DVPunwani

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CHILLER TECHNOLOGIES FOR TURBINE INLET COOLING

This column is the third in an ongoing series covering turbine inlet cooling (TIC). As per the plans for this column described in the December 2003 issue, the current column discusses various chiller technologies for TIC. While all technologies have their advantages and limitations, the selection of an optimum technology for a specific power plant depends on a number of factors, including the plant's geographical location, CT characteristics, plant operating mode, market value of electric energy, and fuel cost.

Technologies

A TIC system that uses a chiller, draws the turbine inlet air across a cooling coil in which either chilled water or a refrigerant is circulated as shown in Figure 1. Typically, airside pressure drop across the cooling coil is about 1 to 2 inches of water column. The chilled water could be supplied directly from a chiller or from a thermal energy storage (TES) tank that stores ice or chilled water. The two most common type of chillers used for TIC are mechanical and absorption. Because of the space limitations of this column, only one type (electric-motor driven) mechanical chiller is discussed here. The non-electric mechanical and absorption chillers will be discussed in the next issue of this column.

Mechanical chillers, also known as vapor compression chillers, are the most common chillers used for TIC. These chillers are similar to those typically used in heating, ventilation, and air conditioning (HVAC) systems for cooling air in large commercial buildings. The refrigerant compressor in a mechanical chiller system could be driven by an electric motor, natural gas engine, or steam turbine. Because of the space limitations in this column, only the electric motor-driven mechanical chiller is discussed. The mechanical chillers driven by natural gas engines and steam turbines will be discussed in the next issue of this column.

A mechanical chiller can cool the turbine inlet air to any temperature down to 42°F. Even though the chiller could cool the inlet air to temperatures even lower than 42°F, the lower temperatures are

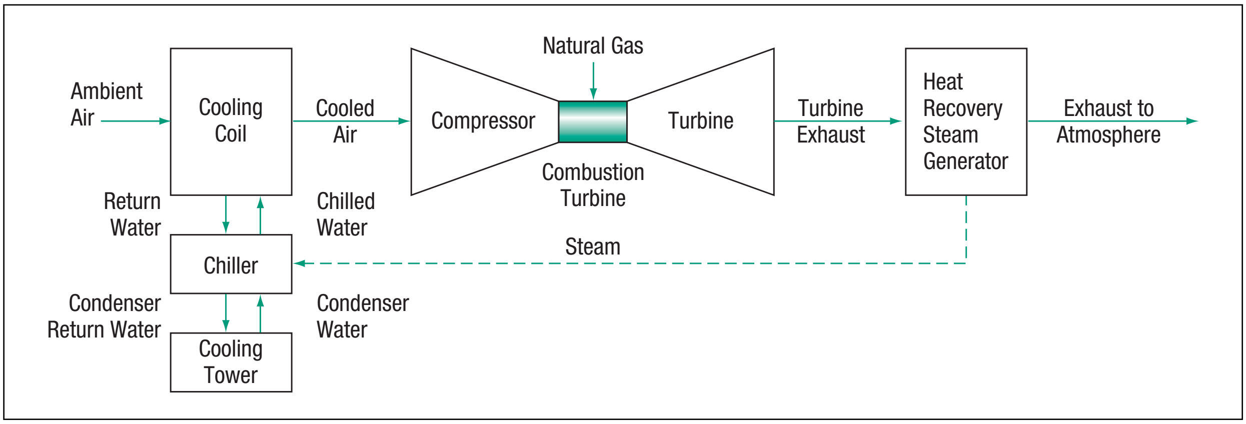

Figure 1: Schematic Flow Diagram for a Combustion Turbine Plant Using Chillers for TIC

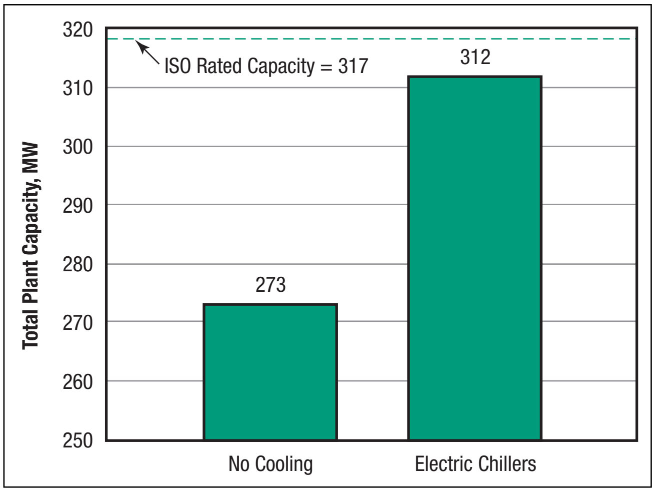

Figure 2. Effect of Using Electric Chillers on Total Plant Capacity

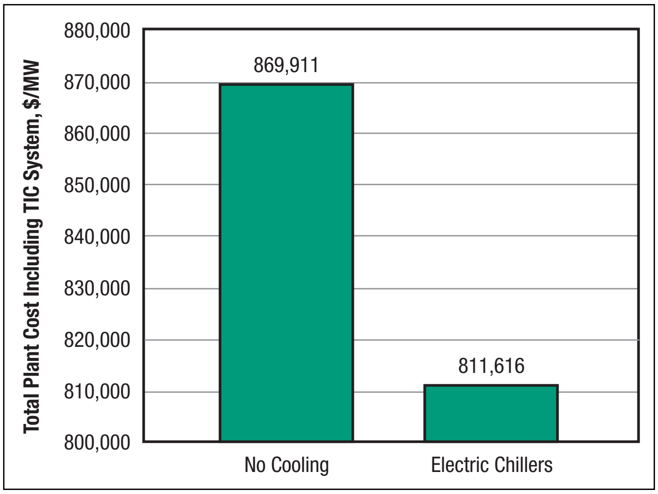

Figure 3. Effect of Using Electric Chillers on Total Plant Cost

typically not used to avoid the potential of forming ice crystals in the bell mouth of the compressor, where the temperature drop is typically about 10°F.

The installed cost of a TIC system using electric motor-driven mechanical chillers (hereafter referred to as "electric chillers") is less than that using other types of chillers. The electric power need of an electric chiller is in the range of 0.7 to 0.8 kW/RT[1], depending on the chiller design. Most of this power requirement is for operating the refrigerant compressor (0.6 to 0.65 kW/RT). The balance of the power is required for operating chiller water and condenser water pumps, and cooling tower fans. In spite of this parasitic power need, TIC systems using these chillers do produce significant net power enhancement for the power plant.

Advantages & Limitations

The primary advantage of using a chiller for TIC is that it allows cooling of the turbine inlet air to temperatures lower than those possible with evaporative cooling technologies and thus, achieves much higher power capacity enhancement. Unlike evaporative cooling, a chiller allows cooling of inlet air to any desired temperature within the limitations of the selected chiller. A chiller also does not require extensive water treatment and consumes very little water compared to evaporative cooling.

The primary disadvantages of a chiller system are its higher capital and maintenance costs compared to evaporative cooling systems. Since the chiller systems also require the inlet air to be drawn through cooling coils, these systems incur a permanent pressure drop (generally a few inches of water column) on the airside, compared to negligible pressure drop for evaporative cooling systems.

Economics

The economics of chiller technologies for TIC discussed here uses an example of a cogeneration power plant located in the Houston, Texas area and having a rated capacity of 316.8 MW (3 industrial frame CTs of 105.6 MW each). When the ambient temperature in Houston is 95°F, dry-bulb and coincident wet-bulb temperature is 80°F, the output of the cogeneration plant without any cooling drops to about 273 MW. This represents a capacity drop of about 44 MW, or a loss of about 14 percent, compared to the rated capacity. If the power plant in this example had deployed an aeroderivative, instead of an industrial, combustion turbine, the loss of power capacity would have been even a higher percentage because aeroderivative turbines are more sensitive to ambient temperature than the industrial turbines.

Figure 2 shows the effect of using electric chillers on total plant capacity when the ambient temperature increases to 95°F and the electric chiller is used to cool the turbine inlet air to 50°F. Total chiller capacity required for cooling the turbine inlet air for the plant is about 18,400 RT. The results in Figure 2 show that the electric chiller increases the net plant capacity to about 312 MW from that of 273 MW without any cooling. Therefore, the electric chiller provides net capacity increases of about 39 MW (or 14%) over the 273 MW capacity of the uncooled plant at 95°F ambient condition.

Figure 3 shows the effect of using an electric chiller on total plant (power plant plus TIC system)

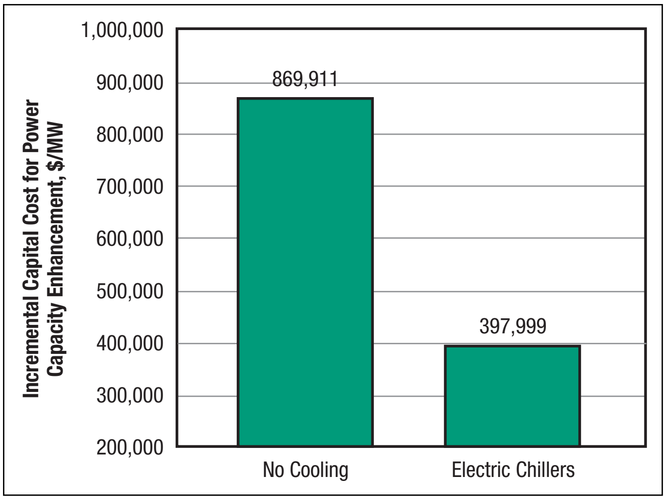

Figure 4. Effect of Using Electric Chillers on Incremental Capital Cost for Plant Capacity Enhancement

cost per MW of the net capacity of the plant for the same conditions as those for Figure 2. The costs in this Figure are based on the following installed costs for the power plant and TIC systems: $750,000/MW for the cogeneration plant at the rated capacity, $834/RT for the complete TIC system (with cooling coil, chillers, pumps, demisters, and cooling towers) with electric chillers.

Based on the above, the total cost of the cogeneration plant without TIC is $237.6 million. When the ambient temperature rises to 95°F and its total capacity decreases to 273 MW, the effective capital cost of the cogeneration plant rises from $750,000/MW to about $870,000/MW for the same total investment of $237.6 million. The results in Figure 4 show that the use of a TIC system with electric chillers reduces the total plant cost from nearly $870,000/MW to $812,000/MW. It should be noted that even though the total plant cost is higher with TIC, its cost per MW is lower because of its higher net capacity when the ambient temperature is 95°F.

Figure 4 shows the effect of TIC with electric chillers on the total plant cost for the incremental power capacity enhancement above the capacity of the uncooled plant at 95°F for the same set of conditions discussed above for Figure 3. It shows that the TIC with electric chillers provides incremental power at a cost of only $398,000/MW or less than half the cost ($870,000/MW) of an uncooled system.

The estimates in Figures 2 through 4 are only "snapshot" results when the ambient dry-bulb temperature is 95°F and the turbine inlet air is cooled to 50°F for the plant's location in the Houston area. On the basis of the information in these figures, it is not possible to determine the annual financial benefits (simple payback period or life-cycle costs, etc.) of using TIC with electric chillers. Further analyses are necessary, using hourly weather data for all 8,760 hours of the year for estimating the net annual production of electrical energy (MWh) and steam, and their respective market values and annual operating and maintenance costs.

Users

Many power plants across the U.S are using various chiller technologies that best suit their needs. A database of some of these installations is available in the Experience Database section of the Website (www.turbineinletcooling.org) of the Turbine Inlet Cooling Association.

Summary

TIC systems using electric chillers allow combustion turbine systems to continue to produce nearly at the rated capacity of the plane, even if ambient temperature increases. In addition, TIC with electric chillers provides incremental capacity enhancement at less than one-half the capital cost per MW of the uncooled combustion turbine systems.

Reference

[1] One Refrigeration Ton (RT) chiller capacity means heat removal capability of 12,000 Btu/h.

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