Thermal Energy Storage for Turbine Inlet Cooling

Gregory Henderson
Manager, Industrial Sales – Americas
Baltimore Aircoil Company
What Is Thermal Energy Storage?

Thermal Energy Storage (TES) is the process of using or a refrigeration plant to store cool water or to build ice during off-peak hours to serve part or all of an on-peak cooling requirement.
Thermal Energy Storage

![Diagram showing the cooling load (tons) over time of day. The load peaks during the afternoon and early evening.](image)
Thermal Energy Storage

Time of Day

Cooling Load (Tons)

TES Storage Cycle

TES Storage Cycle
Thermal Storage System
Environmental Advantages

• Require less kWh than conventional systems
• Utilize efficient power and produce fewer carbon dioxide emissions
• Energy line losses at night are 4% to 5% lower than during the daytime

Types of Cool TES

- **Chilled Water (CHW) TES** (sensible heat)
- **Ice TES** (latent heat)
- **Low Temperature Fluid (LTF) TES**
Chilled Water Storage

• Uses conventional chillers
• Temperatures of 39.2°F/4°C to 42°F/5.55°C
• An insulated tank with cooler denser CHWS stratified below warmer less dense CHWR
Chilled Water Storage
Ice TES
68. Ice Bunker Air Conditioning System, 1934.
Ice TES

- Water to ice off-peak; then melted on-peak to provide cooling
- Requires chillers that can provide low temperature brine (22°F/-5.6°C minimum) to freeze the water in the ice tank
- Requires only 1/4 to 1/6 of the space required for chilled water storage (~3Ft³/Ton-Hour)
  - Takes advantage of the latent heat of ice (144 BTU/lb)
- Only ~60% of chillers and heat rejection equipment required
- Requires less plan area than instantaneous chiller system
- Colder supply water temperature (34°F/1°C to 44°F/6.67°C)
Ice TES
Ice TES
Low Temperature Fluid (LTF) TES

- Similar to CHW TES, but using fluid temperatures < 39°F/3.89°C
- Lower supply temperature (36°F/2.22°C to 39°F/3.89°C)
Summary of TES-TIC Examples

• 25 examples, over 24 years
• 107 CTs, from 1 to 175 MW, new & retrofit
• Ice, CHW and LTF TES
• 2.3 million T-hrs total; 92,000 T-hrs avg.
• TIC for avg. of 6 hrs/day; range 4-13 hrs/d
• Hot weather net power augmentation:
  – range 10 to 42%; most are 20 to 31%.
Example TES-TIC - Riyadh, KSA

Electric utility power generation facility:
10 existing 75 MW Combustion Turbine’s (CTs)
At design ambient air temp of 50 °C (122 °F),
power output only 75-80% of nominal rating.

Saudi Electricity Co. (national electric utility):
– Needs to meet rapidly increasing demand
– Could add 3 more CTs for 30% more power
– Instead chose Turbine Inlet Cooling (TIC)
– TIC has lower capital $/kW than new CTs.
TES Solution / Results

Add TIC (at 3,100 T per CT x 10 CTs). Do not install 31,000 T (non-TES) chiller plant; instead, only 11,000 T, running 17-hrs/night, plus 193,000 T-hr (31,000 T x 6 hr) CHW TES. TES adds 48 MW x 6 hrs net on-peak power; + over $10 million in net capital cost savings!!

*TIC-TES adds 180 MW (30%) net increase, and adds power at <1/2 $/kW of new CTs.*
Chilled Water (CHW) TES for TIC

- Saudi Electricity Company - Riyadh, Kingdom of Saudi Arabia (2005)
- 193,000 ton-hrs CHW TES, with 45.5 / 86.1 °F CHWS / R temps
- 140 ft diameter x 70 ft high (8 million gallon) CHW TES tank
- Provides Turbine Inlet Cooling for 30% more net power in hot weather
# Turbine Inlet Cooling with CHW TES

<table>
<thead>
<tr>
<th></th>
<th>Entire Installation (TIC w/ CHW TES)</th>
<th>Storage Portion Only (CHW TES sub-sys)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Location</strong></td>
<td>Saudi Arabia</td>
<td>Saudi Arabia</td>
</tr>
<tr>
<td><strong>Year in operation</strong></td>
<td>2005</td>
<td>2005</td>
</tr>
<tr>
<td><strong>Peak power</strong></td>
<td>180 MW</td>
<td>48 MW</td>
</tr>
<tr>
<td><strong>Energy storage</strong></td>
<td>288 MWh</td>
<td>288 MWh</td>
</tr>
<tr>
<td><strong>Projected life</strong></td>
<td>30+ years</td>
<td>30+ years</td>
</tr>
<tr>
<td><strong>Round-trip effic’cy</strong></td>
<td>near 100%</td>
<td>near 100%</td>
</tr>
<tr>
<td><strong>Classification</strong></td>
<td>commercial</td>
<td>commercial</td>
</tr>
<tr>
<td><strong>Unit capital cost</strong></td>
<td>$250/kW</td>
<td>$83/kW</td>
</tr>
<tr>
<td><strong>Dispatch period</strong></td>
<td>6 hours/day</td>
<td>6 hours/day</td>
</tr>
</tbody>
</table>
TES-TIC Potential in the U.S.

Assume:

• ~300 GW of total installed CT capacity
• ~50% is to be retrofit with TES-TIC
• ~20% output enhancement from TES-TIC

Then TES-TIC could provide:

• ~30,000 MW of hot weather peaking power, typically at only $200-400/kW, including
• ~180,000 MWh of Energy Storage per day