ASSESSMENT OF SOLAR STEAM INJECTION IN GAS TURBINES

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Motivation & Objectives

• Conventional hybridization
  o Energy production penalty
  o Air extraction difficulties
  o Burner cooling difficulties

• Solar STIG
  o Increased produced energy
  o Fewer construction difficulties
  o STIG: Used technology
  o Solar steam: Used technology
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- MODELLING
- SOLAR STEAM PRODUCTION METHOD
  - Design Specifications & Operating Scenario
  - Performance Simulation
- SOLAR STEAM IN A STIG ENGINE
  - Design Specifications & Operating Scenario
  - Performance Simulation
  - Change Of Operating Point
- SUMMARY & CONCLUSIONS
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Modeling

- Modeling with PROOISIS: an object oriented environment
- TURBO: Brayton cycle components
- WAST: Rankine cycle components
- SOLAR: Solar part components
Modeling

Solar-only STIG

Solar STIG with troughs
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Solar Steam Production Method

- **Tower**
  - Direct steam generation
  - Engine on tower
  - Used technology for Rankine cycles
  - Higher investment cost

- **Troughs**
  - Direct steam generation
  - Experimental stage
  - Engine on ground
  - Lower investment cost
• Fuel-only engine: 5MW, TIT = 1000°C, PR = 10

• Solar field / Water-steam
  o Steam pressure: 35 bar
  o Steam temperature: Saturated steam
  o Receiver/troughs outlet: SAR=12% @ 800W/m² Summer solstice

• Operating scenario
  o Maximum power → TIT constant
  o Yearly continuous baseload operation

• Performance simulation
  o Hourly simulation → Integration → Annual performance
### Performance Simulation

#### Annual Performance Difference Between Solar-only STIG & Fuel-only Engines

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<tr>
<td>ΔE</td>
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- **Tower less season-dependent**
- **Solar STIG results to**
  - Augmented produced energy (higher mass flow, composition change)
  - Augmented fuel consumption (added mass with higher Cp)
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Addition Of Solar Steam

1. Fuel-only engine
2. Conventional STIG (+HRSG)
3. Solar STIG (+Solar evaporator)
• Fuel-only engine: 5MW, TIT = 1000°C, PR = 10
• Heat Recovery Steam Generator
  o Inlet water: 35 bar, 15°C, Outlet steam: 700K
  o Tpinch = 20°C, Tapproach = 15°C
  o Water mass flow → Saturated steam @ evaporator outlet & SAR=6%
• Heliostat field
  o SAR=12% @ 800W/m² Summer solstice
• Operating scenario
  o Maximum power → TIT constant
  o Yearly continuous baseload operation
• Performance simulation
  o Hourly simulation → Integration → Annual performance
Annual Performance Difference Between Solar & Convetional STIG Engines

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Performance Simulation
• Higher energy production, fuel and water consumption
• Similar results if troughs were used (Direct Steam Generation)
• Troughs with oil could be used:
  o Inferior performance (addition of oil-water heat exchanger)
  o Already used technology in commercial state
• Steam injection & chocked turbine with constant TIT → higher PR
• High SAR may result to surge
• In this study:
  ○ SAR=6% → SM ↓ ~25% from fuel-only operation
  ○ SAR=12% → SM ↓ ~50% from fuel-only operation
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Solar STIG studied as an alternative to conventional solar hybridization

- Based on proven technologies (STIG & solar steam)
- Fewer GT modifications
- Augmented energy production

Steam generation method: Tower scheme performs better than troughs

Assessment of performance and operability on addition of solar steam into an already STIG engine

- Produced energy, fuel and water consumption increase
- Surge margin decreases
- Similar results if troughs were used
THANK YOU

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