



Design and Analysis of a 25 MWe Supercritical CO₂ Turbo Machine

Paper 46

Wanming Zhang (presenter)

Research Scientist, GE Vernova Advanced Research

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Amin Changizi (Lead author), GE Vernova Advanced Research

Sylvain Pierre, Yuankang Chen, Dan Bacellar and Thomas Mancuso (co-authors)



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Amin Changizi, Sylvain Pierre, Yuankang Chen
Dan Bacellar, Thomas Mancuso
GE Vernova Advanced Research, Niskayuna, NY

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Motivation & Program Context



DOE decade-long effort to commercialize **sCO₂ RCBC**

- DOE Contract: **DE-EE0010318**

Partners:

- GE Vernova Advanced Research
- SwRI
- Sandia National Laboratories

Target applications:

- CSP Gen3 / Gen3++
- Nuclear and fossil power

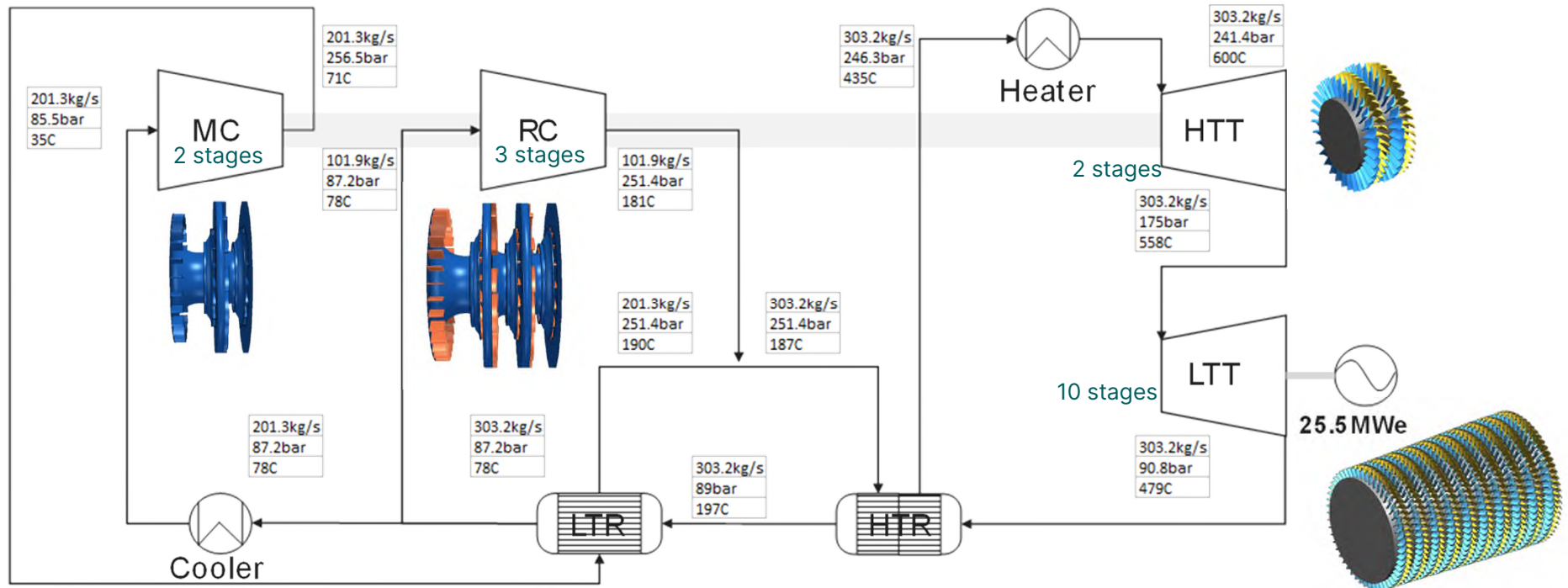
Program target:

- **LCOE ≤ \$0.05/kWh**
- Scope includes turbomachinery, electric machines, rotordynamics, and inputs to techno-economic models

25 MWe Recompression Brayton Cycle Architecture

RCBC cycle with compressor inlet at 35C and turbine inlet at 600C split in 2 spools

- High temperature spool with MC / RC compressors, startup motor, and HTT rotating at 17,000 RPM
- Low temperature spool with LTT synchronized to grid at 3,600 RPM



Aerodynamic Design Methodology

Meanline tools:

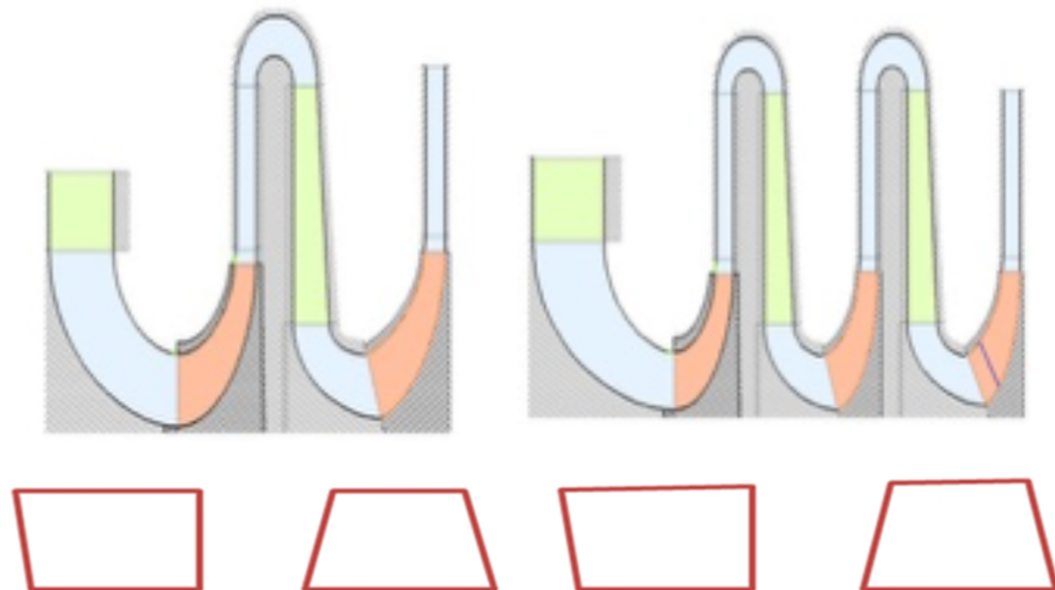
- In-house turbine code
- COMPAL® for compressors

Real-gas modeling:

- REFPROP equilibrium tables

Outputs:

- Stage count
- Flowpath geometry
- Preliminary efficiencies



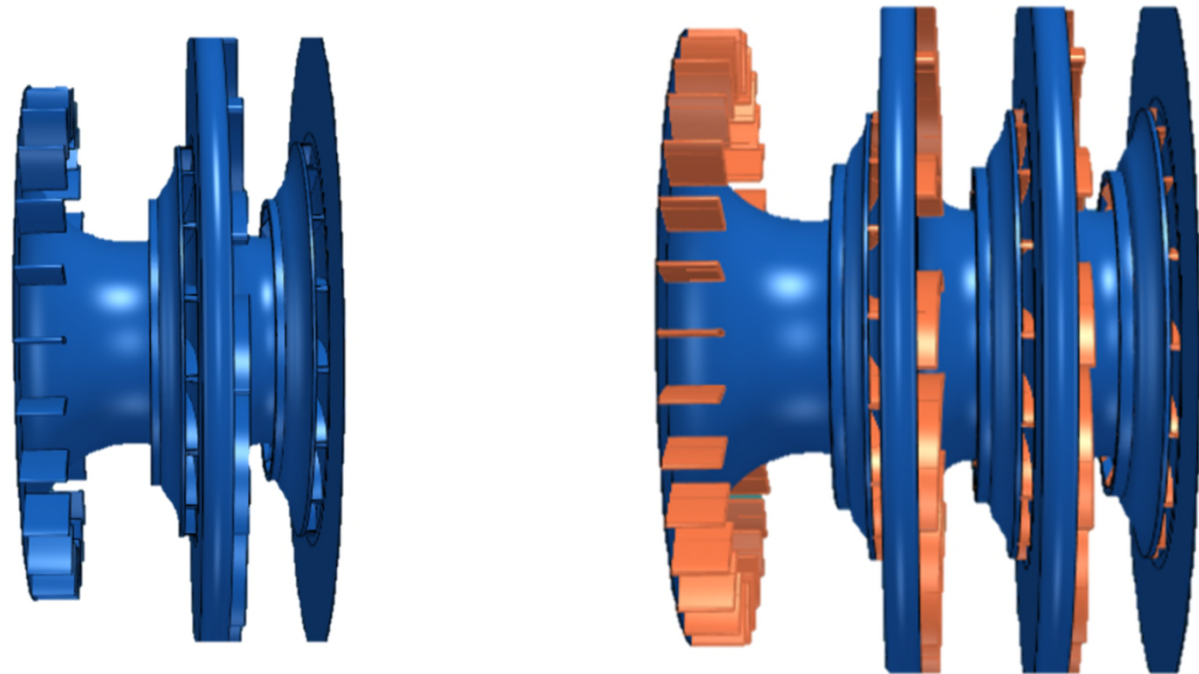
Compressor Design

Main Compressor:

- 2 shrouded impellers
- Radial IGV

Re-compressor:

- 3 shrouded impellers
- Parallel flow path



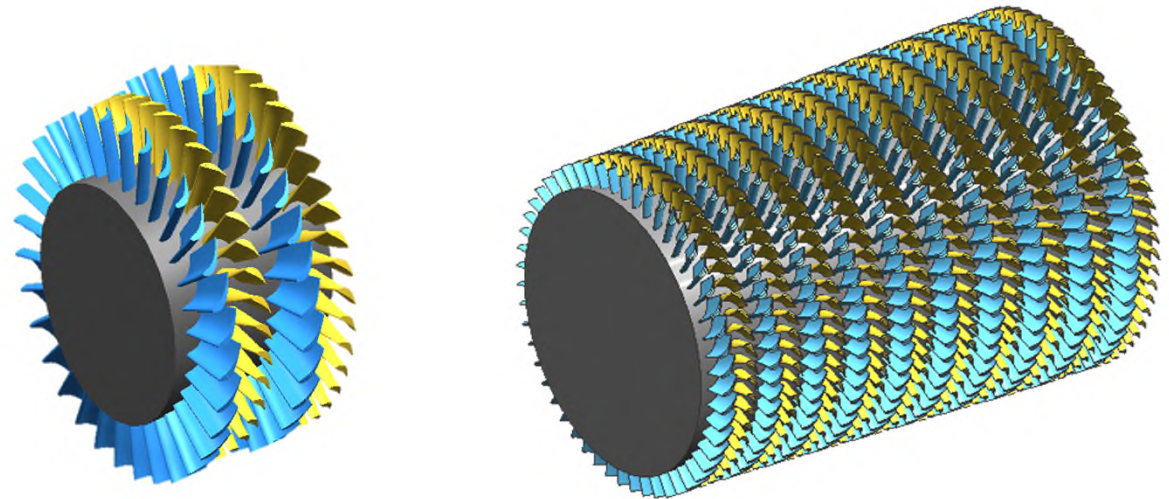
Turbine Design

High-Temperature Turbine:

- 2 axial stages
- Drives compressors

Low-Temperature Turbine:

- 10 stages
- Selected via stage sensitivity study

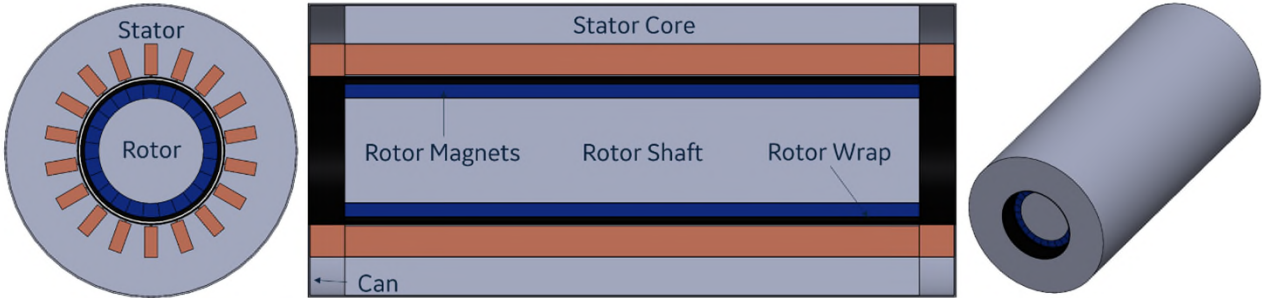


High-Speed Startup Motor Design

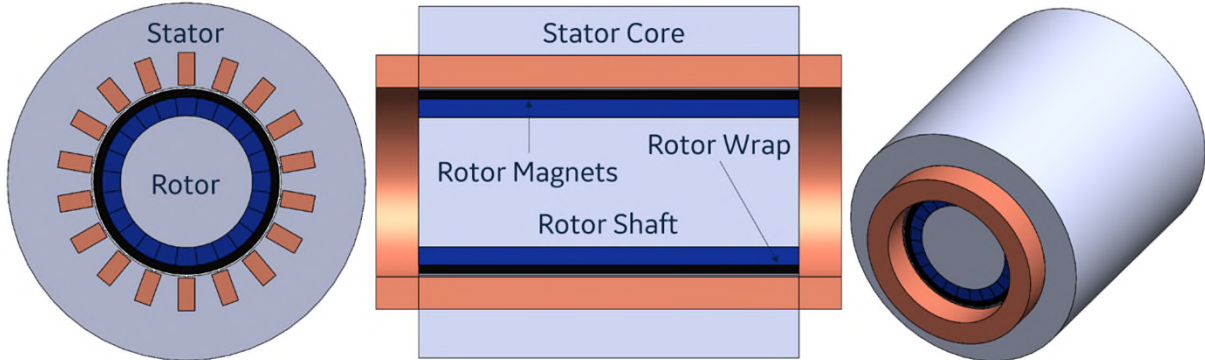


17000 RPM motor for startup
Surface Permanent Magnet (Halbach array)
NdFeB magnets + carbon fiber wrap
Driven by AC-AC converter (98%)

Hermetic motor



Non-hermetic motor



Hermetic vs Non-Hermetic Electric Machine Tradeoffs



Non-Hermetic

- Operates in ambient air, lower windage
- Challenges: Shaft seals required, CO₂ leakage → efficiency loss & GHG release

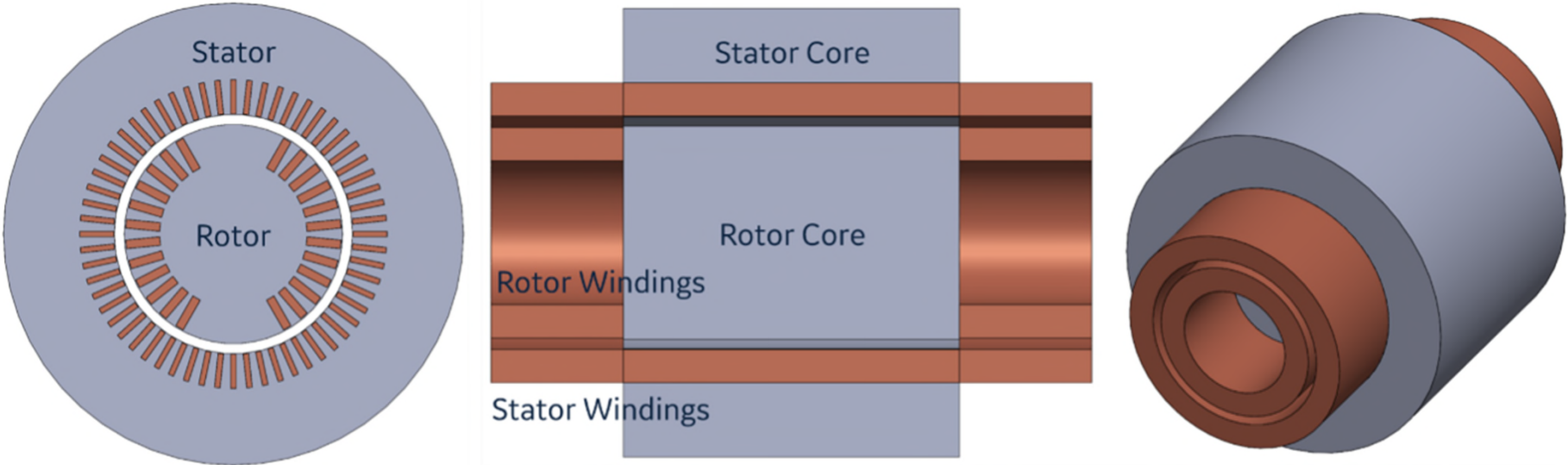
Hermetic

- No leakage
- Challenges: corrosion, canning of electric machine, windage losses in high density CO₂ gas

25 MWe Synchronous Generator

- Potential tradeoff between L/D, windage, and BOM cost:

Design	Rotor L/D	%Windage loss	%BOM Cost
Nominal Diameter	1.49	100%	100%
90% Diameter	2.05	81%	98%
80% Diameter	2.92	64%	100%
70% Diameter	4.36	49%	104%

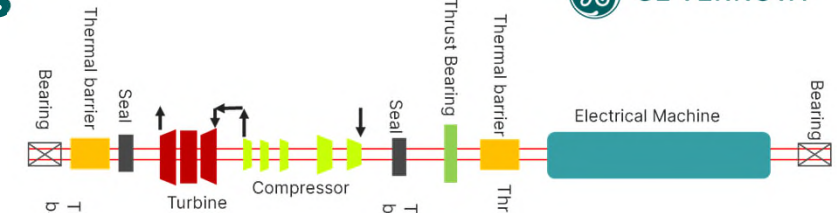


High-Speed Rotor Train Configurations

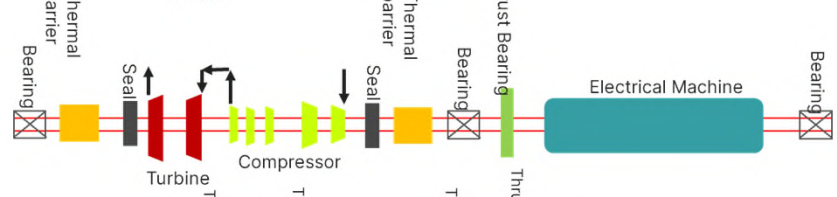
Five configurations evaluated for feasibility:

Configuration	Characteristics
Configuration 1	Two bearings
Configuration 2	Three bearings
Configuration 3	Overhung compressor
Configuration 4	Config. 3 with extra bearing
Configuration 5	Split shaft with flexible coupling

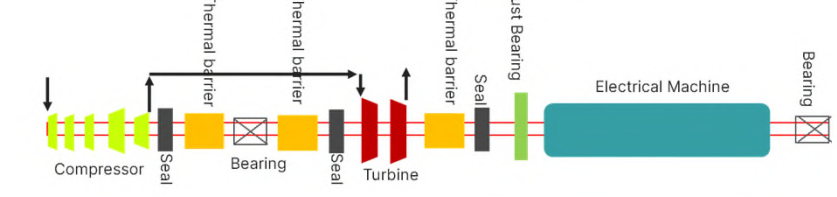
Config. 1



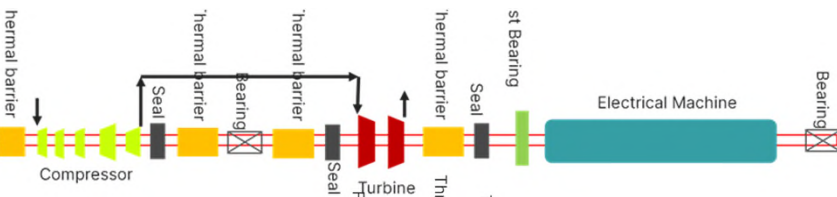
Config. 2



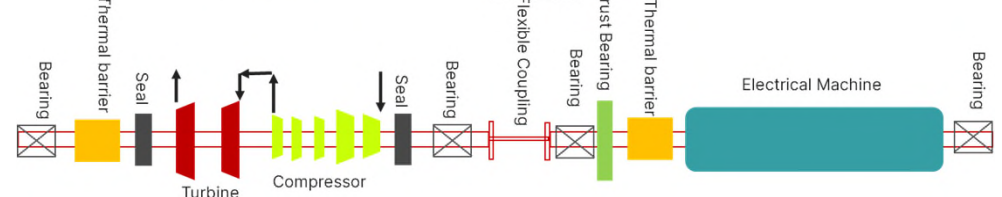
Config. 3



Config. 4



Config. 5

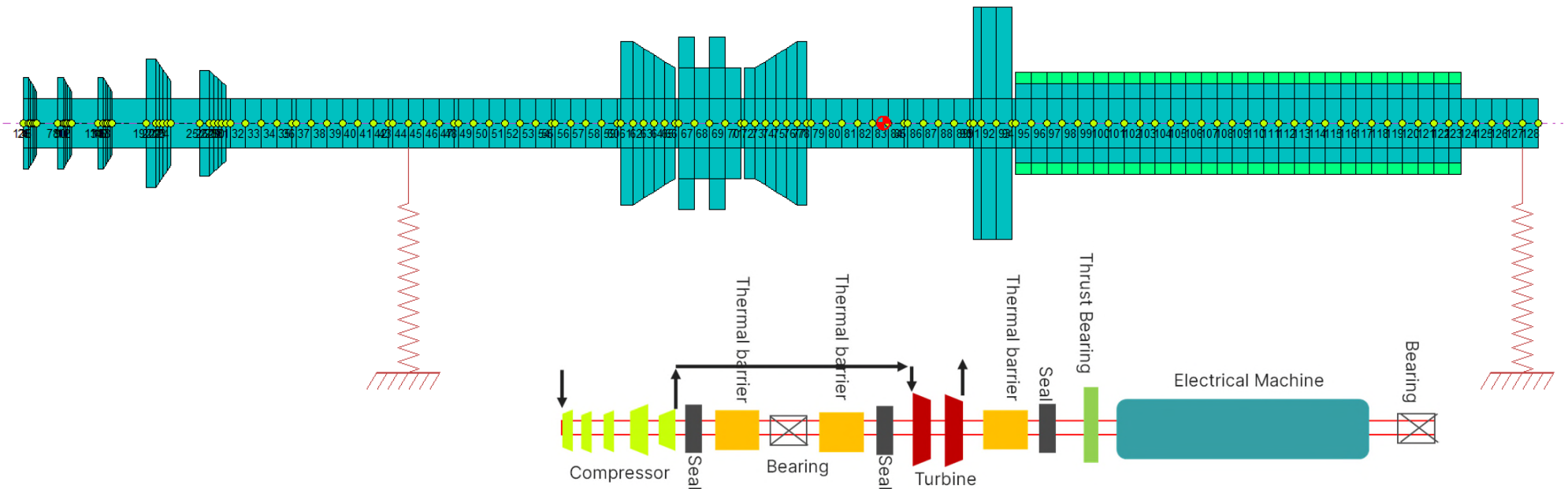


FE Model Example

Finite element rotor model in DyRoBes®

Example shown for Configuration 3

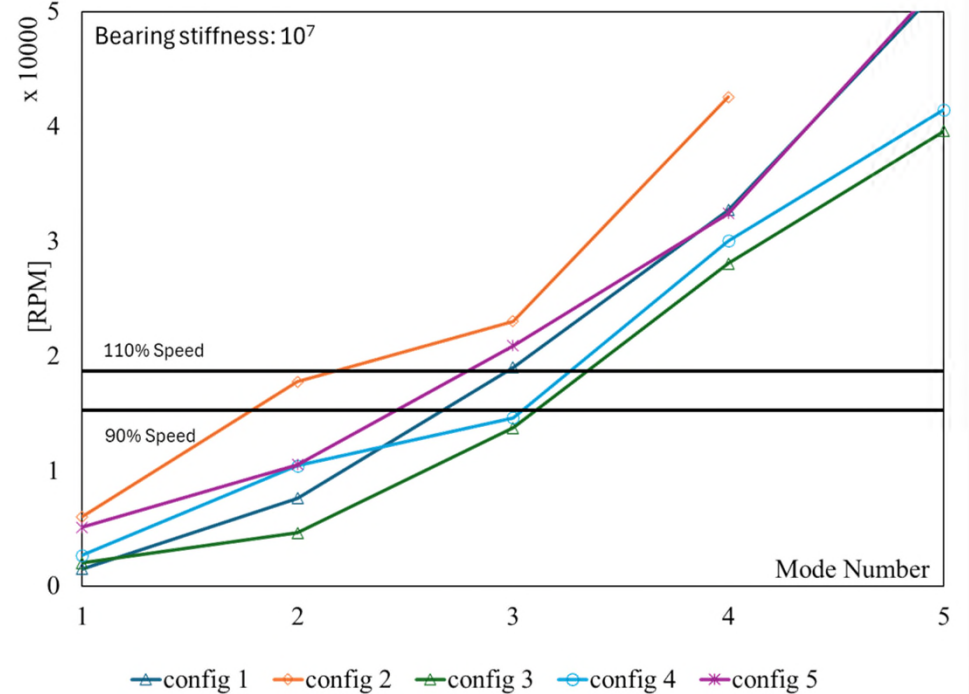
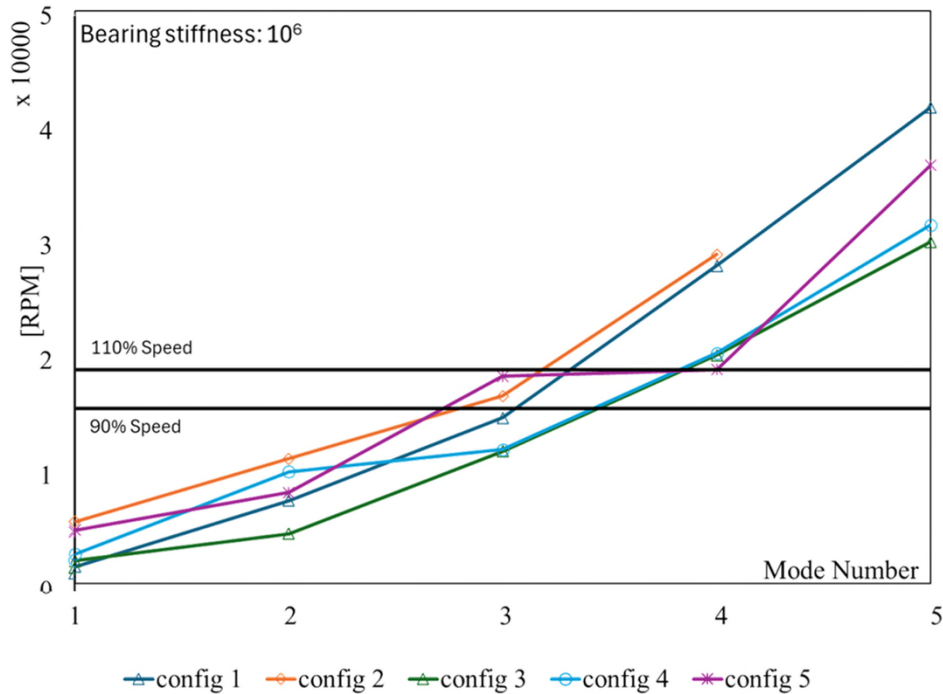
- Analysis provides a clear basis for selecting the optimal configuration.
- It establishes an acceptable (global) range of bearing stiffness for the system.
- These findings guide bearing selection and tuning to keep critical speeds outside the API 617 exclusion band.



Rotordynamic Results

API 617 / 684 criteria, 10% speed margin required

- Critical speeds should not fall within 90–110% of the operating speed; this exclusion band is indicated by grid lines
- Configs 2, 3, and 5 have critical speeds within these bands indicating potential non-compliance and operational risk



Conclusions



- Conceptual 25 MWe sCO₂ turbomachinery developed
 - Compressors, turbine and start-up motor on first train.
 - Turbine and generator on second train synchronized to the grid.
- Hermetic machines feasible with tradeoffs.
- Several configurations evaluated for the first rotor train with representative bearing stiffness.
- Down select of two configurations for future work:
 - Rotor train and motor between bearings.(Config. 1)
 - Rotor train and motor between bearings with the third bearing between compressors and turbine. (Config. 4)

Acknowledgements



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