A flexible plant configuration

CLUTCHES CAN HELP STEAM TURBINES HANDLE VARYING ELECTRIC LOADS AND STEAM DEMANDS IN COMBINED CYCLE AND COGEN PLANTS

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Combined cycle and cogeneration plants have three principal designs to connect the steam turbine to the generator: Multi-shaft, single-shaft that is solidly coupled, and single-shaft that is clutch-coupled. The multi-shaft design uses separate generators for the steam and gas turbines.

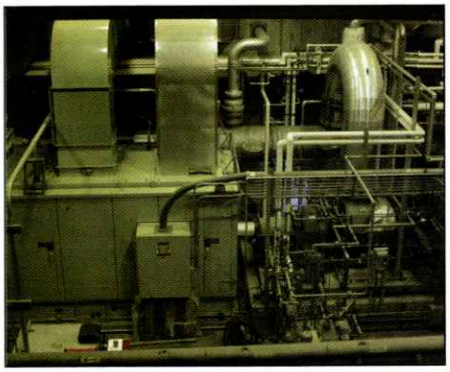
In single-shaft designs, both the steam and the gas turbine drive the same generator. This design reduces the number of generators, transformers, breakers and associated transmission gear required. Therefore, it has a smaller footprint and a simpler steam system.

The solidly coupled design requires the gas and steam turbines to spin at all times, which could pose a problem during start up where the gas turbine can come online before the Heat Recovery Steam Generator (HRSG) starts generating steam. Clutch-coupled designs enable the gas turbine to come up to speed on its own. Once the heat recovery boiler has generated enough steam to drive the steam turbine, it can connect to the generator and boost the output. Hooking up the gas and steam turbine to the same generator allows combined cycle and cogeneration operators to choose the optimum mix of energy inputs and outputs depending on changing operational needs.

Powering the grid

The advantages of the clutch-coupled arrangement include simplified startup, reduced time to generation, lower emissions during the startup sequence, and the ability to pull the steam turbine offline without affecting the gas turbine. The following case studies involving three power plants in the U.S. illustrate clutched-configurations. Each of the plants uses a single-shaft design with a clutch from SSS Clutch Company, Inc. The clutch accommodates changes in turbine speeds during operation (click here in the online version in www.turbomachinerymag.com archives for more details on the SSS clutch).

The Kodiak Electric Association, Inc. (KEA; Kodiak, Alaska) is a member-owned rural cooperative serving nearly 4,000 commercial and residential members, including a U.S. Coast Guard facility. The primary power source is a 20 MW Terror Lake Hydro Project, which is owned by the state and operated by KEA. More than a dozen diesel-fired internal combustion engines or gas turbines, ranging from 0.2 MW to 7.0 MW supplement the hydro power.



Figures 1, 2: The Glenn Ferry, Idaho plant (left) features a saturated steam turbine from Tuthill Energy Systems (now part of Dresser-Rand) clutched to the generator, while the Nyman power plant (right) in Alaska has an Elliott steam turbine

KEA's Nyman Power Plant has two units. Installed in 1978, the first unit consists of a Delaval engine (4,222 hp) with an ABB turbocharger driving a 3 MW Ideal Electric generator. In May 1999, KEA installed a 7.5 MW Ideal Electric generator with two drives — a Solar Turbines Taurus 60 SoLoNOx turbine and an Elliott steam turbine.

"We were going to export steam to the Coast Guard," says Ron Sternberg, KEA's Instrument and Control Technician. "We could divert any extra steam to the steam turbine to augment generation."

KEA relies primarily on the hydroelectric generators, but uses the Nyman Unit 2 as a backup when the reservoir water level drops or the hydro turbines are shutdown for maintenance. The Nyman is not used for peaking.

The Solar turbine is the primary driver for the generator. When power is needed, the utility fires it up and sends the exhaust to the HRSG. Initially just 10% of the exhaust goes to the HRSG in order to slowly heat up the boiler. That ramps up until the boiler reaches 200 psi, at which point the actuator to the steam turbine opens. Once the steam turbine (Figure 2) is up to the same speed as the Solar turbine, about 5,245 rpm, the clutch between the steam turbine and the generator engages, and both turbines drive the generator. At that point the Woodward 505 controller takes over running both turbines. The diesel-fueled gas turbine produces about 4.7 MW and the steam turbine adds about another 1.3 MW to 1.5 MW, depending on ambient temperatures.

Recently, KEA modified the HRSG, installing a guillotine damper to close off the steam from reaching the boiler. This allows KEA to bring up just the gas turbine unit when power is needed in a hurry. "In an outage situation where we need power right away, we can get up to 5 MW in twenty minutes," Sternberg explains, "rather than waiting the three hours it takes to heat up the boiler."

Changing steam needs

Unlike the KEA plant, Quixx Linden Cogen Facility in Linden, N.J., has not been built to supply electricity to the grid. Rather, it provides a single industrial customer — a General Motors truck assembly plant — with electricity, steam, compressed air and demineralized water. Initially Quixx planned to use a single 10 MW - 15 MW steam turbine, but after reviewing the load data received from GM, it opted for three gas and steam units.

"Our contract with GM called for us to follow their load," explains facility manager Patrick Dillon. "During production they have a large welding load and we can have instantaneous swings of 2 MW to 3 MW."

In addition to the changing electrical load, the plant uses steam for heating and process, therefore steam requirements

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vary seasonally. Multiple gas and steam turbines in a single-shaft arrangement provided Quixx with the modular flexibility to quickly adjust electrical and steam output to match GM needs.

The 24 MW nominal plant has three identical generator trains. At one end is a Solar Taurus 60 gas turbine, rated at just under 5 MW connected to a 9.2 MVa Ideal generator. On the other side of the generator, connected via the SSS clutch, is a 3.1 MW saturated steam turbine from Elliott. A HRSG from Energy Recovery International attached to the gas turbine produces 26,000 lbs of saturated steam per hour at 150 psi. Each unit has duct firing to increase capacity. The gas turbines are controlled by the Allen-Bradley Programmable Logic Controller (PLC) provided by Solar, the steam turbines by Woodward governors, and everything ties into the Allen-Bradley plant control system.

The dual-drive arrangement on the generators presented two challenges. One was making sure both turbines and the clutch were properly aligned with the generator in the middle. This was achieved using a laser alignment system. The other was optimizing the controls to account for both the power curves of turbines simultaneously, a job done by engineers from Solar and Elliott.

The plant went commercial in October 1999 and facilities manager Dillon reports that while the heat rates vary with load, the plant has always been profitable.

Power and process

The installations operated by Black Hills Generation (Golden, Colorado) are a mix of the Nyman and Quixx Linden plants. Black Hills Generation manages two units in Idaho to provide steam for food processing plants, but all the electricity is sold to the local utility.

The steam customer is Idahoan Foods, Inc., which sells frozen and dehydrated potatoes under its own and other brand names, as well as providing a wholesale flaked potato product to secondary processors, such as Proctor & Gamble. The cogen plants do not directly provide Idahoan with electricity. Rather, they sell the entire output to Idaho Power under a 20-year agreement.

Black Hills operates two cogen facilities; one in Rupert, Idaho and the other in Glenns Ferry (Figure 1), both located in the southern part of the state. The main driver at both facilities is a Solar Mars 100 SoLoNOx gas driven turbine with an ISO performance of 15,000 hp at sea level. Each of these units is connected with an Ideal generator rated at 10.4 MW continuous duty.

Attached to the exciter-end is a saturated steam turbine from Tuthill Energy Systems (recently acquired by Dresser-Rand Company). The five-stage steam turbine output has been uprated to 1,458 KW and the three-stage Glenns Ferry unit to 1,680 KW. Both units use an SSS clutch between the steam turbine and the generator. Two Allen-Bradley 540 PLCs are used at each location — one dedicated to the plant and the other to the gas turbine control package. Solar was able to package all of this in a turnkey operation, says plant manager Christopher Harriman.

The two Black Hills gas turbines run base-loaded, rather than being dependent upon the requirements of their attached processing plants. The steam turbines, however, are different. The processing plants are not always in operation and, even when they are, their steam requirements vary.

Depending on the facilities' needs, the steam turbine operates as a reverse-acting controller on the steamline pressure, absorbing the remaining portion of whatever steam is generated by the HRSG, Harriman adds. "We have a diverter valve that allows us to exhaust some of the gas up the dry stack, but we configure the plant and operate the controller to minimize any loss of hot gases."