Induction Heating in Supercritical CO_2 Turbines: Supplementing the Cycle for Flexibility

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Exploring the role of induction heating in supercritical CO_2 turbines. Learn how induction can supplement the cycle for startup, stability, and renewable integration.

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Introduction

Supercritical CO_2 (sCO_2) turbines are attracting attention for power generation due to their compact size, high efficiency, and ability to operate across diverse heat sources. In conventional systems, thermal energy is introduced between the compressor outlet and turbine inlet, typically through a heat exchanger or combustor. A new idea being explored is the integration of induction heating inside the turbine system, not as a replacement for compression, but as a supplement to the heating stage. This article examines whether such an approach can improve efficiency, stability, or operability.

Conventional vs. Induction Heating in Turbine Cycles

Resistance Heating: Nearly 100% of electrical input is converted to heat. When applied to the working fluid, the thermodynamic efficiency depends solely on the cycle's conversion efficiency (typically 40–50%).
Induction Heating: Works by generating eddy currents in a metallic liner or susceptor, which then transfers heat to the CO_2. Although practical advantages exist, efficiency is similar to resistance heating, with small extra losses in the power electronics and magnetic coupling.

From a thermodynamic perspective, induction heat does not increase the cycle's efficiency. Adding 1 kW of electric heat still yields only 0.4–0.5 kW of extra shaft power. In pure energy terms, it is less efficient than using the electricity directly.

Practical Advantages of Induction Heating

Despite no net efficiency gain, induction heating may offer operational and design benefits:

Startup and Warm-up: Induction can quickly raise system temperature and pressure without firing the main heat source.
Trim and Ride-through: Smooths turbine inlet temperature (TIT) during fluctuations in solar, geothermal, or exhaust-based sources.
Low-load Stabilization: Keeps recuperators warm, avoiding condensation or corrosion at part-load.
Renewable Absorption: Can convert surplus renewable electricity into partial turbine output, while also providing co-generation heat.

Design Considerations

To integrate induction successfully:

Avoid In-flow Obstructions: Place induction coils outside the pressure boundary and heat a liner, not inserts in the CO_2 stream.
Manage Pressure Drop: Heated surfaces must be smooth and optimized for minimal hydraulic resistance.
Control and Safety: Use closed-loop TIT control and ramp rate limits to protect recuperators and turbine blades.
Electromagnetic Interference: Shield or slot components to prevent parasitic eddy currents in rotors or nearby metals.
Materials and Durability: Susceptors must handle 20–25 MPa pressure and 500–700 °C CO_2 without creep or corrosion.