THERMAL ENERGY STORAGE

Big Batteries that Enhance Turbine Inlet Cooling Systems

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Introductions

Annette Dwyer
- Munters Corporation
- Vice-Chair, TICA

Guy Frankenfield, PE
DN Tanks
Secretary, TICA
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 information space on the TICA Website and access to booths at various electric power trade shows

Become a Member
Turbine Inlet Cooling Technologies - Webinar Schedule

- August 22, 2012: Wetted-Media Evaporative Cooling
- October 18, 2012: Fogging
- December 19, 2012: Chiller Systems
- **February 13, 2013: Thermal Energy Storage**
- April 17, 2013: Wet Compression
- June 19, 2013: Hybrid Systems
Agenda for Today’s Presentation

• Thermal Energy Storage (TES) Concept

• TES application with Turbine Inlet Chilling (TIC) Systems

• Case Studies of a TES with TIC at Natural Gas Power Plants
Energy Storage Concept

- Energy is stored during “off-peak” periods, then distributed during “peak” periods.

- Examples of energy storage systems:
  - Battery in a mobile phone
  - The human body
  - Thermal Energy Storage (TES)
TES with Chilled Water Cooling Systems

TES provides daily dispatch-able electrons
Thermal Energy Storage

- Proven energy storage technology – over 30 years of demand-side history
- Economical first cost – low cost of capital compared to other energy storage
- Long expected useful life – 30+ years
- Practical for extended discharge periods – many hours
- Relatively easy to site (technically and environmentally)
TES Applications

College Campuses

Private Industry & Data Centers

Government & Municipalities

Natural Gas Power Plants
Electric Grid Components

- Generation
- Transmission & Distribution
- End User
U.S. Electric Grid
ERCOT Grid - Hourly Load

System Hourly Load
2011 Summer Peak

Source: ERCOT, www.ercot.com
ERCOT Grid - $/MWh

HB South Region
August 2011

Source: ERCOT, www.ercot.com
2013 Peak Load Week - Generation by Fuel Type

Note – no changes to existing reserves requirements were assumed for this analysis
Natural Gas Power Plant Performance

Performance goes down as outside air temp goes up.
Turbine Inlet Cooling (TIC)

- CT output highly sensitive to inlet air temp:
  - Warmer air = less density = less mass = less power
  - Frame CT’s can lose 15-25% of design power

- Cooling the inlet air aids hot weather output:
  - Chiller-based cooling typically provides 45°F to 50°F inlet air; gains 15 to 25%+ output and improves heat rate;
  - But chiller plants can consume power as a parasitic load during those peak hot weather periods of time

But TIC capital $/kW is less than even the simplest Combustion Turbines.
Turbine Inlet Cooling Improves NG Power Plant Performance

Chiller Plant → TES Tank → Cooling Coil → Chilled Water → Ambient Air → Chiller Plant

Combustion Turbine
- Natural Gas
- Exhaust Gases to Atmosphere or for Heat Recovery for Cogeneration or Combined Cycle System
- Shaft Power
- Electric Generator

Combustion Chamber
- Air Compressor
- Ambient Air
Chilled Water TES Concept

Off-Peak Cooling Mode

Peak Rate Cooling Mode

Inlet Chilling Cooling Coils

Off

ON

CHILLER (ON)

CHILLER (ON)

CHILLER (ON)

CHILLER (ON)

CHILLER (OFF)

CHILLER (OFF)

CHILLER (OFF)

THERMAL ENERGY STORAGE TANK

THERMAL ENERGY STORAGE TANK

WARM

CHILLED

ON

OFF
With TES:

- permanent electric load shift from peak periods to off-peak periods
- energy reduction by taking advantage of cooler ambient conditions at nighttime and running chillers at their optimum conditions
**Thermal Energy Storage (TES)**

- TES can be Ice or Chilled Water (CHW)
- Shifts chiller load to off-peak periods
- CHW TES is increasingly used with TIC:
  - Shifts parasitic load to off-peak, maximizes net kW;
  - Reduces chiller plant capacity and capital cost, which can save more than the cost of the TES

Thus, by incorporating CHW TES with TIC:
- Net capital cost is down
- Net kW is up
Examples of TIC with TES

- Escondido, CA – SDG&E
- New Canton, VA – Dominion
- Jacksboro, TX – Brazos-Jack 1
- Princeton, NJ – Princeton University
- Pasadena, TX - Calpine
Case Study

# 1
Riyadh, Kingdom of Saudi Arabia

- 10 existing simple cycle CT’s, each 75 MW

- At the design ambient air temp of 50 °C (122 °F), power output is only 75-80% of nominal rating

- Saudi Electricity Co. (national electric utility) needed to meet rapidly increasing demand, so they compared:
  - Adding 3 more CT’s, or
  - Retrofit existing turbines with Inlet Cooling & TES

- TIC has lower capital $/kW than new CT’s
Chilled Water TES with TIC

- 193,000 ton-hrs CHW TES
- CHW temps of 45.5°F supply / 86.1°F return
- 140 ft diameter x 70 ft high (8 million gallon) CHW TES tank
- Net power increase of 30% with TIC and TES in hot weather
- TES-TIC produces 180 MW at approximately $250/kW

- TES contributes 48 MW x 6 hrs/day
Case Study

# 2
Cleburne, TX – NG Power Plant

- Retrofit existing SGT6-5000F (501F) combustion turbine with an inlet cooling system:
  - New 1.74 MG TES tank
  - New 3,800-ton modular CHW plant with cooling coils & energy management system
Cleburne, TX - NG Power Plant

Power Plant Performance:

- Before - 227 MW @ 95°F DB / 75°F WB
- After - 266 MW @ T2 of 50°F
- Net - 37.5 MW (16.6% Increase)
### 10 States with Highest MW Potential

<table>
<thead>
<tr>
<th>STATE</th>
<th>Potential MW's From TIC - TES</th>
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<tr>
<td>TX</td>
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<td>770</td>
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<td>PA</td>
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TES-TIC Can Boost Power Plant Output

Estimated 30,000+ MW’s of hot weather peaking potential in the US with TIC-TES
Basic TES System Sizing Requirements

• Key Performance Criteria
  – XX,XXX ton-hrs of useable cooling capacity
  – XX°F chilled water $\Delta T$
  – X,XXX gpm max. chilled water flow rate
Summary

• Thermal Energy Storage (TES) is useful for most chilled water district cooling systems

• Turbine Inlet Cooling (TIC) with TES can increase the power output of a combustion turbine power plant on hot summer days

• There is a huge potential in the U.S. to add TIC-TES to existing NG power plants

• MW for MW, it is more economical to add TIC-TES to existing combustion turbines than to build new NG power plants
Guy Frankenfield, PE
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Q & A
Chilled Water TES - TIC

- Trigen-Peoples District Energy - Chicago, IL (1994)
- 123,000 ton-hours, with 30 / 54 °F CHWS / R temps (7% SoCool LTF)
- 127 ft diameter x 90 ft high (8,500,000 gallons)
- TES serves DC; TIC for 3 x 1.1 MW Turbomeca CTs (SC / CHP)

Photo compliments of Chicago Bridge & Iron Co.
Chilled Water TES - TIC

- Princeton University - Princeton, NJ (2005)
- 40,000 ton-hours, with 32 / 56 °F CHWS / R temps (5.7% SoCool LTF)
- 80 ft diameter x 72 ft high (2,700,000 gallons), sited partially in a pit
- TES serves DC + TIC for 1 x 14.6 MW GE LM 1600 CT (SC / CHP)

Photo compliments of Chicago Bridge & Iron Co.
Chilled Water TES - TIC

- University of Texas at Austin - Austin, TX (2011)
- 30,000 ton-hours, with 40 / 52 ºF CHWS / R temps
- 104.5 ft diameter x 67.5 ft high (4,300,000 gallons)
- TES serves DC + TIC for ~100 MW of various CTs (SC / CHP) on campus

Photo compliments of Chicago Bridge & Iron Co.
Chilled Water TES - TIC

- Calpine-Clear Lake - Pasadena, TX (1999)
- 107,000 ton-hours, with ~39 / 64 ºF CHWS / R temps
- 6,400,000 gallons
- TES serves TIC for 3 x 137.3 MW W-501 D5 CTs (CC / CHP) - 21% boost

Photo compliments of Chicago Bridge & Iron Co.