Steady-State Power Operation of a Supercritical Carbon Dioxide Brayton Cycle

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Presentation Summary

• S-CO$_2$ Brayton Cycle Integrated Systems Test (IST) Overview

• System Operational Overview
  – Loop startup
  – Normal Operating Conditions

• Operational Test Results
  – Normal Power Generation
  – Maximum Power Operation
IST Overview

• 100 kWe IST has been main S-CO$_2$ development focus of BMPC

• Simple Brayton cycle
  – Single variable speed turbine-compressor
  – Single constant speed turbine-generator
  – Single recuperator

• Focus on system control
  – Rapid startup
  – Power changes
  – Shutdown
IST Physical Layout

Turbo-Generator

Recuperator

Precooler

Turbo-Compressor (not visible)
IST Turbomachinery

Turbo-Generator

Thrust Bearing

Turbo-Compressor

Compressor/Diffuser

Turbine
Loop Startup

• Heat up system to supercritical conditions and achieve normal system mass
• Start up both turbomachines to 37,500 rpm
• Heat up system to normal turbine inlet temperature
  – Transition TG from motoring to generating
• Establish normal compressor inlet conditions
Normal Power Operation

• Turbine-generator operates at fixed speed with load regulated to maintain speed
• Turbine-compressor thermal-hydraulically balanced
  – Turbine power = compressor power + losses
• Power level changed by position of compressor recirculation valve
  – Valve nearly full closed at maximum system power
IST Power Limitations

• TG output voltage droops as power is increased

• Voltage droop affects speed and rotor position algorithm causing delay in firing of IGBTs and degradation of power factor
  – Limited to 24 kWe DC (~30 kWe AC) @ 55,000 rpm

• Permanent magnet rotor remagnetized to increase output voltage
  – Resulted in higher power capability
  – New target ~50 kWe AC @ 60,000-65,000 rpm
Maximum Power Operation

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System Mass Flow Rates

Flow (lbm/s)

- TG Turbine
- TC Turbine
- Compressor
- Compressor Recirc

Speed (rpm)

- TG Turbine
- TC Turbine
- Compressor
- Compressor Recirc

Time (seconds)

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Compressor Map

Model Prediction for Design Operating Conditions

Test Data
Summary

• IST continuing to make progress towards the purpose of demonstrating controllability of the S-CO2 Brayton cycle

• System operation up to 40 kWe AC has been demonstrated with good agreement with model predictions

• Normal power operation over range of power levels up to ~50 kWe planned
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