Project Proposal

Inverted Brayton Cycle Gas Turbine Layouts Identification and Evaluation

General Information

Type:	Semester Project (10 ECTS)
Laboratory:	Laboratory for Applied Mechanical Design (LAMD)
Supervisors:	G. Iovanna; Prof. J. Schiffmann
Location:	Neuchâtel[1] (travel allowance offered)
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Background

This semester project is in the context of an ongoing research project at LAMD on the development of a 10 kWe solid oxide fuel cell - micro gas turbine (SOFC-mGT) hybrid power generation system. This hybridization consists of the expansion of the SOFC anode of gas (AOG) through an inverted Brayton cycle (IBC). The AOG is first oxycombusted to increase the temperature and obtain a pure mixture of CO_2 and H_2O. After the oxycombustion, the gas is expanded to subatmospheric pressure through a radial inflow turbine. The steam is then condensed and the remaining gas, composed of pure CO_2, is compressed through a centrifugal compressor to ambient pressure, while the condensed water is extracted by a pump.

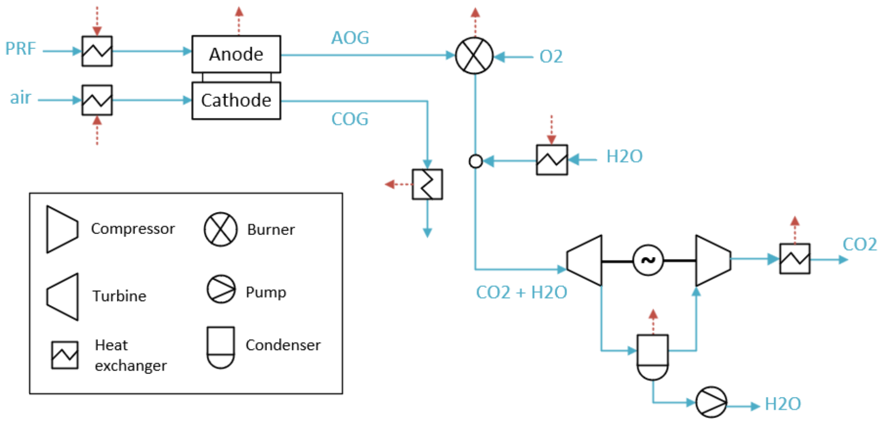


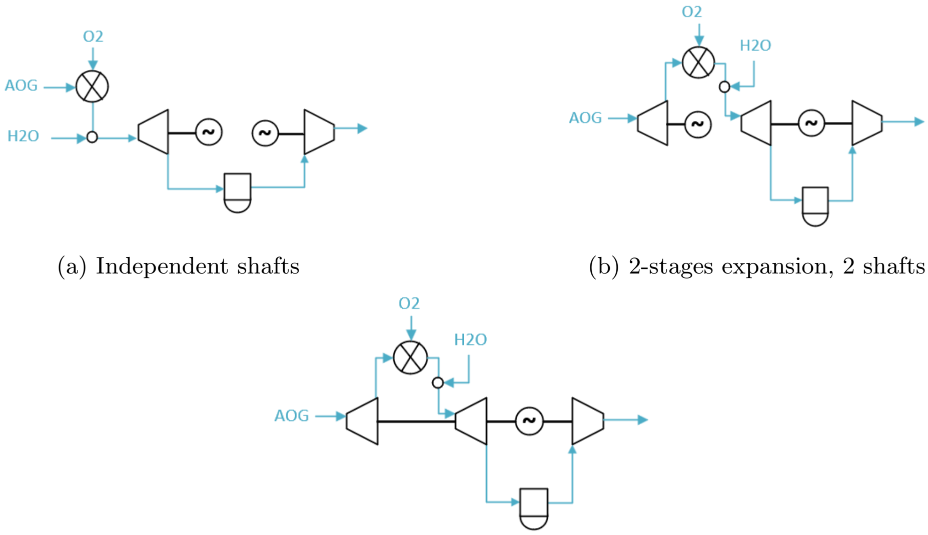
Figure 1: Diagram of the hybrid system with a single stage turbine and compressor mGT

The mGT layout illustrated in Figure 1 consists of a single stage radial inflow turbine and a single stage centrifugal compressor integrated on the same shaft. Many other mGT layouts can be implemented to achieve the same goal. Some examples are illustrated in Figure 2.

Objective

The objective of this semester project is an extended and quantitative comparison of the different mGT layouts suitable for the hybrid power generation system described above. Comparison metrics should include aspects related to performance (isentropic efficiency, net power output) and system complexity.

[1]The possibility to work from the EPFL main campus in Lausanne can be discussed



(a) Independent shafts

(b) 2-stages expansion, 2 shafts

(c) 2-stages expansion, 1 shaft

Figure 2: Examples of mGT alternative layouts

Tasks

1. **Literature review:**
   Study the existing literature on mGT IBC systems. Review of the existing methods for the estimation of the isentropic efficiency of radial turbomachines.
2. **Layouts identification:**
   Identify a set of IBC mGT layouts suitable for the IBC application adapted to the SOFC-mGT system described above. Explore variation in number of compression and expansion stages and different possible rotor configurations.
3. **Comparison metrics evaluation:**
   Estimate the isentropic efficiency of the identified layouts using existing reduced-order models. Evaluate the complexity of the different layouts in terms of number of components, cost, and complexity of the individual components.
4. **Comparative analysis:**
   Establish appropriate weights for the different evaluation metrics and compare the layouts using scoring tables.

NB: adjustments may be required according to progress, results, and project duration.

Prerequisite knowledge

1. Thermodynamics
2. MATLAB

References

[1] E. Facchinetti, D. Favrat, and F. Marechal. Design and optimization of an innovative solid oxide fuel cell–gas turbine hybrid cycle for small scale distributed generation. *Fuel Cells*, 14(4):595–606, 2014.

[2] Victoria He, Michele Gaffuri, Jan Van herle, and Jürg Schiffmann. Readiness evaluation of SOFC-MGT hybrid systems with carbon capture for distributed combined heat and power. *Energy Conversion and Management*, 278, 2023.

[3] Violette Mounier, Luis Eric Olmedo, and Jürg Schiffmann. Small scale radial inflow turbine performance and pre-design maps for organic rankine cycles. *Energy*, 143:1072–1084, 2018.

[4] Violette Mounier, Cyril Picard, and Jürg Schiffmann. Data-driven predesign tool for small-scale centrifugal compressor in refrigeration. *Journal of Engineering for Gas Turbines and Power*, 140(12), 2018. Number: 12.

[5] O. E. Balje. *Turbomachines: A Guide to Design Selection and Theory*. Wiley, 1981.