Class *of* 2006

Groton Generation Station

Groton, SD

Basin Electric Power Cooperative

Record heat tests first LMS100 immediately after COD

The "utility mentality" that paralyzes decision-making at many of the nation's electric companies doesn't exist at Basin Electric Power Cooperative (BEPC), Bismarck, ND. The "super" G&T co-op assesses its needs, lists the options for meeting those needs, conducts the requisite engineering, economic, and risk analyses, and makes a decision. It's a refreshing business model that promotes action based on positives rather than inaction based on the fear of negatives and what others might think.

So it was not surprising that when Basin Electric projected 3% year-over-year increases in power sales to member companies early in the new millennium, the co-op had to begin thinking about capacity additions—sooner rather than later. By 2002 it became apparent that the company's ability to meet projected winter and summer peak loads with its own generation would not be sufficient in the near future.

The utility's peak demand growth typically was 100 MW or less, and generally coincided with high and low seasonal temperature extremes. South Dakota's summer peaks historically have caused more grid and capacity issues than winter.

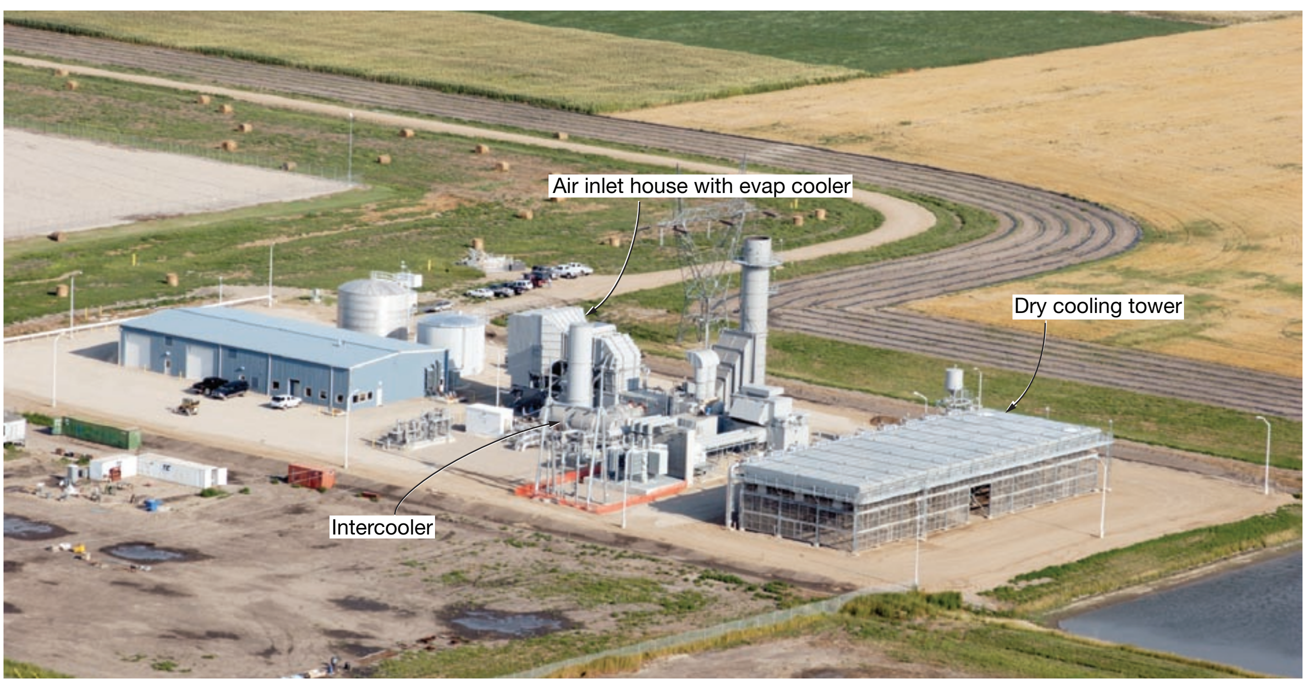
It just so happened that at the time BEPC had to take action, GE Energy was running tests on its promising 100-MW LMS100—a new machine that combined proven components from GE Energy's frames and GE Transportation's aeroderivative engines (sidebar).

True to its culture, Basin Electric reviewed what appeared might be a perfect fit for its members' needs, even though the only operating experience was on the OEM's test unit in Houston. After careful evaluation, the cooperative purchased the first commercial LMS100 for a site five miles south of Groton, SD.

To learn more about some of the innovative projects that Basin Electric owns outright, or is a partner in, read the article on the award-winning Northern Border Recovered Energy Project, "How to make 'green' power with a simple-cycle gas turbine," elsewhere in this issue.

Dick Shaffer, BEPC's project coordinator for Groton, says the utility investigated 10 potential sites for the plant before selecting one located 18 miles southeast of Aberdeen. Its attributes:

- Both a 345- and a 115-kV substa-



Basin Electric's Groton Generation Station, site of the world's first commercial LMS100, will begin installing a second unit this year and bring it online early in 2008 tion already existed near the site. First is operated, maintained, and partially owned by Basin Electric; latter is owned and operated by the utility's dispatch agent, the Western Area Power Administration (Western). Grid connection required only construction of a 0.5-mile line from the generator step-up transformer to the Western yard and the addition of a breaker in the 115-kV substation.

- Firm gas was available via the Northern Border Pipeline only 12 miles to the south. A 10-in.-diam spur line (sufficient capacity for two LMS100s) was constructed, connecting the site to the 42-in. main. With the average mainline pressure sufficiently higher than that required by the GT, only a fuel conditioning skid was required. Interestingly, Basin Electric's Great Plains Synfuels Plant delivers the pipeline-quality gas it makes from coal through the Northern Border line. Since some of that is burned at Groton, one could consider this the first IGSC (integrated coal-gasification simple cycle).
- Water for NO_x control, and for makeup to the evaporative cooler in the air inlet house, totals 75 gpm at full load. It comes from an underground potable-water pipeline that passes through the Groton site.
- The grid in the Groton area traditionally experiences low voltages and was an ideal location for injecting power during periods of high demand.

Other than the work identified in the foregoing bullet points all that was needed to prepare the site for construction was some grading and installation of a storm-water runoff pond. The permit to construct was received in August 2005 and the plant was declared commercial last July 1.

GE was both the equipment supplier and the EPC. However, this was not a turnkey project; BEPC was involved every step of the way.

Basin Electric chose the LMS100-PA model, which has a single annular combustor and is dual-fuel capable. However, there is no plan to burn oil at this time and no storage tank is installed at the site. Shaffer notes that regulators do not require dual-fuel capability when a generator has firm gas supply and transportation contracts.

The utility bought an oil-capable engine to hedge long-term fuel-supply risk. The slight increase in price associated with installing in the factory some difficult-to-retrofit engine accessories required to burn oil just made sense to engineers.

The engine also is equipped with a synchronous clutch (Maag Gear Co Ltd, Zurich) between the GT and the generator. It permits operation in the synchronous condensing mode to provide VAr support when needed. During commissioning, the unit demonstrated its ability to start and synchronize to the grid; decouple the GT and allow the generator to continue spinning; restart the GT and re-engage the clutch, and then proceed

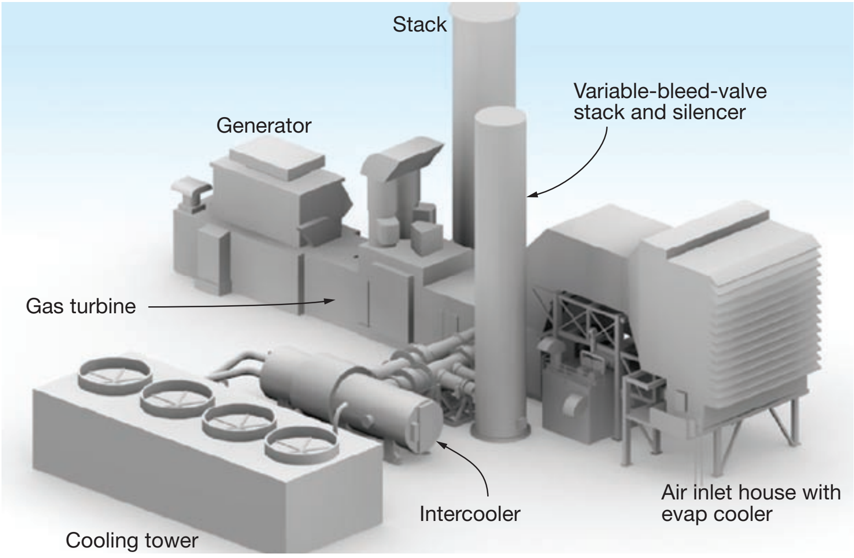
LMS100 features several 'firsts' for both the OEM, industry

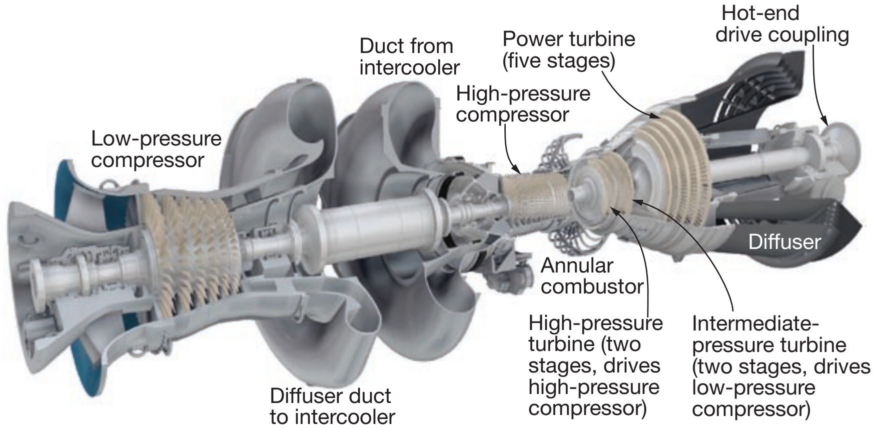
New product development is expensive. So when GE engineers rolled up their sleeves to design what its product literature infers is the "all-everything" gas turbine (GT), it made good sense to take the best of what the company had done previously and use that as a starting point.

But before exploring the design of the engine, let's look at what the OEM says are the LMS100's attributes. Perhaps the best one-word description for the machine is "versatile," as evidenced by the following:

Simple-cycle configuration suitable for peaking and mid-range service. Engine's high efficiency, low first cost, sustained hot-day power, and 10-min starts with no cycling penalty support its selection for peaking applications. Note that rated output at ISO conditions for engines burning natural gas and equipped with dry, low-emissions (DLE2) combustion systems is 98.7 MW; efficiency is 46% at full load. High part-load efficiency (40% at half the full-load rating) and load-following capability contribute to its suitability for mid-range operation.

Steam injection for power augmentation (GE calls this STIG) offers significant improvement in both efficiency (50%) and power output (112.2 MW), plus enhanced operational flexibility. Regarding the last point, variable STIG allows the opera-





to full power. Shaffer reports that while the unit is equipped for synchronous condenser operation, Basin Electric is still in negotiation with Western regarding that service.

First fire was Apr 19, 2006. All required commissioning tests were conducted in the first two weeks of June. Many of the installation and commissioning issues were typical to those experienced with other simple-cycle plants, but the sub-zero weather and the newness of the LMS100 presented challenges to meeting the schedule.

It took five months from arrival of the GT package at the site to first fire and an additional 60 days for commissioning. The OEM estimates that lessons learned at Groton should reduce this to 100 days for centerline installation and 45 days for commissioning of a simple-cycle machine without a clutch.

Operating experience. Groton has a staff of two—Plant Manager Tony Skonhovd and an O&M technician—that normally works days only. BEPC is in the final phase of enabling remote startup and operation—including the disengaging and re-engaging of the synchronous clutch—from its Leland Olds Generating Station in Stanton, ND.

Shaffer says Groton has a much better heat rate than Basin Electric's other peakers. The unit has logged more than 150 starts and 500 hours of operation to date, and this winter is operating anywhere from one to three days a week. BEPC predicts the unit will run at about 10% capacity factor early in its life.

Groton was needed as soon as it went COD, last July and August being among the hottest and driest months in the history of the northern Great Plains. It operated during portions of 18 days in July, producing nearly 13,000 MWh, and for portions of 13 days in August, producing 6100 MWh. "Growing pains," adds Shaffer, "prevented the unit from running more than it did." Early issues primarily were with peripheral equipment, not with the engine itself. They have since been addressed and have not recurred.

However, one area still not meeting expectations is starting reliability. High vibration on the turbine side of the clutch has been an intermittent problem. Investigations into the root cause of the problem are underway. The machine is robust, continues Shaffer, and it performs well once it's up and running. An example: On a recent sub-zero day Basin Electric got 104 MW from Groton.

Cold-weather issues have been a nuisance and have required additional insulation and heat tracing, and revisions to control logic. However, one would expect this problem to exist only during the first winter. A piece of failed thin-wall tubing traveled into the combustor, but no damage was identified by borescope exam or after disassembly.

In sum, the LMS100 experience has been positive and Basin Electric's confidence in the machine is expressed best by its order in early January 2007 for a second unit at Groton. CCJ

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tor to inject all of the steam available into the GT or route it to process—depending on the price electricity and thermal energy.

Combined cycles incorporating the LMS100 are capable of 54% efficiency. Designers say that the engine's relatively low exhaust temperature (varies from 737F for STIG-equipped units to 784F for machines with the DLE option), reduces the cost of materials used in the exhaust system as well as the size (and cost) of steam-plant components. Duct firing can increase output by up to 30 MW.

Combined heat and power (CHP). The engine's high power-to-steam ratio allows it to produce approximately the same amount of steam as a CHP system using an LM6000 while delivering twice the electrical output. Thermal efficiencies of 85%, or higher, reportedly can be achieved with productive recovery of both exhaust and intercooler energy.

Grid support. Output of the LMS100 varies little for grid frequency reductions of up to 5%. Thus the unit helps support the grid in times of high demand and load fluctuations.

What's inside the box

The LMS100 incorporates components from GE Energy's frame machines and GE Transportation's aeroderivative engines and is said to represent the most extensive collaboration of design and manufacturing in the company's history. Four GE business units and three other companies participated in the development program. The system model illustrated in this sidebar facilitates understanding of how key components go together and how the LMS100 works. Keep in mind that the actual plant layout for any user will depend on site conditions.

Flow path. Compressed air from the low-pressure (LP) compressor is cooled in either an air-to-air or air-to-water heat exchanger (intercooler) and ducted to the high-pressure (HP) compressor. The intercooler reduces the amount of work done by the HP compressor thereby increasing power output and efficiency.

As for the engine proper—shown in the cutaway drawing—note that the six-stage LP compressor was derived from the MS6001FA. The machine's so-called "supercore"—which includes the 14-stage HP compressor, combustor, and HP turbine, is derived from the CF6-80C2 and CF6-80E1 aircraft engines which power many Boeing 767s and 747s. Design of the new two-stage intermediate-pressure turbine and the new five-stage power turbine is based on the latest aero technology.

Emissions control. The LMS100 is available with a single annular combustor (SAC) equipped with 30 gas fuel nozzles or a gas-only DLE2 combustor, which has 15 nozzles. A SAC with water injection for NO_x control can be configured for gas only, liquid-fuel only, or dual-fuel operation; the SAC with steam injection for NO_x control is equipped to burn only gas. Machines incorporating STIG for power augmentation also have SACs that burn only gas. NO_x emissions from all four system configurations: 25 ppm. To reduce NO_x further, a selective catalytic reduction (SCR) system is installed. Low-temperature catalyst can be used without tempering air because engine exhaust is less than 800F.

Maintainability features. Modular construction permits replacement of the aero components without total disassembly. For example, a leased or spare "supercore" can be installed in 24 hours when depot maintenance is required. The power-turbine module also can be replaced within an additional 24 hours.

Split-casing construction of both the LP and HP compressors permits comprehensive onsite inspection and blade replacement. Borescope ports allow a degree of machine condition assessment without disassembly.

Regarding service intervals, here's what the OEM recommends:

- Every 25,000 actual fired hours (no multipliers apply for cycling service), onsite hot-section replacement.
- Every 50,000 actual fired hours, depot maintenance. This includes overhaul of the hot section/power turbine, including inspection of all systems.