Operation and Maintenance

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ABSTRACT

Operation of small-scale cogenerators is automatic. Whether the cogeneration system is intended to run 24 hours/day or within hourly parameters, it will be sensitive to preset limits on time, temperature, or internal operating parameters. Of course, the system may be started and stopped manually or via computer commands entered manually, but usually that's only done when the system is restarting after a manual or forced shut down.

OPERATIONS

Let us look at these variations of control and operation:

Time

A facility, say a commercial laundry, opens its doors at 6:00 a.m. and uses the cogeneration system to provide hot water and electricity. It may set the cogeneration system to start up an hour before normal facility operations in order to insure the hot water production is up to specified temperatures in the storage tanks. Any electricity produced during this "pre-operative" phase may be given or sold back to the utility presuming the electrical load in the facility is very light.

When full facility operation is underway, the cogeneration system is producing hot water and electricity to meet the needs of the facility per its design parameters. Design parameters mean that at any given time, the constant production of the cogeneration system may fall short of the facility's needs, in which case standby systems, i.e. the facility's hot water heaters and or the public utility's electricity, will be fed into the system automatically. Should the cogeneration system's output exceed the facility's needs in hot-water temperature, an automatic bypass will engage causing excess heat of the hot water to be exhausted via a dump or blow-off radiator while the electric production will remain constant. Should the cogenerator's electrical output exceed that of the facility's needs, that electricity will be given or sold back to the utility. All this happens automatically with the cogeneration system and facility systems set up to accomplish these variables.

When normal shutdown of the facility is planned for 10:00 p.m., the timer system of the cogenerator will kick in and shut the cogenerator down at a prescribed time, possibly as soon as a half hour or so after official closing time. Should the facility decide to extend or shorten its hours of operation, the manual control of the cogeneration system can override the timer controls and either keep the cogenerator running or shut it down sooner than planned.

Temperature

Smaller cogeneration systems of up to 30 kW may prefer to operate without a blow-off or dump radiator and use thermostatic controls to shut down the cogeneration system if the hot-water temperature should exceed preset maximums due to lower hot-water usage. In these kind of systems the hot water is often produced at temperatures in excess of the facility's needs and is stored in hot-water storage tanks. Mixing valves will regulate actual facility needs by introducing cold water to the elevated hot-water temperatures to produce the required "mixed" temperature for the facility.

This method allows the cogeneration system to continue to operate during periods of low hot-water usage, producing electricity, while the temperature of the water rises inside the storage tank. If the temperature rises to a preset maximum where danger to the cogeneration system may occur, the cogenerator will automatically shut down. The facility will then be drawing its electrical needs from the utility grid. When the temperature in the storage tank subsides to a preset value, the cogenerator will automatically start and continue to run until again the needs are exceeded.

This kind of control is practical when knowledge of the facility's needs are well known so that too many shut-downs are avoided during normal operating times. Of course, a timer system may also be used if the facility also has less than a 24-hour/day operational time.

By not incorporating a blow-off radiator, the user of the cogeneration system avoids having to report FERC efficiency results to the utility annually. It is taken for granted by both FERC and the utility that all the produced heat is used by the facility, and the electricity is fully used whether by the facility or the grid.

Internal Operating Parameters

The cogeneration system will be instrumented to respond to its own operational and safety needs. Typical of the instruments that are employed in cogeneration systems are:

- Low oil pressure
- High coolant temperature
- Low coolant temperature
- High output voltage
- Low output voltage
- High or low frequency
- High generator temperature
- Low gas pressure (fuel)

The utility to which the cogeneration system is connected will be particularly interested in the system's ability to shut down on high- or low-voltage output and high-or low-frequency output for safety reasons to their own grid conditions. They often require a demonstration of the system's ability to shut down when those conditions occur before official interconnection permission is given. This is referred to as the "trip test." It is conducted with an electric-voltage inducer called a variac that is connected to the output wires of the cogenerator while the system is down. Low and high voltages are simulated to see whether the contactors trip shutting the unit down.

Monitoring of the cogeneration system's operational parameters is often done automatically and remotely via a dedicated telephone line. If a shutdown occurs, the system is set to call the monitoring station alerting it to the shutdown, usually giving the reason the system shut down. The monitoring station has the option of evaluating the reason for the shutdown, restarting the system manually to see if the shutdown was due to an anomaly and then watching closely to see if performance is normal, or shutting the system down in a lock-out condition and dispatching a service supervisor to the job site. Monitoring may be done by the company under contract for performing the maintenance of the system or by the user of the cogeneration system or by both.

MAINTENANCE

Maintenance starts with good design and good quality assurance in the factory and good installation parameters in the field. That is true of almost any mechanical and/or electrical system.

An example of how design can affect maintenance is found in the way the engine is attached to the generator. In small systems, 10 to 30 kW, and especially in the early days of small-scale cogeneration, this attachment was made by a distinct coupling between the engine and the generator. They were commercially procured, and incorporated self-aligning and shock-absorbent features to maintain integrity of alignment and absorption of thrust. Both these features would affect the bearing systems of the engine and the generator if allowed to become misaligned in the vertical or angular direction or if excess thrust was produced in the horizontal direction. Commercial couplings accomplished these safeguards but exposed themselves to wear and eventual replacement. It is not unusual to replace couplings every 4,000 hours of operation.

A better design was to attach the generator to the engine by extending the engine shaft to be integral with the generator and using a ring flange on both the engine and generator to mate those two elements together. This totally eliminated the coupling and assured alignment in the vertical and angular directions. Thrust bearings in each component took up any horizontal thrusts. This feature eliminated the maintenance associated with couplings as well as the expense of replacing the couplings periodically.

Good quality assurance, or quality control, at the factory level insures that good designs are produced with accuracy. There's no sense in having a good design like the mating-ring flanges if those flanges are machined incorrectly thus causing stress on the engine shaft, which destroys the bearings.

But, notwithstanding good designs and good quality control, every mechanism with moving parts will require maintenance, both preventive and forced. Preventive maintenance is the periodic changing of oil, filters, spark plugs, seals, and coolant. Forced maintenance is the replacement of engine pistons due to overheating or abrasion causing an unexpected failure and subsequent shutdown of the system. Both types of maintenance will require shutdown of the system, but preventive maintenance will reduce the periods of forced maintenance and can be done during optimum hours. In cogeneration work, optimum hours are when the utility is not charging peak prices for electricity. Peak electrical prices are generally in the late spring through summer and early fall months when heavy electrical loads are being experienced, especially during afternoon hours. During those months, preventive maintenance must be done in early morning or evening hours to preclude a planned shutdown of the system. Obviously, preventive maintenance is important during these periods to avoid forced shutdowns at inopportune times.

Any heavy maintenance such as engine overhaul should be done before electric utility peak-price periods begin.

MAINTENANCE CONTRACTS

Most users of cogeneration systems will prefer to have the provider of the system do the maintenance under a maintenance contract. The two most common types of maintenance contracts are "lump sum in advance" and "production sums in arrears." Both types of contracts encompass not only preventive maintenance but also include replacement of any component or part in the entire cogeneration system that was provided under the sales contract. This is referred to as an "extended maintenance and warranty" contract. In each case, monitoring of the system remotely is often included in the contract.

Lump Sum In Advance

This type of maintenance contract stipulates a lump-sum payment that varies with the cogeneration system size. The larger the system, the higher the maintenance cost. One manufacturer quotes prices as such:

kW Size Cogeneration System	*Annual Maintenance Cost*
40 kW	$6,630
60 kW	$8,970
120 kW	$11,000
250 kW	$17,500

Payments for this type of contract are usually made annually or quarterly in lump sums.

Production Sums in Arrears

In this type of maintenance contract, the payment will be made by the client based on the production of the cogeneration system. Normally it is based on the kilowatts produced in any given period. Sometimes it will be based on the hours the cogeneration system ran during a given period. In most cases the period in question will be a month. Therefore, if a 120-kW cogeneration system runs for 650 hours during the month of July and produces 78,000 kW, the client will pay a maintenance fee of $0.016/kW, or $1,248 for the month of July. That payment will be due on or about August 10. The same format holds true if the payment is based on hours of operation and the $/hour will vary with the size of the machine, while in a kilowatt-production-based maintenance contract, the $/kW may remain the same because the power production will vary with the size of the machine.

Often, the "production sums in arrears" contract will result in slightly higher maintenance fees annually than the "lump-sum" contract if the cogeneration system runs virtually perfectly during the year. For instance, in the above example, the customer would be paying $1,248 per month (12 months = $14,976 per year or $3,976 more than if they had paid "lump sum in advance." However, the customer gets the satisfaction that if the machine only ran 60% of its allotted time and produced only 60% of its maximum power, they would only pay $8,985 for the year rather than the $11,000, whether the machine ran or not. Also, the time-cost factor of money comes into play with the "lump sum in advance" contract versus the "production sums in arrears" contract.

The customer may or may not have a choice as to what type of contract is offered him, but if he knows the differences, he may be able to influence the type of contract he wants and, therefore, gets.

One last issue is that at times a client may forsake the extended-warranty facet of the maintenance contract and opt to pay a time-and-material cost for both preventive maintenance as well as for replacement components and parts. In this case the client and provider may agree on a flat monthly fee to pay for the preventive maintenance and monitoring facets of the system, but then have the client pay an hourly cost for any work done in parts and component repair or replacement as well as the cost of the parts in question. These fees are negotiated between client and provider.

Mr. Kolanowski's article has been abstracted from his recent book, *Small-scale Cogeneration Handbook*, published by The Fairmont Press, 700 Indian Trail, Lilburn, GA 30047.

ABOUT THE AUTHOR

Bernard F. Kolanowski, a graduate mechanical engineer from Pennsylvania State University, has spent most of his working career in the field of application engineering of cogeneration projects. Starting in the early 70's, he became heavily involved in these projects with Ingersoll-Rand Company. He then moved into the waste-to-energy field, another form of cogeneration. Burning industrial, municipal, pathological and hazardous waste in two-stage, clean burning incinerators at over 2000°F created hot stack gases that could be effectively used in waste heat boilers to generate steam or hot water for in-plant processes.

He decided to enter the small-scale cogeneration field where market size was huge, while the machinery to serve that market was small. Representing various manufacturers in 120 to 120 kilowatt cogeneration systems, he applied that new technology in various commercial and industrial applications from the typical coin-operated laundry to the nursing home, hospital and hotel areas where hot water needs were part of everyday business.

Mr. Kolanowski joined the Capstone Turbine Corp. in 1999 to help exploit the newest technologies in MicroTurbines for on-site electrical generation and resultant cogeneration.

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