Reversible Counter-Rotating Turbomachine to Enable Brayton-Laughlin Cycle

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Project Vision: Develop the practical reversible gas turbine engine for a pumped thermal energy storage cycle.
The Team

- 50 person technical staff
- Turbomachinery for Advanced Energy Systems
- Performed pioneering R&D w/ Prof. Laughlin (2011-2015)
- Detailed design work for Google-X (2015-2018)
- 5 Acre campus, 38,000 SF; Testing & fab

Brayton Energy, LLC
- MIT Gas Turbine Lab
- Blade geometry aerodynamic optimization

Dr. Choon Tan
Prof. Ed Greitzer
The Concept: Pumped Thermal Electric Energy Storage

Counter-Rotating Reversing Turbomachine*: Nearly Symmetrical Thermodynamics and Aerodynamics

Thin leading and training edges – incidence angles in both directions optimized for minimal deviation

Cold Compressor (electrical charge mode)

Cold Turbine (electrical generation mode)

Polytropic efficiencies

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<th>TT</th>
<th>TS</th>
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<tbody>
<tr>
<td>Cold compressor</td>
<td>0.945</td>
<td>0.927</td>
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<tr>
<td>Cold turbine</td>
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<td>0.894</td>
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<tr>
<td>Hot compressor</td>
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<tr>
<td>Hot turbine</td>
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<tr>
<td>Average</td>
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*patent pending
The Economic Advantage

- Conventional design practice suggests separate machine for the Brayton cycle heat pump and the Brayton cycle turbine generator.
- The ducting and valves to use two separate turbomachines sharing common recuperator, hot heat source, cold storage, and heat rejection HX results in high losses and costs.

- Consolidation into one machine can be achieved via a full set of interstage variable position stators, or with the simpler counter-rotating turbomachine; either design represents a major economic breakthrough for the energy storage cycle.
  - DAYS TES may eliminate the recuperator, which is required conventionally to match operating temperature range to molten salt constraints

* Conventional system based on prior work: separate charge and generating turbomachines w/ switching valves, interconnecting piping, and molten salt TES
* DAYS system employs solid particle hot TES system, leveraging Brayton and Sandia Gen3 learnings
Counter-Rotating Layout and Hardware
Next Steps at Brayton

▪ Fabricating 1/5th scale turbomachine – to test in both modes

▪ Evaluating salts, sand particles, and other appropriate thermal storage systems

▪ Controls and transient modeling, with rigorous attention to physical parameters of this turbomachine, the interconnecting ducting, heat exchangers, and a practical system layout

▪ Seeking strategic partners to build full scale system
  • Dual-function turbomachine
  • Hermetic magnetic bearings
  • No gearbox, frequency conversion (inverter)
  • Turbine-compressor polytropic efficiencies averaging over 93%
Reversing Turbomachine to Enable Laughlin-Brayton Cycle

for Thermally-Pumped Electrical Energy Storage

• 50 MW\textsubscript{e}
• $370$/kW\textsubscript{e} *
• 65% Round Trip Efficiency