Evaluation of Steam Cycle Upgrades to Improve the Competitiveness of US Coal Power Plants

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Background – Strategy

- Reduce coal consumption of existing utility fleet by decreasing heat rate, via increase in steam cycle efficiency
- Upgrade steam temperature for higher cycle efficiency
  - Average efficiency of US coal-fired fleet = 33% HHV
  - Efficiency increases to 41.4% HHV at 1,350°F steam temperature
- Advanced Ultra-supercritical (A-USC) steam conditions
- Employ advanced high-temperature materials
  - Result of DOE-funded materials R&D
- Expect higher capacity factor from increased plant efficiency
Motivation for A-USC Coal-Fired Power Plants

Plant Efficiency (HHV) as a Function of Steam Temperature

- Studies: Sub-Bit/Lignite
- Studies: Bit.
- Plant Data: Sub-Bit/Lig.
- Plant Data: Bit.
- US Fleet Average 2010 (NETL)

Notes: Studies are a summary for DOE/NETL, EPRI, and IEA Reports (pulverized coal with no carbon capture and storage)
Efficiency is plant design, location, and site specific
Factors include: temperature, pressure, cycle configuration, plant size, cooling water temperature, auxiliary loads, environmental requirements

<600°C (SC)  600-650°C (USC)  700-760°C (A-USC)
Background – Challenges for A-USC Technology

- Greenfield A-USC steam plants may not be cost effective
  - Conventional USC (1100°F or 593°C) power plants use lower cost materials
- A-USC retrofits may be more cost effective option
  - Significant reuse of existing equipment – decreased capital cost
  - Increase only steam temperature – not steam pressure
    - Limit the scope of equipment replacement
      - Superheater and reheater panels
      - Steam turbine
      - Piping between the superheater/reheater and steam turbine
Technical Approach - Summary

- Maximize the applicability of the study results to existing fleet
  - 300+ units with 2,400 psia (16.6 MPa) main steam (subcritical)
  - 100+ unit with 3,500 psia (24.1 MPa) main steam (supercritical)
- Insure that results reflect actual situations in US fleet
  - Data from existing operating units supplied by Southern Company
- Employ an experienced technical team that has worked together on prior DOE-funded AUSC project (ComTest)
## Technical Approach – Upgrade Cases Planned

<table>
<thead>
<tr>
<th>Case Name</th>
<th>Main Steam Pressure</th>
<th>Main Steam Temp.</th>
<th>Reheat Steam Temp.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subcritical Base Case</td>
<td>2400 psi (16.6 MPa)</td>
<td>1000°F (538°C)</td>
<td>1000°F (538°C)</td>
</tr>
<tr>
<td>Subcritical USC Option</td>
<td>2400 psi (16.6 MPa)</td>
<td>1100°F (593°C)</td>
<td>1100°F (593°C)</td>
</tr>
<tr>
<td>Subcritical A-USC Option 1</td>
<td>2400 psi (16.6 MPa)</td>
<td>1200°F (649°C)</td>
<td>1200°F (649°C)</td>
</tr>
<tr>
<td>Subcritical A-USC Option 2</td>
<td>2400 psi (16.6 MPa)</td>
<td>1000°F (538°C)</td>
<td>1350°F (732°C)</td>
</tr>
<tr>
<td>Subcritical A-USC Option 3</td>
<td>2400 psi (16.6 MPa)</td>
<td>1350°F (732°C)</td>
<td>1350°F (732°C)</td>
</tr>
<tr>
<td>Supercritical Base Case</td>
<td>3500 psi (24.1 MPa)</td>
<td>1000°F (538°C)</td>
<td>1000°F (538°C)</td>
</tr>
<tr>
<td>Supercritical USC Option</td>
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<td>1350°F (732°C)</td>
</tr>
<tr>
<td>Supercritical A-USC Molten Salt</td>
<td>3500 psi (24.1 MPa)</td>
<td>1350°F (732°C)</td>
<td>1350°F (732°C)</td>
</tr>
</tbody>
</table>
Project Objectives

- Technical and economic feasibility of steam cycle upgrades to typical U.S. pulverized coal power plants
  - Subcritical: 2300–2600 psi (16.6–17.9 MPa)
  - Supercritical: 3400–3600 psi (23.4–24.8 MPa)
- Maintain steam pressures at their original values, and increase main and reheat temperatures from 1000°F (538°C)
  - USC (i.e., 1100°F or 593°C)
  - A-USC conditions (≥1300° or 704°C)

Improve heat rate while minimizing power plant modifications
Project Structure - Tasks

1. Project management and planning
2. Evaluation of technical feasibility
   - 2.1 Thermodynamic performance models of base case at full load
   - 2.2 Impact of upgrades to base cases at full load
   - 2.3 Part load performance for flexible operation scenarios
   - 2.4 Dynamic modeling of system for fluid circulation
3. Unit dispatch modeling (EPRI’s US-REGEN model) to 2050
4. Capital cost estimation to AACE Class III (+/-30%)
5. Overall economic evaluation
# Project Structure – Team

<table>
<thead>
<tr>
<th>Team Member</th>
<th>Funder</th>
<th>Role</th>
</tr>
</thead>
<tbody>
<tr>
<td>US DOE NETL</td>
<td>✔</td>
<td>Funder</td>
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<tr>
<td>EPRI</td>
<td>✔</td>
<td>Lead Organization, Economic Evaluation, Unit Dispatch Model</td>
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<tr>
<td>GE / Alstom Power</td>
<td>✔</td>
<td>Boiler and Steam Turbine Costs, Dynamic Modeling</td>
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<td>AECOM (EPC)</td>
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<td>Blance of Plant Costs</td>
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<tr>
<td>Hendrix Engineering</td>
<td></td>
<td>Thermodynamic Performance, Modeling &amp; Analysis Calculations</td>
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Project Support Acknowledgement & Disclaimer

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