Best Practices for Hybrid Systems for Capacity & Efficiency Enhancement of Combustion Turbines During Hot Weather

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Who is TICA?

- The Turbine Inlet Cooling Association (TICA) promotes the development and exchange of knowledge related to gas turbine inlet cooling.

- The TICA website is one-stop source of TIC technical information, including Installation Database & Performance Calculator.

- TICA is a non-profit organization.
TICA Member Benefits

- Access to full/detailed version of TIC Installation Database
- Access to full/detailed version of the TIC Technology Performance Calculator
- GT Users get access to the TIC Forum
- Suppliers have access to advertisement space on the TICA Website and access to booths at various electric power trade shows

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List of Series of Turbine Inlet Cooling Best Practices Webinar Presentations

- June 11, 2014: Wetted-Media Evaporative Cooling
- August 9, 2014: Fogging
- October 8, 2014: Chiller Systems
- January 22, 2015: Thermal Energy Storage
- February 11, 2015: Wet Compression
- April 8, 2015: Hybrid Systems
Agenda:

• Why Cool Combustion Turbines (CT)
• What are Hybrid Systems
• Best Practices for Using Hybrid Systems
• Maintaining your Hybrid System
During hot weather, just when power demand is at its peak............

1. CT Total Power output decreases up to 35% below rated capacity
   (Extent of the decrease depends on the CT design)

2. Efficiency decreases leading to increased fuel consumption (heat rate) and
   emissions per kWh........up to 15% more fuel consumed
   (Extent of the decrease depends on the CT design)
Why CT Power Output Capacity Decreases with Increase in Ambient Temperature?

• Power output of a turbine is proportional to the mass flow rate of hot gases from the combustor that enter the turbine

• Mass flow rate of combustor gases is proportional to the flow rate of the compressed air that enters the combustor

• Compressors provide compressed air and are volumetric machines, limited by the volumetric flow rate of inlet air they can pull or suck in

• As ambient temperature increases, the air density decreases. This results in a decrease of the mass air flow rate

• Reduced mass flow rate of inlet air reduces the mass flow rate of the combustor gases and hence reduced power output of turbine
Why CT Efficiency Decreases with Increase in Ambient Temperature?

- Compressor of a CT system consumes almost two-third of the turbine’s gross output
- Compressor requirement increases with increase in air temperature
- Increased power required by the compressor reduces the net electric power available from the CT system
Effect of Hot Weather on CT Generation Capacity Depends on CT Design

Up to 19% capacity loss at peak demand for this CT
Turbine Inlet Cooling Overcomes the Effects of the CT Characteristic During Hot Weather

- **Net CT Power Output, % of Design**
  - **No Cooling**
  - **With TIC**
  - **Rated Capacity**

- **Ambient Dry-Bulb Temperature, F**
  - 60
  - 70
  - 80
  - 90
  - 100

- **Graph**
  - **With Cooling**
  - **No Cooling**
  - **Rated Capacity**

**Graph Details**

- **Y-axis**: Net CT Power Output, % of Design
- **X-axis**: Ambient Dry-Bulb Temperature, F
- **Legend**:
  - No Cooling
  - With TIC
  - Rated Capacity

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**TURBINE INLET COOLING ASSOCIATION**

turbineinletcooling.org
Hybrid Inlet Cooling Systems

• Hybrid systems are systems that use more than one technology together to achieve the desired inlet condition

• Systems which draw elements from different technologies to:
  – Maximize Power Output
  – Minimize Heat Rate
  – Operational flexibility as economics change
  – Reduction of capital costs by using existing resources. .... Site Specific
Inlet Cooling and Power Augmentation Technologies

- Evaporative (Media or Fogging)
- Chilling (Mechanical or Absorption)
- Thermal Energy Storage
- Wet Compression
- Hybrid
Example Hybrid Inlet Cooling Systems

- Electric Chiller with TES
- Electric Chiller with Absorption Chiller
- Electric Chiller with IC Engine Chiller
- Any Technology with Wet Compression
- Chillers with Fogging
Pyschrometric Chart for Some TIC Examples

Legend
Wetted Media: A-B
Fogging: A-C
Indirect Cooling: A-D
Indirect + Direct Evap. Hybrid: A-D-E
Two Indirect Cooling + One Direct Evap. Hybrid: A-D-F-G

Energy Sources for Hybrid Inlet Chilling Systems

- Waste Heat
- Steam
- Fuel - Natural Gas, Fuel Oil, etc.
- Solar
- Other - LNG, Natural Gas, etc.
Waste Heat as Energy Source

- Process Hot Water
- Exhaust Gas off back end of HRSG
- Heat Recovery from engine driven equipment (e.g. chillers !!!)
Use Hybrid Concept to Support Auxiliary Systems ... 

- Generator Cooling
- Lube Oil Cooling
- Step-Up Transformer Cooling
Examples of Hybrids

- Rolls Royce Trent 64 uses fogging and wet compression
- Rolls Royce Mehoopany uses chilling and wet compression
- Dominion Energy uses fogging and wet compression on 7EA’s
- LM6000’s uses chilling and wet compression
Examples of Hybrids

Las Vegas Cogen
- LM6000’s (4)
- TIC System
- Fogging followed by chillers to cool inlet air to 50°F
- Only fogging when ambient <70°F
- Chiller (absorption) alone when humidity is high
Hybrid Systems Example

Calpine Clear Lake Cogeneration, Pasadena, TX (1999*)

Gas Turbines
- Three W501D (106 MW each)

Hybrid System
- Absorption chillers followed by mechanical chillers
- Absorption chillers (8,300 tons operating on hot water heated by HRSG exhaust) produce chilled water at 41°F and mechanical chillers (1,200 tons) operating in series further reduce the chilled water temperature to 38°F for storage in a 107,000 Ton-hrs TES tank
Cooling Location

Typical Coil, evap media and Fogging nozzle location

Silencing panels
Maintaining your Hybrid System

- Daily Inspections
- Monthly Inspection
- Yearly Inspections
System Inspection (Daily)

- Pump seals both water and oil/grease
- System leaks
- Operating pressures
- Instruments
- Noise
- Vibration
System Inspection (Monthly)

- All Items for weekly
- Water quality
- Amp Draws on equipment
- Belts worn?
- Hoses
Chilled Water Pumps
System Inspection (yearly)

- Duct work condition
  - Materials of construction
    - Coating systems
  - Drain System
  - Obstructions
- Water Source
- Control System Integration
- Nozzles
- Evaporative media condition
System Inspection (yearly) conti.

- TES Tank Conditions
  - Materials of construction
    - Coating systems
- Instruments
- Chiller Tubes
- Winterization
Coil Inspections (downstream)
System Components
Thermal Energy Storage
Thermal Energy Storage Tank With Ice Makers
Chiller Building
Recap

- Use equipment to its maximum efficiency
- Use existing equipment as much as possible
- Use waste heat source available
- Maintain the equipment
- Maintain the water quality
- Be creative
Thank You!

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