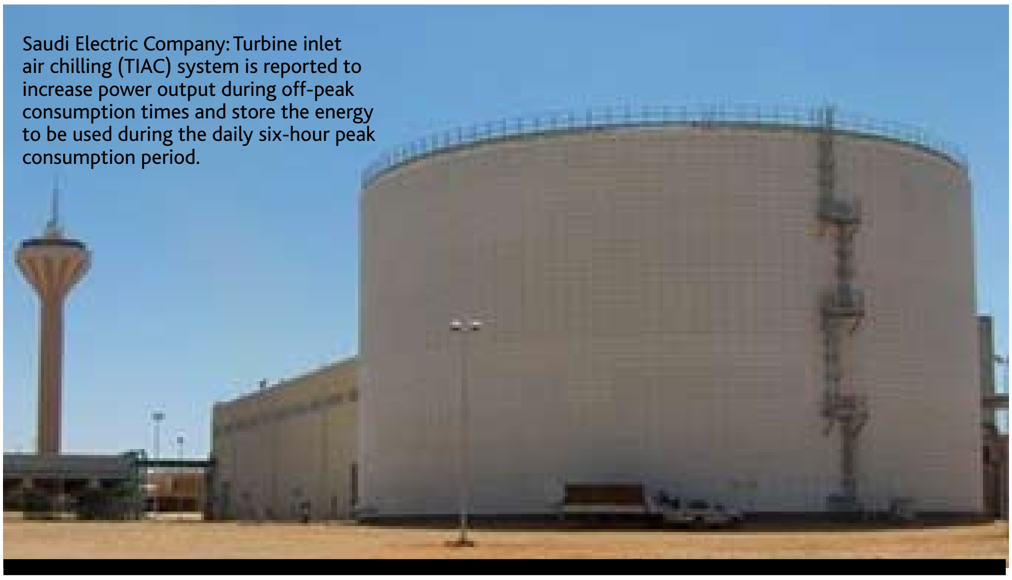

Saudi Electric Company: Turbine inlet air chilling (TIAC) system is reported to increase power output during off-peak consumption times and store the energy to be used during the daily six-hour peak consumption period.

INCREASING POWER AND ROI WITH TURBINE INLET AIR CHILLING

Despite innovations in harnessing unconventional energy, we will still need conventional plants to provide guaranteed capacity, believes Sam Abdalla, and demonstrates that applying TIAC to existing assets provides a "bridge" solution to meet today's peak power demands, especially in the GCC region.

While there is much promise in solar, wind and geothermal power technologies to help offset carbon emissions and produce the renewable, cost-effective electric energy of the future, it must be recognised that they will never be reliable as sources of firm capacity and will always need to be backed up by traditional power generation equipment. With the need to get on-line and ramp up quickly to address the vagaries of nature, it would seem that combustion turbine systems, either in simple cycle or combined cycle configurations, would be the systems of choice to provide the required firm capacity. Combustion turbines are here to stay, at least in the medium term.

Combustion turbine technology is mature, and improvements in the technology tend to be small and costly. However, there are other proven technologies that are affordable and easy to implement that can help boost power production from existing combustion turbine units, while also reducing emissions. These tested solutions can serve as the "bridge" from inefficient thermal power production to the innovative technologies of tomorrow. Turbine Inlet Air Chilling (TIAC) is one such proven solution that helps gas turbine power plants boost power production affordably and efficiently.

THE TECHNOLOGY

The rated capacity of any gas combustion turbine is based on the standard ambient air conditioning of 15°C, 60% RH and 1 atmosphere pressure at sea level, as defined by the International Standards Organization (ISO).

> THE PURPOSE OF TIAC IS TO RESTORE THE POWER OUTPUT OF A COMBUSTION TURBINE AT ELEVATED AMBIENT TEMPERATURES TO ITS RATED CAPACITY OR BETTER

A combustion turbine's power output is proportional to the mass flow of gas passing through the machine. At high ambient temperatures, air is less dense, and therefore, the mass of air flowing through the machine, for the same volume, is lower than at ISO conditions. Thus, as ambient temperature increases, the turbine's output decreases (Figure 1). The purpose of TIAC is to restore the power output of a combustion turbine at elevated ambient temperatures to its rated capacity or better. Inlet cooling can be accomplished in two ways – evaporative cooling, in which the inlet air is passed through a moist medium that cools the air through evaporation of the liquid coolant (water);

and mechanical cooling, in which the inlet air passes through cooling coils (cooled with chilled water) and undergoes both sensible and latent cooling. The big difference between the two methods is that evaporative cooling cannot cool the air below the ambient wet bulb temperature, whereas mechanical cooling can cool the inlet air to the dew point and below. Mechanical TIAC gives the operator the ultimate control of the turbine's inlet air temperature, enabling the system to operate at the optimum inlet temperature all the year around (Figure 2)

This technology is applicable to all combustion turbines (CTs), whether operating in simple-cycle, cogeneration, or combined-cycle systems. The technology can be applied on newly installed gas turbines and as retrofit on the existing ones.

HOW DOES IT WORK?

By cooling the ambient air, the density of the air increases and the

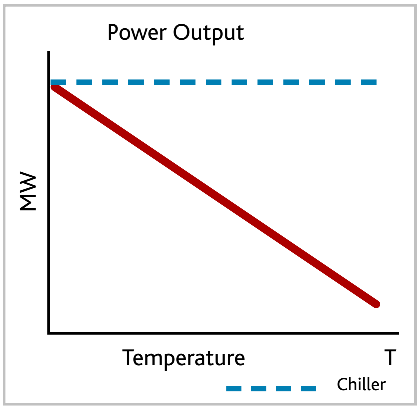

Figure 1: Combustion power output v/s ambient temperature

mass flow rate to the gas turbine increases, leading to higher power output (the same concept as the car turbo-charger).

The cooling is accomplished by installing a heat exchanger (cooling coil) downstream from the air filter elements (Figure 3). The chilled water flows through the heat exchanger, thereby cooling the inlet air to the required air temperature.

The chilled water is produced in a chiller plant, using electric- or steam-powered chillers (Figure 4).

The TIAC chiller plant is often supplemented with a Thermal Energy Storage (TES) system. This allows the peak cooling load, which occurs for only a few hours a year, to be served by a chiller plant that is sized for the average cooling load. The chiller plant runs all the time at a more or less constant load and is either cooling inlet air or charging the TES tank with chilled water. When the cooling load is greater than the chiller plant's capacity, the additional load is served from the TES tank. Saudi Arabia has excellent examples of the effective use of TES, including Saudi Electric Company's Power Plant 8, which combines an 11,000 TR chiller plant and a 195,000 Tonne-Hour thermal energy storage tank. The combination of TIAC and energy storage increases total plant output by 25%.

TIAC IN THE GULF REGION

The six countries of the Gulf Cooperation Council (GCC) – Bahrain, Kuwait, Oman, Qatar, KSA and the United Arab Emirates – enjoy sunny climates the year round, with very high ambient temperatures and

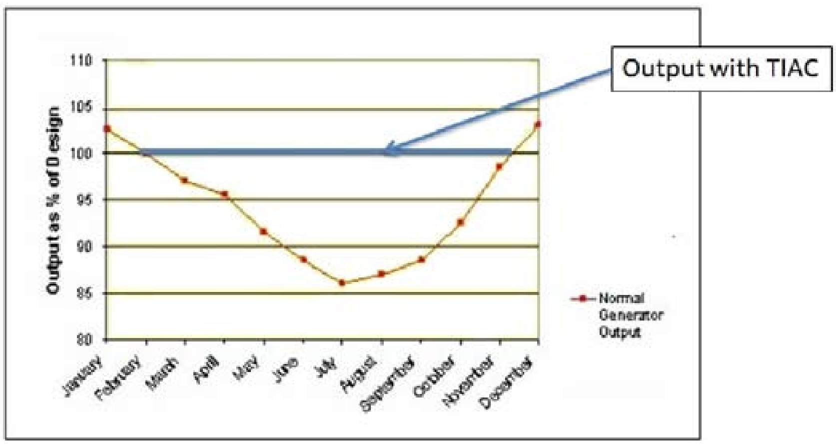

Figure 2: Turbine power output with mechanical TIAC

relative humidity in the summer season. These high ambient conditions cause the gas turbines' output to deteriorate significantly. Ironically, this occurs when more power is required due to the high demand for cooling.

AT MARKET PRICES, IT COSTS ABOUT $800/KW TO BUILD A NEW SIMPLE CYCLE POWER PLANT, WHILE INSTALLING TIAC COSTS AROUND $300/ EQUIVALENT KW

As an example, let us look at an F class combustion turbine that has an ISO power output of 300 MWe. At an ambient dry-bulb temperature of 50°C, the machine will produce only around 210 MWe, whereas the same combustion turbine can produce more than 300MW in the winter season, when the ambient temperature is below 15°C, ie, at ISO or better. Thus, with TIAC, and assuming there is no change in power purchase rates from season to season, the turbine will provide at the very least a 30% increase in revenue in the summer season, thus enabling investors to improve asset utilisation and achieve a higher return on investment.

TIAC IN SAUDI ARABIA

The table, above right, presents the approximate installed power capacity (GW) in the GCC region in 2011.

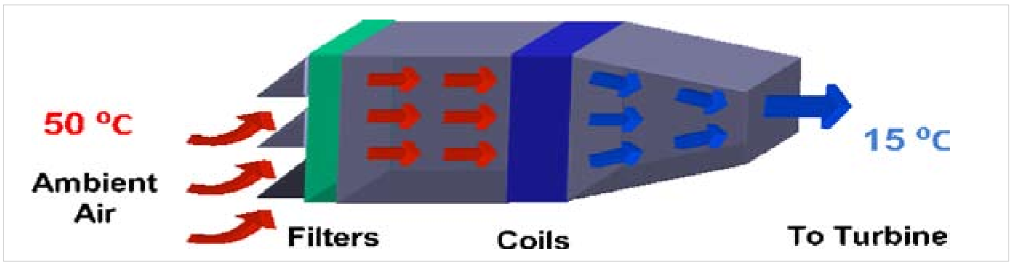

Figure 3: TIAC coil placement

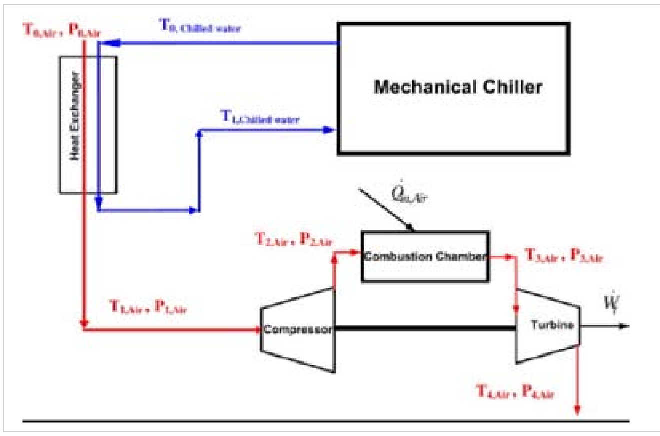

Figure 4: The chiller system

1	KSA	48.0
2	UAE	26.8
3	Kuwait	10.7
4	Bahrain	3.3
5	Oman	4
6	Qatar	5.4
	GCC	98.3 GW

Since KSA has the highest installed power production capacity, let's take an analytical look at the impact of TIAC on the country's existing gas turbine fleet. In the 1990s, Saudi Electric Company (SEC) realised the valuable economic benefit of TIAC. As of today, there are nearly 100 gas turbines across the SEC network with an installed TIAC system. Additionally, there are two IPP projects under construction for ARAMCO, which will be equipped with TIAC. Taking a look at the power boost and economic benefits of TIAC, it's easy to understand the advantages for Saudi Arabia and areas with similar climates.

According to an SEC official, approximately 35% of Saudi Arabia's installed capacity is simple cycle and nearly 10% is combined cycle. This results in approximately 20 GW of power production using combustion turbines.

Let's do the maths on the benefit on TIAC. TIAC can add up to 30% capacity in summer season, so the prospective added power using TIAC is equivalent to approximately 6 GW of installed capacity.

At market prices, it costs about $800/kW to build a new simple cycle power plant, while installing TIAC costs around $300/ equivalent kW. The savings is approximately $500/KW for TIAC. When applied to the 6 GW estimated above, the result is CAPEX saving of about $3 billion.

It is also important to consider that the operation and maintenance of a gas turbine is substantially more expensive than TIAC. Capacity provided through the use of TIAC has an O&M cost of approximately 50% of the O&M cost of capacity provided by a conventional combustion turbine. Additionally, TIAC can be installed and brought on-line relatively quickly, with an average time frame of seven to 10 months from project inception to finish.

We should continue to innovate and evolve the energy technologies of the future, but there will still be the need for conventional plants to provide guaranteed capacity. The GCC countries will need to build new power plants to address these needs. Meanwhile, applying TIAC to existing assets provides an ideal "bridge" solution to meet today's peak power demands, reliably and affordably. Furthermore, applying TIAC to new construction enables the owner to extract all the potential power output available from that asset, increasing ROI and building value. ■

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