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About This Newsletter

Power RE-View reports on evolving issues of interest to underwriters relevant to today's global electric power generation industry.

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Large Single-Shaft Combined-Cycle Units

What's the latest trend in combined-cycle power plant configuration? One answer would be large single-shaft units, but what does this mean? To answer this, let's first look at a few basics.

Electricity can be produced by a number of methods including using a gas turbine to drive an electrical generator. This is referred to as a *simple (or open) cycle unit.* Also used are steam turbines to drive electrical generators. *Combined-cycle (CC)* electrical generation plants use a gas turbine (or gas turbines) and steam turbine together resulting in a higher overall thermal cycle efficiency of the plant. The relatively hot exhaust gases from the gas turbine are directed into a Heat Recovery Steam Generation (HRSG) unit. The steam produced is then expanded in a steam turbine connected to an electrical generator. Up until recently, a CC plant typically consisted of two or three gas turbines (See *Power Re-View,* Vol. 1, No. 3, page 3 for a discussion), a HRSG and a steam turbine. Each gas turbine had its own electrical generator and the steam turbine had its own generator as well.

It is possible, however, to arrange a large gas turbine connected to a single electrical generator and steam turbine all in one "string" (or train) or as the title implies: a *single-shaft combined-cycle unit.* The advantage is that this arrangement results in high overall efficiency and a smaller footprint than conventional designs, which also has a positive impact on the overall cost of the plant. Figure 1 shows a general layout of such a configuration.

Berkshire Power's 270 MW combined-cycle plant in Agawam, Massachusetts is one such example of a single-shaft combined-cycle concept employing an Alstom GT 24 gas turbine. This configuration utilizes a synchronous clutch between the generator and steam turbine allowing a start up of the gas turbine only and bringing the steam turbine online later during the start up cycle. The generator in this arrangement has *dual* drive ends as shown in Figure 1. The Alstom single-shaft combined-cycle plant actually has a two-casing steam turbine with a IP/LP (intermediate/low pressure) turbine connected to a HP (high pressure) turbine by a reduction gear. The HP turbine in this arrangement runs at 9000 RPM while the IP/LP turbine runs at 3600 RPM (in 60 cycle applications).

Siemens Westinghouse is another manufacturer that employs a similar arrangement utilizing a self-synchronizing clutch. This allows for shorter start up and shutdown times, as well as having many of the attributes listed above. Siemens Westinghouse Power Corporation is the regional business entity in the Americas for the Siemens Power Corporation.

Designs by other manufacturers may have no clutch with the generator being at the end of the train. The gas turbine and steam turbine therefore have to be started up together, which may complicate the start-up procedure somewhat. General Electric, for example, uses a dual extended generator arrangement (Figure 1) as well. However, for larger gas turbine units (7FA and up) GE puts the generator at the end of the train. The advantages, according to GE, are that the steam turbine is not required to drive through the generator collector and generator rotor removal is greatly facilitated. Generator rotor removal for the dual extended generator arrangement may require the removal of the steam turbine to create sufficient axial clearance. Other ways to facilitate the removal of the generator rotor may include: sliding the generator sideways on specially designed rails. The rotation of the entire generator is 90 degrees so that the generator axis is perpendicular to the axis of the entire train.

For a more thorough description of single-shaft combined-cycle units, please read the article by Dr. A.S. Leyzerovich (available through the Internet at: http://energy-tech.com).

Nomenclature

All manufacturers refer to their products with a certain nomenclature or acronyms that are descriptions of the type of hardware used. For example, Alstom refers to the installation in Agawam as KA24-1 ICS. “KA24” indicates that it is a combined-cycle installation with a GT24 as the combustion turbine; “1” indicates a “single shaft” unit and “ICS” depicts “Integrated Combined Cycle,” a registered trademark by Alstom. General Electric describes their single-shaft combined-cycle units as STAG units (STAG stands for Steam Turbine And Generator). Siemens designates its 501G single shaft arrangement with GUD 1S.501G. The 501G is self evident, 1S represents single shaft and the GUD is German for gas and steam (“Gas und Dampf”).

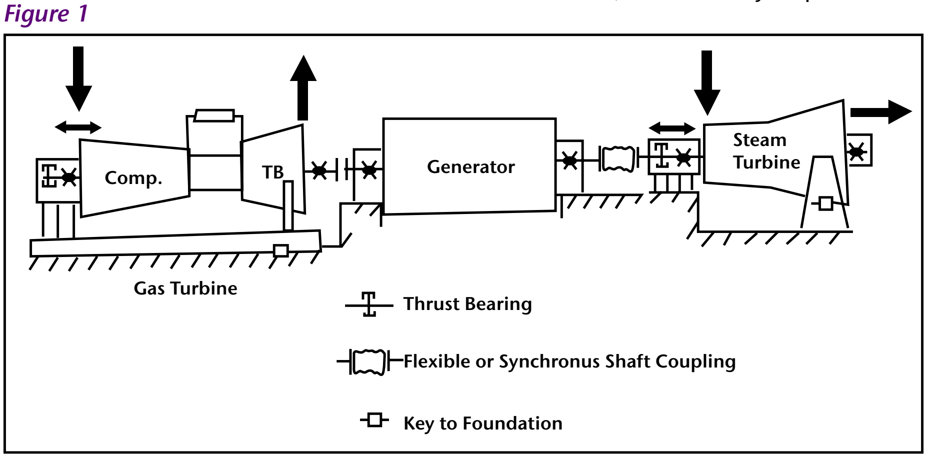
Conclusions

At the present time, relatively few combined-cycle single-shaft plants have been or are being built for the 60-cycle market. However, a significant number of 50 cycle turbines of single-shaft construction are in operation worldwide, especially in Asia and England.

One of the disadvantages of this arrangement is that a steam turbine failure may shut down the entire unit. This may not be the case with conventional, combined-cycle plants (two or more generators) where the gas turbine could continue to run in a simple-cycle mode (although much less efficiently). From an insurance underwriting perspective, the single-shaft CC designs may represent a higher risk depending what kind of coverage is being provided. Questions about continued gas turbine operation in case of a steam turbine failure need to be asked and the answers evaluated carefully especially as regards any business interruption exposure.

There is little question, however, that all major manufacturers such as General Electric, Siemens and Alstom are featuring the single-shaft concept, since it represents the future of efficient electrical power production.

Figure 1



Source: *Single-Shaft Combined-Cycle Power Generation Systems,* T.O. Tomlinson

Lease Engine Programs

Gas turbine failures are not just costly; they often require considerable time to repair the equipment and return to service. One way to reduce the outage time is to simply install another engine in place of the failed one. With this in mind, all of the major manufacturers of aero-derivative gas turbine generators offer lease engine options. Typically, the failed engine can be removed and replaced with a lease engine from a pool of like machines in as little as 72 hours. It may take longer for sites not easily accessible (or foreign locations) and also depending on where the pool is located. Mode of transportation is a further concern especially if no nearby airport is available.

While industrial gas turbines of the larger sizes are bulky and have substantial weight, aero-derivative gas turbines are relatively light and much easier to handle. They are also highly standardized, interchangeable and therefore lend themselves to a pooling arrangement. Once the failed engine is removed, it will be sent to a repair shop and a leased engine will be installed and operated while the original engine is being repaired. At a later date, after repair of the original engine has been completed, the leased engine will be removed from the site while the repaired, original engine will be re-installed. Where a lease engine contract is in place, the Business Interruption exposure is considerably reduced which could be reflected in the policy terms.

Typically, belonging to a lease engine program requires the operator of the equipment to pay up-front money to the manufacturer in order to be guaranteed a lease engine if the need arises. In addition, a rental fee will be charged to the operator by the manufacturer to cover the "aging of the engine" (increase in operating hours or wear and tear) for the duration of the period the leased engine is on site and operating. It is important to remember that aero-derivative gas turbines such as the General Electric LM2500, the Pratt & Whitney FT8 and the Rolls-Royce Avon require separate power turbines that are not usually covered by the lease engine contract. Power turbines are not mechanically connected to the gas turbine but are mechanically connected to the electrical generator. Power turbines are generally more reliable than gas turbines (gas generators) because they operate at much lower temperatures, around 1000° F. As a result, they are not usually included in lease engine programs. Should problems with power turbines surface, they can most often be resolved with in-place repairs.

There is another group of aero-derivative gas turbines of larger size, such as the General Electric LM6000 and the Rolls-Royce TRENT, where the power turbine is an integral part of the unit. The power turbine is mechanically connected to the gas turbine and drives the electric generator directly. Lease engine programs for these units, of course, include the power turbine as it is an integral part of the engine.

Another manufacturer, SOLAR, does not have aero-derivative gas turbine generators in their product line.

Photo Courtesy of Solar Turbines

The Taurus™ 60 Mobile Power Unit (5.5 MW) from Solar Turbines features a modular design with plug-in connections for rapid set up. It is easliy transported over land as shown above.

Nevertheless, their machines, while at a lower output (less than 20 MW), compete with suppliers of aero-derivative gas turbines. They have developed their own methodology to reduce downtime due to engine failures. SOLAR will guarantee the availability of an exchange engine within days in case of a turbine failure. The exchange engine will be installed and left in place while the original engine will be repaired at SOLAR and then be put into an engine pool ready for shipment to another site (or customer) when a need arises. A fee is collected by SOLAR to fund the program (usually in form of a $/KW for each operating hour). This replacement engine program is also utilized when the turbine has reached its limit of operating hours and is due for a major overhaul. Instead of a lengthy shutdown, a replacement engine is installed reducing the down time by a considerable amount.

Somewhat negating the need for lease engine contracts is the fact that some of the more popular aero-derivative engines can be obtained with relative ease in case of an emergency. Even without an engine lease agreement in place, LM2500, LM6000, FT8 and others can be easily made available by the OEMs. There are also a considerable amount of engines available (both new and used) from dealers who specialize in keeping an inventory of such engines to serve the power generation industry. The condition and reliability of engines of course is always of prime importance and may be questionable for units supplied from non-OEM sources. This must be evaluated in each case before buying and installing engines. A detailed review of the operation and repair history of any engine is required before the engine is installed.

Points to consider when evaluating a lease engine program:

- How many engines are available and how big is the pool? One spare engine for every five to 10 engines in the pool is reasonable.
- Where are the spare engines located and how long does it take to get to the site? Normally, this is not a big issue within the U.S.
- Are there any customs difficulties when crossing national borders? This could be a big issue when dealing with non-U.S. installations.
- What are the rental costs for the lease engine while temporarily operating at the site?
- Lease engine contract conditions.

Lease engine contracts obviously have great merits and are often executed in plants where aero-derivative engines are operating. This is especially true in plants owned by independent power producers where any appreciable downtime cannot be tolerated or have unwelcome and possibly grave financial consequences. As such, they are also of significance to underwriters who should be familiar with their terms and conditions.

Gas Turbine News

After Market Pains: Long Lead Times—Higher Prices

General Electric's acquisition of Kvaerner Energy is a further sign that OEMs (and especially GE) have stepped-up their efforts to buy companies with reverse engineering expertise and thus rob power plants of cheaper repair options. A UK power plant that used a Kvaerner repair facility in Saudi Arabia, for example, has stopped using it as pricing and "other things" changed after the GE take-over. Over the past year or so in particular, power plant managers have noted extreme price rises in the aftermarket. "There is a widespread feeling that OEMs exploit their virtual monopoly over certain parts of the service market and keep prices artificially high" according to a Frost and Sullivan consultant. Traditionally, parts for repairs of steam and gas turbines have by in large been procured from OEMs. That is changing fast since many power plants use more non-OEM produced parts for reasons described above.

Source: Turbomachinery International, September/October 2001

Comment: Long lead times for parts, high prices and the use of non-OEM parts of course impact the insurance industry and underwriting. Make sure that you use updated information when you underwrite an account.

W501G at Charlton, Massachusetts Is Operational

This PG&E NEG (Natural Energy Group) power plant located in Charlton (Massachusetts) is a 360 MW natural gas-fueled combined cycle plant. The plant, which began commercial service in April 2001, provides electricity to the open market in New England through the New England Independent System Operator (ISO). The Siemens Westinghouse Power Corporation gas turbine (W501G) in this plant is one of the very early units of this type (serial number 2). It has an increased power output and increased efficiency in part because of the use of closed loop steam cooling in the combustion chamber. Twenty-eight W501G turbines have been sold to date with just a handful in operation.

Source: Diesel and Gas Turbine Worldwide, October 2001

Comment: It will be interesting to follow up on the reliability of these new turbines. Underwriters need to be reminded that the loss of revenue for units as large as this one (360 MW) can be a very large number (approx. $432,000 per day at an assumed 5 cents per KW-Hr).

Pratt & Whitney Repairs GE Turbine Blades

Pratt & Whitney Power Systems has developed and implemented an advanced cut back repair procedure that has returned to service a full set of (General Electric) 7FA buckets. The plant involved is the Hartwell Energy Facility in Hartwell, Georgia operated by Dynegy. The purpose of the repair is to eliminate cracks (by grinding) and to apply a proprietary coating to all the blades. Inspections performed after 700 fired hours and 95 starts have found no problems.

Source: Diesel and Gas Turbine Worldwide, October 2001

Comment: As is perhaps known, General Electric has advised their customers to inspect turbine blades for cracking and to perform modifications. It is interesting to note that in this case a non-OEM company has been chosen to perform this repair on a critical turbine part. As noted in earlier Power Re-View *articles, the competition for repairing turbines is heating up and ultimately benefits operating plants because of lower prices for parts and services.*

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Steam turbine orders are on the increase. "I've never seen anything like it in all my 30 years with the company" says the head of Alstom steam turbine product support in Paris, France. He was referring to the large order influx for steam turbines the company has seen over the past two years, making Alstom the leading manufacturer of steam turbines in number of units and megawatt capacity. The leading market is North America where Alstom sold 36 units of which 75% are combined cycle steam turbines. This of course is a reflection of the many combined cycle plants that have been built or have been proposed over the last years. Some of these Alstom steam turbines are used in plants of other manufacturers' gas turbines. It shows a willingness of the plant owners to mix and match makes for optimum performance. Siemens Westinghouse Power Corp. (SWPC) similarly reports orders for steam turbines increased from 7,000 MW in 1998, to 11,000 MW in 1999 and to 22,000 MW in 2000. General Electric, too, reports increases in sales. They point out in addition that they see an increase in budgetary activity for coal projects.

Source: POWER, January/February 2002

Comment: The unprecedented huge number of combined cycle power plant proposals and actual orders is the reason for the increase in gas turbine and steam turbine sales. For the insurance industry, it means more business. It also means that some of the older, inefficient and polluting power plants will be retired. The reliability of the new turbines should be quite good. Fewer losses can be expected, but the severity of losses will be higher than with the retired equipment. A thorough risk evaluation needs to take this into account so that underwriters can make the necessary adjustments. The guidelines in the turbine manuals already reflect these newer and higher exposures.

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