Turbine Inlet Cooling: Good for Plant Owners, Rate Payers and the Environment

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Vice Chair, Turbine Inlet Cooling Association

Electricity Committee Meeting,
National Association of Regulatory Utility Commissioners

San Francisco, CA

July 31, 2006
Turbine Inlet Cooling Association

» Founded in 2000

» Not-for-profit trade association

» Membership consists of manufacturer’s, consultants and power plant owners

» Mission is to educate and demonstrate the economic and environmental benefits of TIC technology to combustion turbine plant owners, policy makers, and government agencies.
Overview

- Combustion turbine (CT) fundamental flaws
- Turbine Inlet Cooling (TIC) overcomes the effect of the flaws
- Economic and environmental benefits
- Technology options available for TIC
- Suggested regulatory changes for removing barriers to TIC implementation
Combustion Turbine Power Plants
Fundamental Flaws

During hot weather, just when power demand peaks,

1. Power output decreases significantly
   - Up to 35% below rated capacity
   - Depends on the CT characteristics

2. Fuel consumption (heat rate) and emissions increase per kWh
Combustion Turbine Power Plants
Fundamental Flaw #1

Greatest generation capacity loss coincides with peak demand.
Combustion Turbine Power Plants
Fundamental Flaw # 1

EFFECTS OF COMPRESSOR INLET AIR TEMPERATURE ON GAS TURBINE POWER OUTPUT

Up to 19% capacity loss at peak demand for this CT.
Combustion Turbine Power Plants
Fundamental Flaw # 2

Note: Heat rate is proportional to fuel consumption per kWh
Turbine Inlet Cooling Overcomes the Effect of the CT Flaws

➔ TIC is simple
  - Cool the ambient air before it enters the turbine
  - Just as we cool the air entering buildings

➔ TIC technologies are proven
  - Hundreds of plants already benefit from TIC
  - TICA web site database of 100+ plants worldwide
Turbine Inlet Cooling Overcomes the Effect of the CT Flaws

The graph shows the relationship between ambient dry-bulb temperature and net CT power output as a percentage of design capacity. The lines represent different cooling conditions:

- **No Cooling**: A straight line indicating a decrease in power output as the temperature increases.
- **With TIC (Turbine Inlet Cooling)**: A less steep line showing a reduced decrease in power output.
- **Rated Capacity**: A horizontal line indicating the capacity remains constant regardless of temperature changes.

The graph demonstrates that Turbine Inlet Cooling significantly mitigates the impact of ambient temperature on CT power output, allowing for operation at near-rated capacity over a wider range of temperatures compared to no cooling.
Turbine Inlet Cooling Technologies

- Evaporative cooling
- Fogging
- Air cooled and water cooled chillers
- Absorption chillers
- Thermal storage with chillers
- Other technology combinations
Turbine Inlet Cooling
Economic Benefits

→ Captures “lost / hidden” capacity during hot weather
  • when most needed
  • when most valuable

→ Minimizes the need to build new power plants to meet peak demand
Turbine Inlet Cooling
Economic Benefits

➔ Enhances CT asset value
  ● Reduces capital cost per MW of capacity
  ● Improves fuel efficiency
    (lower fuel use and cost per kWh)

➔ Reduces cost for ratepayers by allowing lower capacity payments for power producers
Turbine Inlet Cooling
Environmental Benefits

- Offsets operation of inefficient and higher-emission power plants
- Improves operation of efficient and cleaner combustion turbine plants
  - Reduces pollutant emissions (SOx, NOx, particulates)
  - Reduces global warming gas emissions (CO₂)
  - See quantitative details in Exhibit 1
- Minimizes, delays, or eliminates new plants
## Turbine Inlet Cooling Environmental Benefits

### Emissions* for 100 MW for 400 hours

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Combined-Cycle CT</th>
<th>Simple-Cycle CT</th>
<th>Steam Turbine</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO2 Emissions, Tons</td>
<td>Natural Gas</td>
<td>Natural Gas</td>
<td>No. 6 Fuel Oil</td>
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<tr>
<td></td>
<td>16275</td>
<td>24993</td>
<td>44730</td>
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<tr>
<td>NOx Emissions, Tons</td>
<td>1.60</td>
<td>7.33</td>
<td>78.00</td>
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<tr>
<td>SOx Emissions, Tons</td>
<td>0</td>
<td>0</td>
<td>265</td>
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</tbody>
</table>

* Source: Ray Pasteris, Strategic Energy Services, Inc

* TIC Implementation Priority Order For Minimizing Emissions
  - Combined-Cycle CT Systems
  - Simple-Cycle Systems
Suggested Changes To Regulatory Structure

→ Realize full potential of existing CT plants
  ● Use TIC before allowing new plants to be built

→ Exempt TIC from environmental re-permitting
  ● Impact of TIC is similar to ambient temperature naturally going down

→ Calculate capacity payments for plant owners on the basis of systems incorporating TIC
  ● Consistent with the PJM affidavit made to the FERC
  (Summary shown in Exhibit 2)
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**Exhibit 1**

TICA Presentation at the NARUC Meeting July 31, 2006

<table>
<thead>
<tr>
<th>Unit Type</th>
<th>Combined-Cycle CT</th>
<th>Simple-Cycle CT</th>
<th>Boiler + Steam Turbine</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prime Mover</td>
<td>Frame CT- STG</td>
<td>Frame CT</td>
<td>Condensing STG</td>
</tr>
<tr>
<td>Fuel</td>
<td>Gas</td>
<td>Gas</td>
<td>No. 6 Oil</td>
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<tr>
<td>Fuel Sulfur (% Wt.)</td>
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<td>0</td>
<td>0.01</td>
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<tr>
<td>Plant Age (Yrs)</td>
<td>&lt; 5</td>
<td>&lt; 5</td>
<td>&gt; 30</td>
</tr>
<tr>
<td>Heat Rate (BTU/kWh)</td>
<td>7,000</td>
<td>10,750</td>
<td>13,000</td>
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<tr>
<td>NOx Control</td>
<td>DLN-SCR</td>
<td>DLN</td>
<td>LNB w/ FGR</td>
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<td>NOx Target (PPM)</td>
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<td>9</td>
<td>NA</td>
</tr>
<tr>
<td>NOx (Lbs/MMBTU)</td>
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<td>0.0341</td>
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<tr>
<td>SO2 (Lbs/MMBTU)</td>
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<tr>
<td>Incremental Capacity (MW)</td>
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<td>100</td>
</tr>
<tr>
<td>Hours of Operation</td>
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<td>400</td>
<td>400</td>
</tr>
<tr>
<td>Fuel (MMBTU)</td>
<td>280000</td>
<td>430000</td>
<td>520000</td>
</tr>
<tr>
<td>CO2 Emissions, Tons</td>
<td>16275</td>
<td>24993</td>
<td>44730</td>
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<tr>
<td>NOx Emissions, Tons</td>
<td>1.596</td>
<td>7.3315</td>
<td>78</td>
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<tr>
<td>SOx Emissions, Tons</td>
<td>0</td>
<td>0</td>
<td>265.2</td>
</tr>
</tbody>
</table>

LNB = Low Nox Burners  
FGR = Flue Gas Recirculation  
DLN = Dry Low NOx  
SCR = Selective Catalytic NOx Reduction

Source: Ray Pasteris - Strategic Energy Services, Inc. 215-736-8170
Exhibit 2

A Summary of the affidavit (incorporating turbine inlet cooling) made to the Federal Energy Regulatory Commission on behalf of the PJM ISO
Exhibit 2
TICA Presentation Made to the Electricity Committee of NARUC on July 31, 2006

Cost of New Entry Combustion Turbine Power Plant Revenue Requirements
Summary of an independent study conducted for PJM Interconnection, LLC

A team of Strategic Energy Services, Inc. and The Wood Group completed a study in August 2005 for PJM Interconnection, LLC (PJM). The study determined the Cost Of a New Entry (CONE) generator by technology and the resulting fixed revenue requirements. The cost was expressed in $/MW-year or $/MW-day for PJM’s three regions.

A 20-year after tax discounted cash flow economic model was created to determine the revenue required for a CONE CT project to earn the target internal rate of return for the investor/owner. The costs included capital recovery and annual fixed operation and maintenance expenses.

The study evaluates CT systems with and without Turbine Inlet Cooling (TIC) at ambient temperatures of 92°F dry-bulb and 78°F wet-bulb. The following table summarizes the capital costs (Investments) for two GE 7241/7FA combustion turbines systems, with and without TIC.

<table>
<thead>
<tr>
<th>Net plant output, MW</th>
<th>Without TIC</th>
<th>With TIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>297.3</td>
<td>336.1</td>
<td></td>
</tr>
</tbody>
</table>

| Plant proper capital cost, $     | 116,248,000 | 124,656,000 |
| Investment per kW, $/kW          | 391.00      | 370.90      |
| Incremental capacity provided by TIC, MW | NA | 38.8 |
| Incremental investment for TIC, $ | NA | 8,400,000 |
| Incremental investment for the incremental power provided by TIC, $/kW | NA | 216.50 |

TIC increases the total net plant output of the system by 38.8 MW and decreases the capital cost by $20/kW ($371 vs. $391). The additional first cost for the incremental power provided by TIC is $216/kW.

Because the incremental and blended investments per kW are lower for the CT with TIC, the evaluation team recommends that PJM use TIC for determining the revenue requirements for the CONE generators. PJM agrees with that recommendation and included the details of this study in the affidavit made on its behalf to the Federal Regulatory Commission (FERC). The information for this summary has been extracted from pp 89 – 94 of the affidavit. Details of the affidavit are available at the PJM website: [http://pjm.com/documents/ferc/documents/2005/20050831-er05-___-part-5.pdf](http://pjm.com/documents/ferc/documents/2005/20050831-er05-___-part-5.pdf)