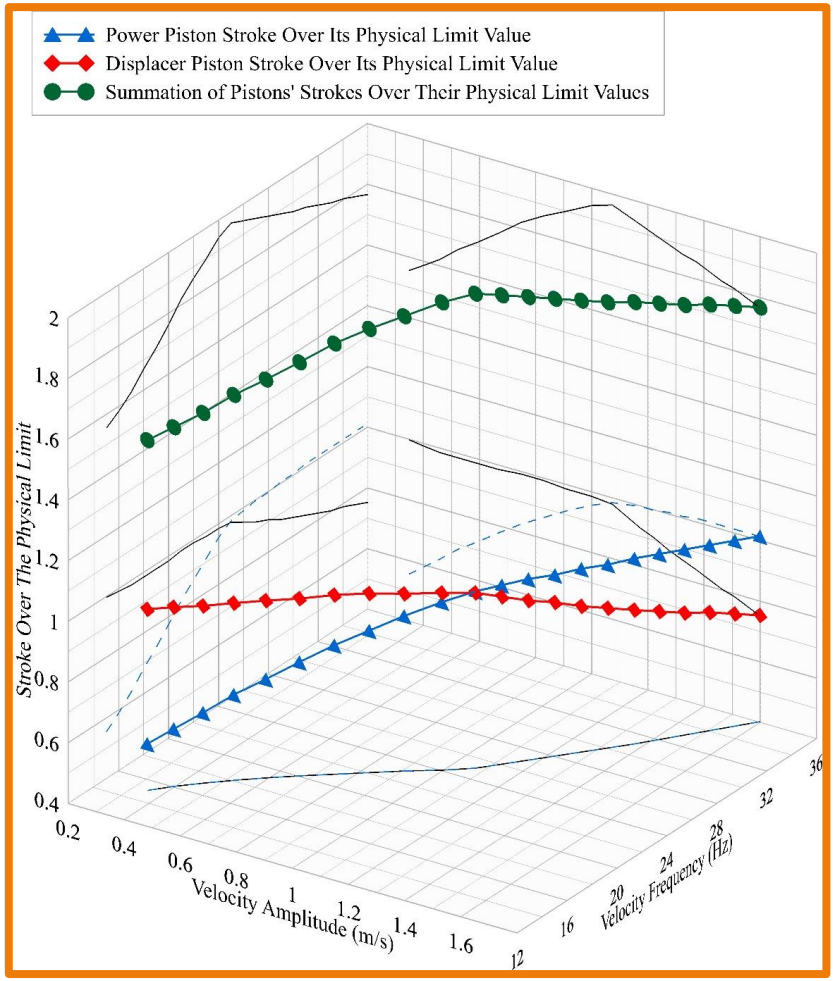
- At a constant reference velocity amplitude, its frequency should be as small as possible

- At a constant reference velocity frequency, its amplitude should be as large as possible

Results and Discussion

1- FPSE-PMLSM (Optimizing)



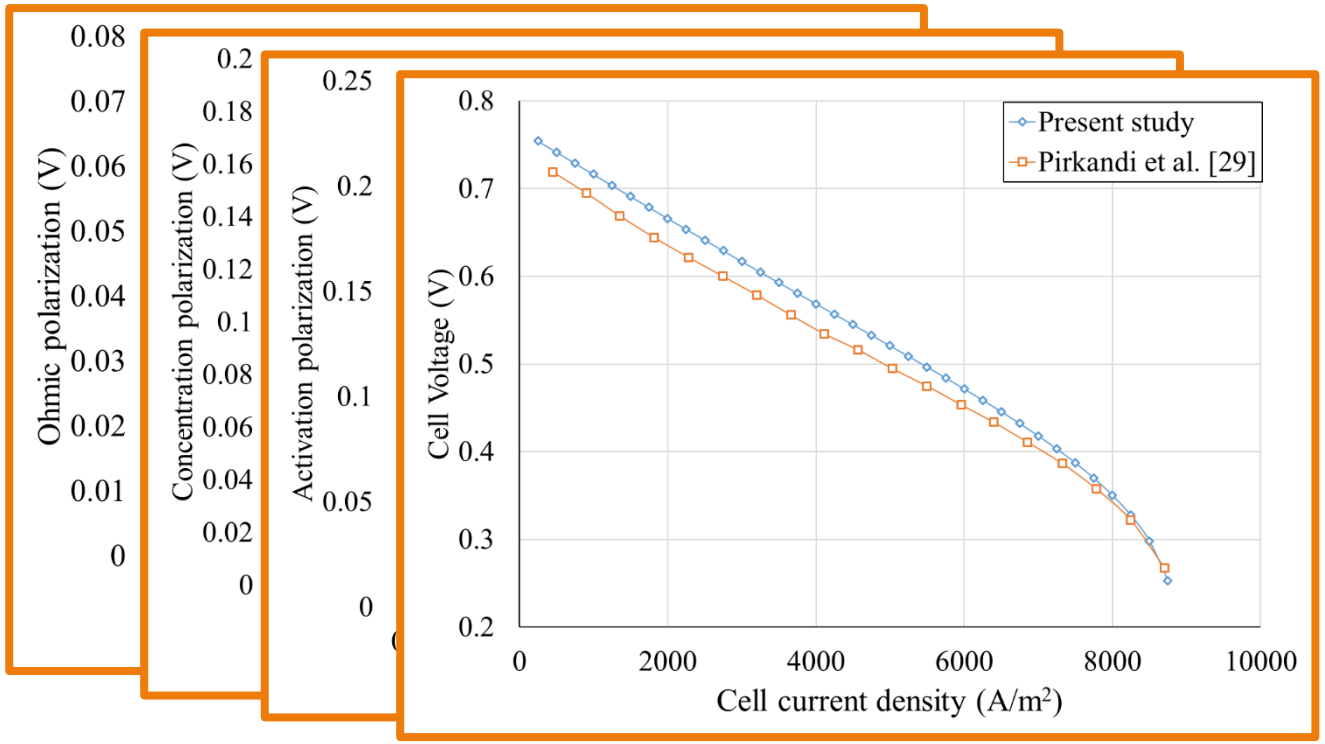


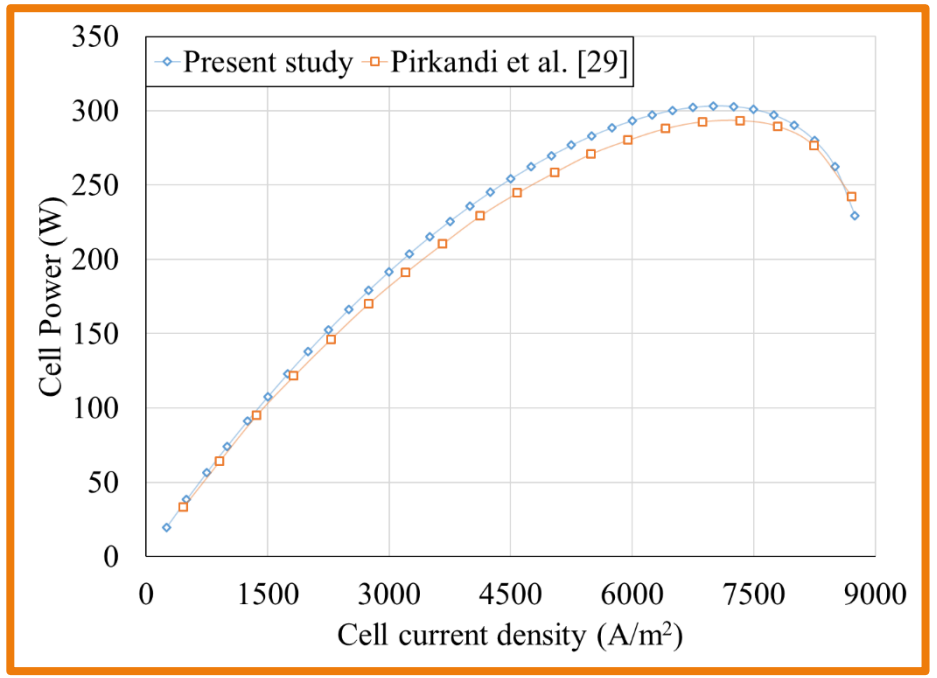
- Optimal working point: 1.075 $m \cdot s^{-1}$ and 25 Hz

- Both strokes are important

Results and Discussion

1- IRSOFC



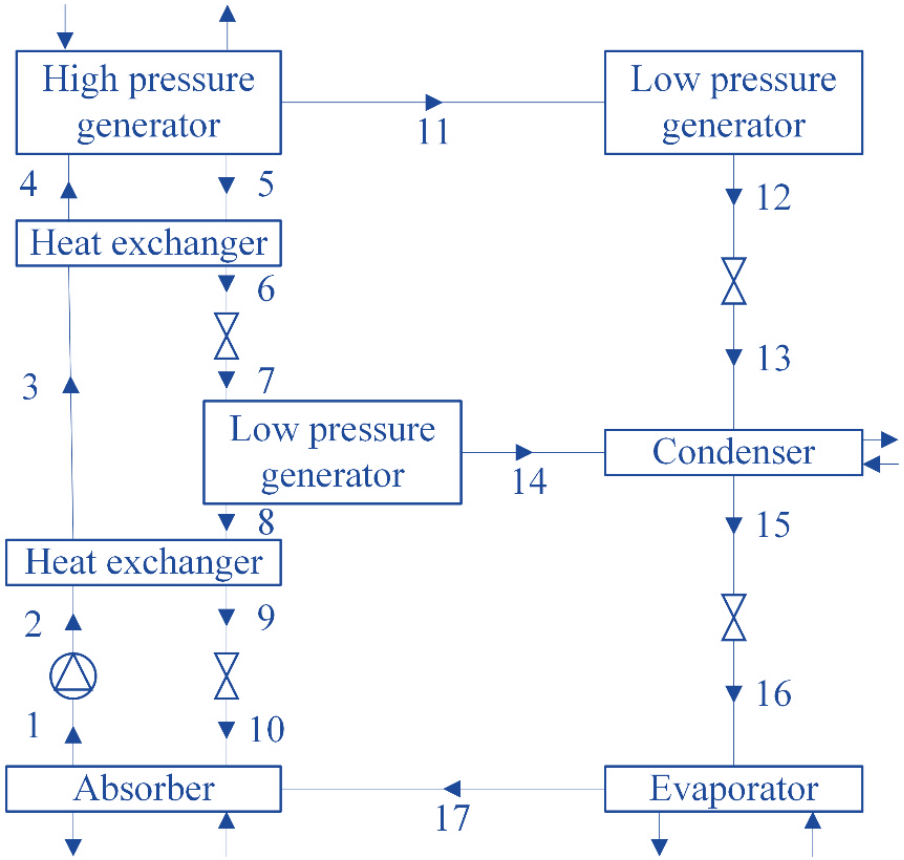


- By increasing the current density, the cell voltage is decreasing

- The IRSOFC model is valid

Results and Discussion

1- DEACH

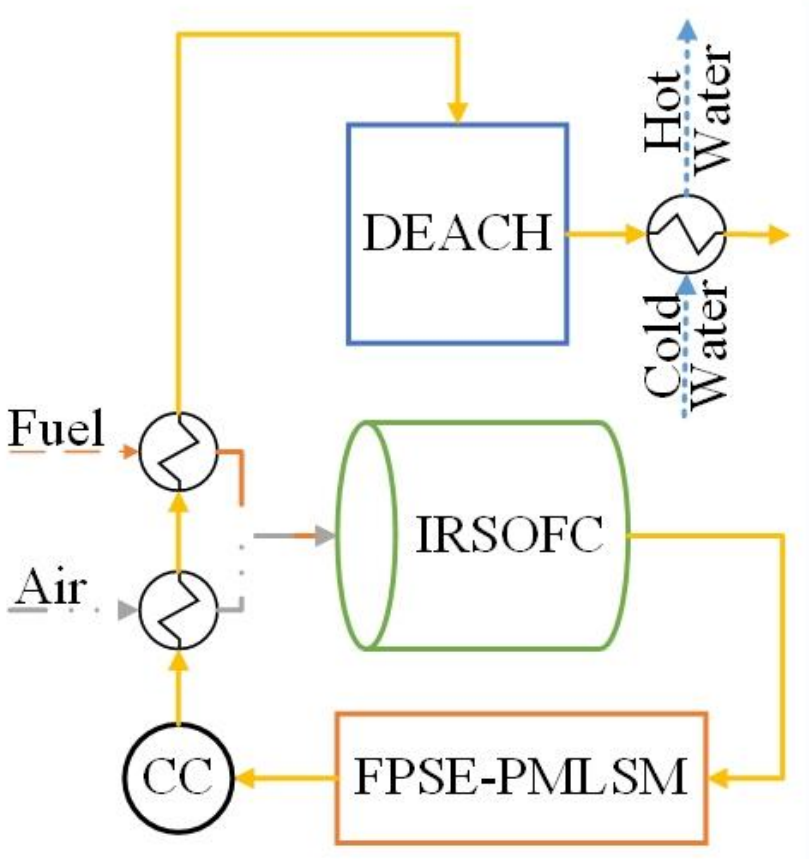


- The refrigerant and the absorbents are water and lithium bromide, respectively

- Components of the DEACH are in three pressure levels and five temperature levels

	Present Study	Gebreslassie et al.	Error (%)
COP	1.6012	1.655	3.2

Results and Discussion
2- Trigeneration System



IRSOFC	1981 W
FPSE-PMLSM	279.4 W
DEACH	1366.6 W
Hot water	0.27 kg/s (60˚C)
Input heat	6165.4 W

$$\eta = \frac{Power_{IRSOFC} + Power_{FPSE-PMLSM} + \dot{Q}_{DEACH} + \dot{Q}_{Hotwater}}{\dot{Q}_{Input}}$$

$\eta_{total} = 72.14\%$ 40% ↑

$\eta_{electrical} = 36.7\%$ 14.1% ↑

Conclusion

- A nonlinear thermo-dynamic model of a Free Piston Stirling Engine (FPSE) to have enough accurate results was developed.
- An electrical model of a Permanent Magnet Linear Synchronous Machine (PMLSM) was established.
- A combined thermo-electro-dynamic model of the FPSE-PMLSM was developed that allowed to do an optimization based on the control system.
- Internal Reforming Solid Oxide Fuel cell (IRSOFC) and Double Effect Absorption Chiller (DEACH) were modeled and validated.
- A combined Trigeneration system (IRSOFC-FPSE-PMLSM-DEACH) was studied and the improvement of the efficiency was shown.
- The enthalpy pumping loss of the FPSE was also studied.

Publications

- Majidniya, M., Boileau, T., Remy, B., & Zandi, M. (2020). Nonlinear modeling of a free piston stirling engine combined with a permanent magnet linear synchronous machine. Applied Thermal Engineering, 165, 114544.

- Majidniya, M., Boileau, T., Remy, B., & Zandi, M. (2020). Performance simulation by a nonlinear thermodynamic model for a Free Piston Stirling Engine with a linear generator. Applied Thermal Engineering, 116128.

- Majidniya, M., Boileau, T., Benjamin, R., & Zandi, M. (2019, June). Modélisation thermo-électrique d'un moteur Stirling à piston libre et d'une machine synchrone linéaire à aimant permanent avec sa commande. In congrès annuel de la Société Française de Thermique.

- Majidniya, M., Boileau, T., Benjamin, R., & Zandi, M. (2019, June). Thermoelectric modeling of a Free Piston Stirling Engine (FPSE) combined with a Permanent Magnet Linear Synchronous Machine (PMLSM) with its control system. In International Conference on Renewable Energy and Distributed Generation of Iran.

Thank you for your attention

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