An Introduction To Turbine Inlet Chilling

Tom Tillman – Turbine Air Systems
January 16th, 2013
Sponsored by: Turbine Inlet Cooling Association (TICA)
AGENDA

• Turbine Inlet Chilling 101
  – Chilling Attributes / When It Makes Sense / System Overview / Design Considerations

• Turbine Inlet Chilling Technology Types
  – Mechanical Chillers / Absorption

• Turbine Inlet Chilling Retrofits
  – Power Plant and Air-Filter Retrofit Considerations

• Turbine Inlet Chilling With Thermal Energy Storage
  – Thermal Energy Storage Overview

• Questions and Answers Session
TAS MANUFACTURING CAPABILITIES

- ISO 9001:2008 Registered
- 240,000 square feet fabrication/assembly area
- 47,000 Square feet of office space
- Crane Capability – Single 80-Ton Pick
- ASME Section 9 Compliant Welding Program
- Third party NDE (x-ray, mag particle, etc)
- In-house pneumatic system pressure/leak testing
WHY TURBINE INLET CHILLING?

“The fundamentals of a gas turbine are such that on a hot day the gas turbine loses output and operates less efficiently.”
TIC TECHNOLOGY ATTRIBUTES

• Produces “hidden” MWs with existing assets at costs less than new built generation
• Adds significant flexibility to operations
• Maintains ideal gas turbine air temperature
• Allows for arbitraging night time power pricing for day time peak pricing with thermal storage capability
• Eliminates weather risk
• Provides emissions predictability
• Provides opportunity to offset degradation
• Achieves all of the above with lower non-fuel O&M costs
WHEN TIC MAKES SENSE

• Market demand in the form of:
  • High peak power demand or growing peak power load profile
  • Non-energy sales revenue in addition to energy sales (capacity payments – PJM market in US)

• Climate suitable to TIC (hot and humid environment)

• Muni / Coop / Gov’t Utility looking to take advantage of incremental power improvement with existing assets

• Need incremental power in a relatively quick timeframe compared to new build generation (permits, construction, etc.)

• Short on a Power Purchase Agreement (PPA) obligation and needs incremental power from the installed asset
CHILLING COMPONENT OVERVIEW

- TAS D-35 Chiller Package
- TES Tank
- Coil Retrofit
- Secondary Pump Skid
DESIGN CONSIDERATIONS

Power Plant Considerations
- Desired Plant Output
  - Satisfy Capacity Contract
  - Satisfy Competitive Specification
- Site Utility Limitation
- Optimal Heat Rate
- Thermal Energy Storage Shift (Charge vs. Discharge)
- Ambient Design
  - Dry Bulb / Wet Bulb
  - Target Inlet Temperature
  - Mass Flow
- Space Availability
- Energy Source
  - Steam or Electrical Supply

Chiller Considerations
- Inlet Coil Design
  - Face Velocity
  - Pressure Drop
  - Freeze Protection
- Chiller Package Design
  - Refrigerant Type
  - Heat Rejection Technology (Water / Air / Absorption)
- Pump Redundancy
- Cooling Tower Mat’ls / Sound
- Electrical
  - Feeds
  - Standards (NEC / IEC)
  - Protection (Arc Flash)
  - Controls
WATER-COOLED MECHANICAL

Ambient Air

Coils

Cool Air

Compressor

Turbine

Coil Condensate

Chiller

Evaporator

Expansion Valve

Condenser

Compressor

Power (kW)

Heat Rejection via Evaporation

Cooling Tower

Make-Up Water

Make-Up Water
Inlet Air Coils
(Heat exchanger)

Combustion Turbine

Ambient Air

Cool Air

Compressor

Turbine

Coil Condensate

Power (kW)

Refrigerant Types
• R-717 (Ammonia)
• R-290 (Propane)
• R-134a (HFC)

Heat Rejection
To Air

Air Cooled
Condensers

Evaporator

Expansion Valve

Compressor

Chiller
## ABSORPTION CONSIDERATIONS

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
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<tbody>
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<td>• Significantly lower electrical load</td>
<td>• Higher capital cost</td>
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<tr>
<td>• Good use of waste heat if available such as:</td>
<td>• Low thermal efficiency</td>
</tr>
<tr>
<td>– Hot water</td>
<td>– Higher water consumption</td>
</tr>
<tr>
<td>– LP steam</td>
<td>– Not good in an air-cooled application</td>
</tr>
<tr>
<td>• Well paired with a Thermal Energy Storage (TES) system, that allows the</td>
<td>• Larger equipment footprint</td>
</tr>
<tr>
<td>absorption chiller to operate at constant load</td>
<td>– Requires around 1/3 more cooling tower capacity compared to mechanical</td>
</tr>
<tr>
<td>• All</td>
<td>chiller</td>
</tr>
<tr>
<td>• Can be prone to vacuum leaks</td>
<td>• Potentially reduced life expectancy compared to mechanical chiller</td>
</tr>
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<td>• Possibility of solution crystallization</td>
<td>– Highly dependent on quality of maintenance</td>
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SHIFT IN TECHNOLOGY ACCEPTANCE

- Historically Turbine Inlet Chilling (TIC) applications have been limited to aeroderivative peaking power plants only
- In the past 5-years there have been significant awards in chilling advanced combined cycle power plants globally
- Application advantages:
  - Ancillary services
  - Capacity payments
  - **SuperPeak™**
  - Grid flexibility with increased renewable penetration
  - Storage as spinning reserve
  - Compliments night time wind generation

USA located 3 x 1 MHI 501G Power Plant

TAS F-70 Chiller Packages

Turbine Inlet Cooling Association
TURBINE INLET CHILLING RETROFIT

Secondary Pump Skid

TES Tank

Coil Retrofit

TAS F-70 Chiller Package

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RETROFIT PROJECT EXAMPLE

- Customer: Confidential
- Site location: Texas
- Project Timing: 2008-2009
- Outage Duration: ~15-30 Days
- Construction Man-Hours: ~50,000
- Construction Duration: ~9 Months
- Project Timing: 2008-2009
- Turbine OEM: GE Frame 7FA
- Power Plant Type: 2 x 1 Combined Cycle
AIR FILTER RETROFITS

- Erection of Filter Platform Extension
- Existing Filter Removal
AIR FILTER RETROFITS

Right Hand Coil Module

Four Coil Modules Installed

New Transition
AIR FILTER RETROFITS

Filter Module Installed

Coil Module Access Platforms

Coil Assembly Header
FILTER HOUSE RETROFIT FEATURES

- Coil Module Sizing
- Filter House Transition
- Coil Location
- Filter House Obstructions (Forward / Aft)
- Filter House Structure / Modifications
- Filter House Ducting (Concentric / Eccentric)
- Outage Considerations (Timing / Interference)
- Chilled Water Pipe Routing
- Condensate Return
CONCENTRIC VS. ECCENTRIC

BEFORE

• Eccentric Inlet Duct
• Extended Inlet Duct for Fogging

AFTER

• Concentric Inlet Duct
• New Spacer Elevates Inlet Duct
• Existing Filter House Utilized
• Parallel Construction Activities
• TIC Retrofit Should Not be Additive to Turbine Outage Durations
• At Site Construction Duration ~6 Months
• Duration From Execution to Outage ~50 Weeks
• Critical Path Retrofit Components are Air Filter Retrofit Kits / Coil Assemblies (30-35 Weeks)
• Work Can be Done In Parallel with Hot Gas Path / Major Outage Work
• Schedule Coordination a Must
• Consider Winter Outage for Performing Work
### TYP. RETROFIT OUTAGE DURATIONS

<table>
<thead>
<tr>
<th>Site</th>
<th>Duration Days Planned</th>
<th>Duration Days Actual</th>
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</thead>
<tbody>
<tr>
<td>Georgia - Unit #1</td>
<td>21</td>
<td>12</td>
</tr>
<tr>
<td>Georgia - Unit #2</td>
<td>21</td>
<td>14</td>
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<tr>
<td>PJM - Unit #1</td>
<td>13</td>
<td>15</td>
</tr>
<tr>
<td>PJM - Unit #2</td>
<td>13</td>
<td>15</td>
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<tr>
<td>PJM - Unit #3</td>
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<td>32</td>
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<tr>
<td>PJM - Unit #4</td>
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<td>32</td>
</tr>
<tr>
<td>Texas #1</td>
<td>18</td>
<td>15</td>
</tr>
<tr>
<td>Texas #2</td>
<td>26</td>
<td>23</td>
</tr>
<tr>
<td>Texas #3</td>
<td>29</td>
<td>20</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td><strong>21</strong></td>
<td><strong>20</strong></td>
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- Planning durations should be 3-4 weeks
- Contractor equipment / site familiarity and capability very important
- Outage duration typically dictated by gas turbine / steam turbine maintenance
- Site coordination during proposal phase required
FILTER HOUSE COIL PIPING DESIGN

Reverse Return Header Piping

Left Hand Coil Header Piping

Right Hand Coil Header Piping
Thank You!

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http://www.turbineinletcooling.org/coolingcalculator.html