1500-MW plant in Philippines adds over 60 MW with evap inlet cooling

By Robert Farmer

Evaporative coolers retrofitted during combined cycle plant operation have more than paid for themselves in the first year of service.

Owners and project engineers who automatically dismiss the idea of evaporative air inlet cooling as impractical for gas turbine installations in hot and humid tropical countries may want to reconsider.

A 1500-MW IPP plant powered by six 250-MW combined cycle modules has been retrofitted with evaporative air inlet cooling that has increased total plant output by 40 MW to over 60 MW during peak demand periods in the "hot and humid" Philippines:

☐ **Climate**. Local ambient air conditions drop from 99% humidity and 26°C at night down to around 45% humidity and 36°C in the afternoon.

☐ **MW Gain**. Gas turbine unit output has been increased by about 7 MW in the morning to over 10 MW during the afternoon peak demand period.

☐ **Retrofit**. Evaporative coolers were installed with gas turbines online most of the time except for structural lifts over the generator terminals.

First Gas Power Corp., the independent power plant owner, says the cost of the evaporative cooling retrofit program more than paid for itself within the first year of operation.

The original 1500 MW plant was developed as a phased construction project with commissioning of a 1000-MW Santa Rita station in August 2000 followed by a 500-MW San Lorenzo station in October 2002.

Both stations are owned by subsidiaries of the Philippines' First Gas Power Corporation in which BG Group (British Gas) has a 40% interest. The remaining 60% is owned by First Generation Holdings.

Santa Rita came in below its budgeted £556 million completion estimate, says First Gas Power, and San Lorenzo within its £303 million budget. Siemens, which built both stations, still operates and maintains them on behalf of the owners.

Initially, Santa Rita burned liquid fuel before switching to natural gas operation in January 2002 when gas became available from the Shell/Chevron/PNOC Malampaya field.

First Gas Power sells the electric power output of the plant to the Manila Electric Company (Meralco) under 25-year power purchase agreements that are effective until 2025 for Santa Rita and to 2027 for San Lorenzo.

Payment schedule

Both generating facilities are part of the Philippine government program to develop the downstream market for natural gas produced from the big Malampaya gas field in Palawan about 500 km offshore the Batangas site.

During a normal weekday, the two stations supply a significant portion of the electric power consumption of Luzon including the capital, Manila.

The owners are paid primarily for the Net Dependable Capacity (NDC) of each combined cycle module as determined by a performance test every 6 months, corrected to reference conditions. In addition they are paid for actual MWh exported.

A few years ago First Gas Power and Siemens made a technical and economic evaluation of competitive inlet air cooling technologies to assess op-

Santa Rita 1000-MW station. The first of two combined cycle stations at Batangas, on the main Philippine island of Luzon, built around four V84.3A single-shaft combined cycle power blocks rated 250 MW and 56.8% efficiency each at 32°C sea level and 80% relative humidity site conditions, on natural gas fuel. The gas turbines have been retrofitted with evaporative air inlet cooling to enhance hot day performance.

tions for increasing plant output, especially during peak demand periods.

Usually, evaporative inlet air cooling is automatically ruled out for hot and humid tropical countries. "This seems to be largely because people only consider yearly average temperatures and humidities," explains equipment cooling supplier Munters.

"In reality the physical quantity of water vapor in the air does not change much from hour to hour or day to day. The difference is that as the air gets warmer, it is able to 'hold' more water vapor, and the relative humidity decreases."

Typically, in the Philippines, air at close to 99% humidity and 26°C temperature during the night declines to only 45% humidity when the air reaches 36°C in the afternoon.

This explains why even in the tropics there is significant potential for inlet air cooling during the peak demand at the hottest part of the day.

Evaporative air cooler. Photo of installation being made during scheduled 5-day gas turbine inspection outage. Three-sided design meets structural codes for power stations to withstand 200 kph winds and earthquakes up to magnitude 8.

Evaporative cooling

Santa Rita project engineers say that key technical considerations in favor of evaporative cooling included the following factors:

- amount of water added to the airflow is determined and ultimately limited by basic physics which eliminates any requirement for temperature and humidity sensors, injection-rate calculations, active controls,
- natural control of the water flowrate results in negligible risk of compressor blade erosion and attendant operator intervention and maintenance, and
- inlet cooler upstream of the air intake filters makes the coolers readily accessible without any unit downtime, e.g. dismantling the inlet box.

There is one potential drawback to the location, they note, in that downstream filters operate in what is effectively a saturated atmosphere – and, if not replaced by new filter elements, may fail.

In five of the six units where the evaporative cooler was installed and fine filter exchanged, there was no problem, say Munters engineers. The one exception was where the filter was not changed. Already heavily loaded at the time of cooler commissioning, they explain, it subsequently burst.

Fast track project

Responsibility for supply and installation of the evaporative coolers at Santa Rita and San Lorenzo stations was coordinated between Siemens and Munters.

Delivery of the cooler body, pads, droplet separators, and associated equipment including circulating pumps, conductivity sensors, etc was handled by Munters.

Removal of weather hoods, design and construction of a support structure, and interface to all existing equipment was carried out by Siemens Power Operations.

Additionally, Munters supplied an engineer to supervise construction and commissioning of the first two units, after which Siemens built and commissioned the remaining units.

Overall the project took about six months (including 6 weeks shipping time) from placing the order to having all units commissioned – with the first two cooler installations completed on a priority basis in time for upcoming NDC capacity tests (performed on a fixed semi-annual schedule).

Those first coolers were installed with a downtime of around five days scheduled in parallel with each unit's gas turbine minor inspection.

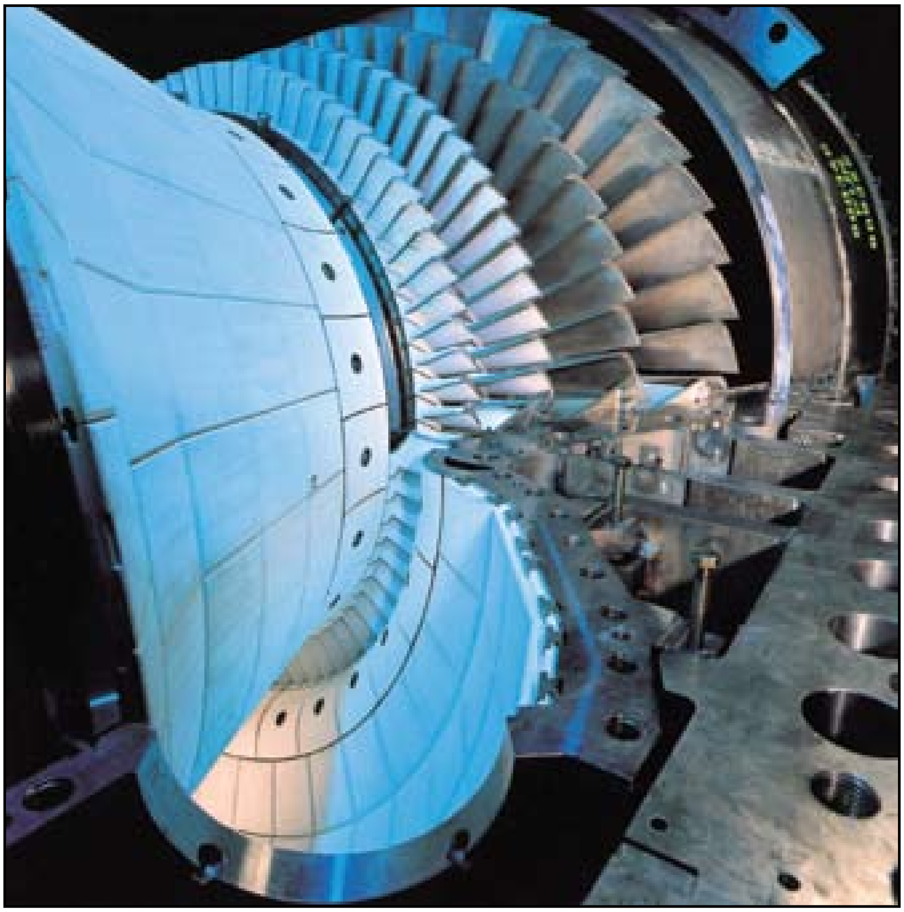
For the remaining four units, the coolers were installed with the gas turbines fully online, although all units had a minimum of 36 hours offline because of the need to lift structural beams over the top of the generator terminals and bus ducts.

Performance improvements

The last cooler was commissioned and made operational in January 2007. Since then, say Munters project engineers, all six coolers have been operating continuously at better than 87% warranted efficiency.

Efficiency is easy to quantify. However, since power gain is determined by prevailing ambient conditions, it is difficult to assign an "average increase in power output" to the evaporative coolers.

Nonetheless, during the January 2007 capacity tests, the increase attributable to the coolers was approximately 7 MW per gas turbine unit, which represents a nominal improvement of about 2.8% in output.



SGT6-4000F/V84.3A gas turbine. F-class design features large annular combustor with replaceable ceramic heat shields and air-cooled turbine section with thermal barrier coatings on the first two stages.

Furthermore, during the hours of afternoon peak demand, operators have experienced gains of more than10 MW per unit (over 4% improvement in net plant output).

Siemens as the O&M contractor and First Gas Power as the station owner both receive higher payment as a result. In addition, the grid operator has more power available for frequency support during peak demand and fewer brownouts caused by grid overload.

Combined cycle units

Essentially a single combined cycle complex, the San Lorenzo and Santa Rita stations are built on the same site and operate from a single control room, with shared facilities including diesel plant for black start, water treatment, fuel delivery and storage.

Santa Rita station is powered by four single-shaft combined cycle blocks and San Lorenzo has two blocks, each powered by a V84.3A gas turbine (SGT6-4000F), steam turbine, and unfired heat recovery steam generator.

The combined cycle blocks are design rated at 250 MW base load output and 56.8% efficiency each, at 32°C ambient sea level and 80% relative humidity site conditions, on natural gas.

The heat recovery steam generator for each 250-MW unit is an unfired, reheat, triple pressure type manufactured by Babcock Hitachi, with a natural circulation horizontal drum boiler.

Multi-fuel capability

All of the gas turbines are equipped with multi-fuel burners enabling them to operate on a variety of liquid fuels as well as on natural gas.

In the event of an interruption or unusual pressure drop in the natural gas supply, the gas turbines switch automatically to operate on any one of a pre-specified range of liquid fuels.

These include condensate, naphtha, No. 2 distillate or any combination such as distillate/condensate, distillate/naphtha or condensate/naphtha.

This not only provides exceptional operational flexibility, accommodating the necessary annual total of 24 days for routine maintenance of the natural gas pipeline, but also insures maximum security of supply to the grid.

To eliminate problems due to water injection for NOx reduction when operating on liquid fuels, de-mineralized water is pre-mixed in the fuel treatment plant and the fuel is fed to the burners as a stable water-fuel emulsion.

Gas turbine

The Siemens V84.3A (SGT6-4000F) designed specifically for 60-Hz power generation applications is ISO rated at 186 MW base load and 38.3% simple cycle efficiency.

With its cold-end generator drive and axial exhaust, the design facilitates heat recovery steam generation installations and makes for a compact, high powered combined cycle module.

In single-shaft combined cycle configurations, the gas turbine is solidly coupled to the generator while the steam turbine drives the other end of the generator through a synchronous self-shifting clutch. This allows decoupling the steam turbine to operate the gas turbine in simple cycle if necessary.

Technical design and construction features include a large annular, 'walk-in' combustion chamber with 24 hybrid burners. The dry low-NOx combustion system operates on natural gas with water injection used for NOx reduction on liquid fuels.

Ceramic combustion chamber tiles line the combustor interior to protect against thermal stress. These tiles are individually replaceable in the event of damage.

The 15-stage axial flow compressor features optimized flow distribution with computer-developed controlled diffusion airfoils.

Advanced cooling technology single-crystal turbine blades on the first stage with thermal barrier coatings and film cooling allows turbine rotor inlet temperatures above 2390°F which was the introductory rating. ■