Reversing Turbomachinery: A Central Enabling Technology of Thermal Grid Storage

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A person with a new idea is a crank until the idea succeeds.

Mark Twain
The Problem – Part I

The Problem – Part II

YOU HAVE JUST CROSSED OVER INTO...

THE TWILIGHT ZONE
The Problem – Part III

Sources: R. Fu et al., NREL/TP-6A20-7174, Nov. 18; S. Few et al., Energy Policy 114, 578 (2018); D. Feldman et al., NREL/TP-6A20-66592, Aug. 16; T. Key et al., EPRI 1023144, Feb 13; T. Lüth et al., Energy Proc. 155, 379 (2018); C. S. Turchi et al., NREL/TP-5506-22856, May 19; N. Diorio et al., NREL/TP-6A20/64987, Nov. 15.
Marry Salt Tanks from Andasol ...
With Closed-Cycle Brayton Engine

Viola! Reversible Thermal Storage
Recuperated Version
Relevant Equations

Ideal Adiabatic: \[
\frac{dT}{T} = \left( \frac{\gamma - 1}{\gamma} \right) \frac{dp}{p}
\]
\(T = \text{Temperature}\)
\(p = \text{Pressure}\)
\(\gamma = \text{Specific Heat Ratio}\)

Compressor: \[
\frac{dT}{T} = \frac{1}{\eta_c} \left( \frac{\gamma - 1}{\gamma} \right) \frac{dp}{p}
\]
\(\eta_c = 0.91\)

Turbine: \[
\frac{dT}{T} = \eta_t \left( \frac{\gamma - 1}{\gamma} \right) \frac{dp}{p}
\]
\(\eta_t = 0.93\)

\[\xi = \frac{T_0^+}{T_0} = \frac{T_1^+}{T_1}\]

\[\eta_{store} < 1 - \frac{2T_{Dump}}{T_1 - T_0} \left( \frac{1}{\eta_c} - \eta_t \right) \frac{\ln(\xi)}{\xi - 1} = 0.7\]

The Problem – Part IV
Old Mandate: Minimize Weight!
… Load Turbine Stages Heavily!

New Mandate: Minimize Cost
... Load Turbine Stages Lightly!
Reversible Blading Strategy
Reversible Compressor

\[ \mathcal{U} \]

[Diagram of a reversible compressor showing flow directions and symbols.]
Reversible Turbine

\[ \omega r \]

\[ u_z \]
... But Modern Turbocompressors Already Have This Property!

Left: Rotor of Siemens SGT5 series power gas turbine. (Courtesy of Siemens AG)

Right: Stators of General Electric J79 aircraft engine (progenitor of LM1500 stationary gas turbines) on display at Deutsches Museum in Munich. (Credit: O. Cleynen).
Designed as a *Charge* Compressor, it functions reasonably well as a turbine, flowing in opposite direction.

Image Courtesy of Brayton Energy LLC, 3 Feb 20.
Majority of the entropy is generated in the wakes due to incidence losses and trailing edge deviation, but peak entropy level is at Counter Rotating Turbomachine Hot Machine – Turbine Mode. Velocity Contours at 50% span. Image courtesy of Brayton Energy LLC, 3 Feb 20.
The Reversible Turbomachine Is Essential Because ...
It reduces the $ per engine watt by a factor of 2.