Life Is On | Schneider Electric

Effective turbine controls for cogeneration facilities

by Hector Buchelly

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Introduction

When operating a manufacturing or production facility of any type, constant and consistent power is of paramount importance. A loss of power, even if only for a short period of time, can have a drastic impact on production. Many process facilities employ cogeneration plants to take advantage of excess heat, lower the costs of purchasing power from the grid, and ensure consistent power to the process. Gas- or steam-driven turbines of various sizes and brands are crucial to the operation of the cogeneration plant. Most of these turbines were purchased decades ago, quite possibly with the development of the facility itself, and the control systems are becoming increasingly obsolete. This slow degradation of controls leads to increased, and preventable, downtime when utility tie-in power is lost and generators are slow to respond or malfunction during heavy load. To address this issue, cogeneration facilities are increasingly looking toward redundant and modular control systems that offer greater safety and reliability. This paper focuses not on turbine replacement, but on the upgrade/replacement of the integrated governor and excitation system controls. In many instances, a control system upgrade will extend the life of existing turbines, avoiding costly refurbishment and downtime of the cogeneration plant.

Typical reasons for an overhaul of the controls

Supplier and system design issues for older systems

Even with older equipment, many turbines still have the potential for high efficiencies by using modern control systems. Unfortunately, the control systems that govern these turbines are not aging as well as the turbines they control and are increasingly in need of maintenance. Depending on the brand of turbine, supply of parts and specialists can be an issue. With many of the companies that built the older systems located in Europe or overseas, availability of parts is limited. Downtime therefore increases when there is an issue with that equipment. Depending on the age of the control system, some parts might not even be available due to an obsolete design. Parts either have to be fabricated or a compatible replacement found; neither of these options is ideal or cost effective.

Additionally, older systems have the problem that few operators and engineers know how to maintain these legacy systems. Even reliable older systems are being evaluated for replacement because they have effectively become a “black box” to the technicians and engineers that service and repair them. Facility managers want to be certain that repairs can be done right away if needed since major pieces of process equipment that cannot function present an operating risk. For instance, on older systems, governor computations are gathered using signal pressures with specifically designed components. Most of these components are not readily accessible. The turbine governors themselves are often of a customized design that dates back decades and, although reliable, is generally not well understood.

As turbines are being evaluated for replacement, producers are also moving to newer, better-understood, and more reliable turbine control systems. From about the 1960s until the 1990s, control systems were largely analog. During the 1990s analog controllers and plantwide control systems began to be replaced with digital systems; however, those early digital systems still had analog input and output interfaces that were very susceptible to noise or deterioration. Over time, this led to degradation in performance and process interruption. To correct these issues, cogeneration facilities are modernizing control systems through the use of digital electronic systems that are commercially available worldwide. These new systems are well documented and training is readily available by the suppliers. They are also more reliable and offer greater safety provisions than the older analog counterparts.

Production uptime and operation

Modern cogeneration facilities are being designed with redundancy in mind and are engineered so that no single point of failure will result in a loss of production, including the control system. This requirement is manifested not just in the design, but also in the ability to obtain replacement parts within 24 hours. With older turbine systems, the components and engineering support, including those of the control system, were available only from original equipment manufacturers (OEMs).

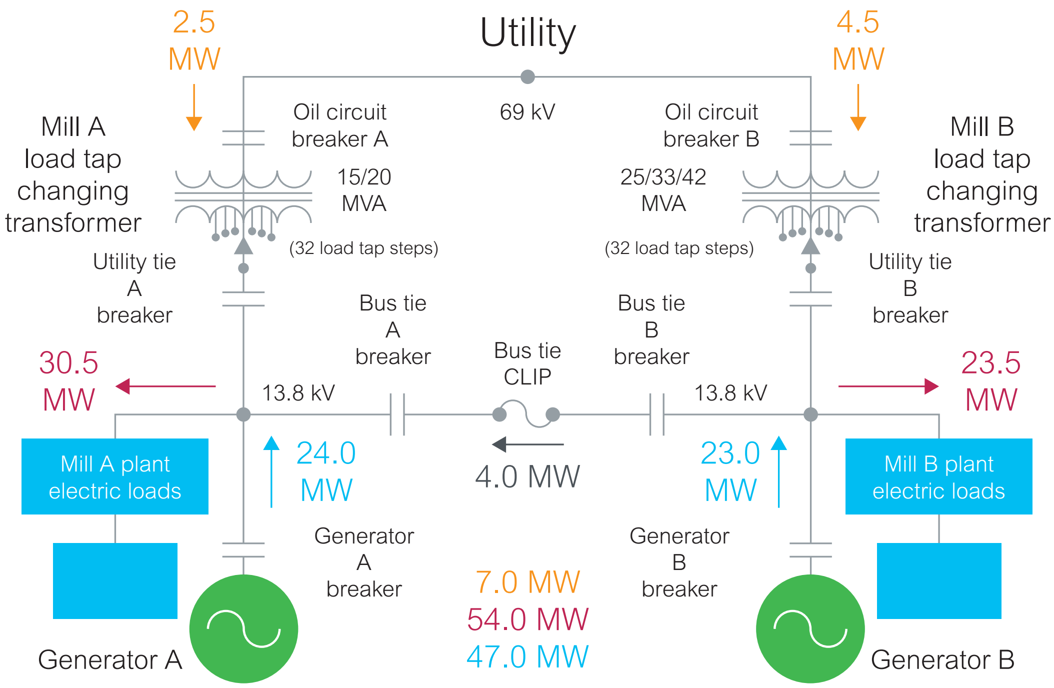

Figure 1
Single line diagram

To cope with this issue, cogeneration facilities required a reliable control system that could manage several key processes:

- Steam header pressure
- Bus voltage
- Electric power (watts and VARs) import or island control

Controlling these inputs would allow a two-turbine facility to manipulate varying loads in a constant operator-set ratio of loads. Both units could then be loaded equally or in proportion to operational needs. With preceding control systems this manipulation was not possible, and systems often implemented the power rate without operation intervention and without setting new peak power requirements.

Maintaining turbine control during loss of tie-line power

While most cogeneration facilities should be able to operate smoothly through a complete loss of utility power, there would still be some amount of plant production process downtime. During this time, the on-site steam plant would still remain in operation, but operating at a reduced production rate level until the utility power connection was restored. Most importantly, this would avoid a complete steam production shutdown, which typically results in a loss of plant production measured in hours and possibly days.

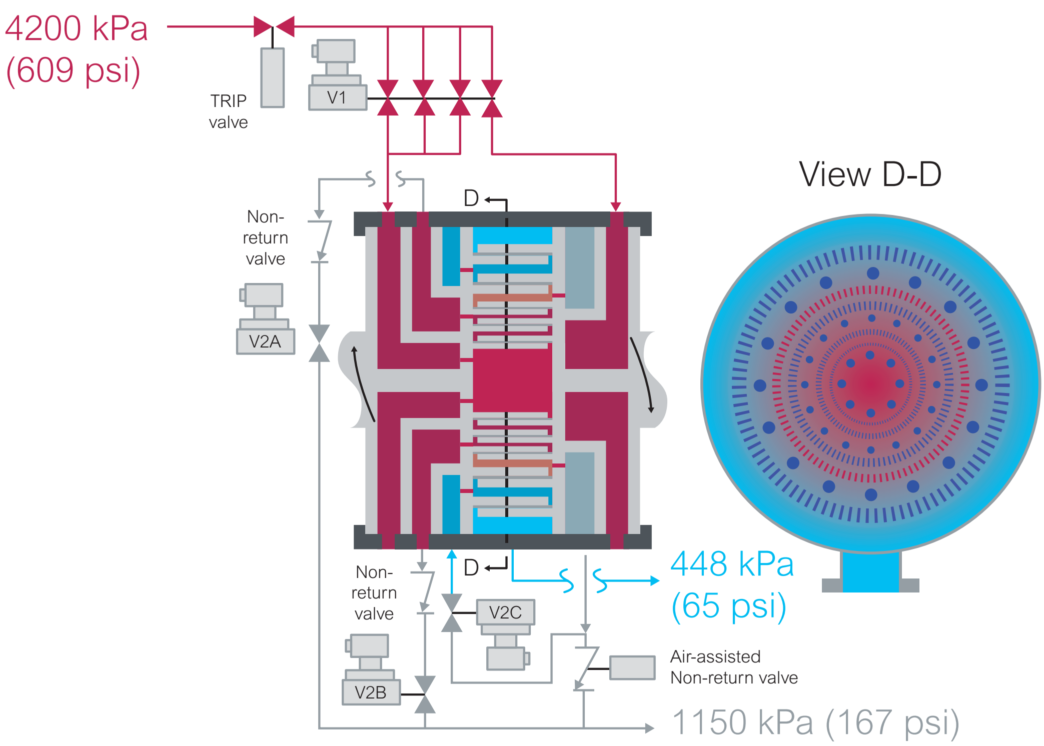

Figure 2

Radial steam turbine extraction steam flow control

A scenario familiar to many cogeneration facilities with older control systems is the sequence of events leading to a loss of power originating with either an interruption of service from the utility or with the cogeneration facility itself. Assuming the cogeneration facility supplies only part of the power required to sustain the production processes, in the event of a loss of tie-line power, the generators on-site are instantaneously overloaded. The only available stored energy is in the momentum of the mass of the generator rotors. The turbine rotors begin to slow and the frequency change is detected by a relay, which immediately tries to shed load in large increments, causing a loss of power to various sections of the facility. Unfortunately, this usually does not stop the frequency decay of the turbines, and breakers continue to trip and shed load in the form of shutting down other facility processes. At this point, the electrical load begins to balance heatsink against electrical generation and, if the turbine control system is capable, the governor control system starts gaining control and stabilizing the turbines. Given the required response time, a control system must be able to respond immediately and without human intervention to avert the above scenario.

As a result of this scenario, all planning for the loss of utility tie-line must be programmed and tested into the overall facility control system. The key factors in this control system are the turbine governor that automatically and seamlessly transfers speed/frequency control, and the generator excitation system that will be responsible for switching from parallel to the utility control modes into isolated local island bus voltage control.

Integrated governor and excitation systems

Modern cogeneration facilities are being designed with redundancy in mind and are engineered so that no single point of failure will result in a loss of production, including the control system.

In the past several years, the governor and excitation control systems have been integrated to lower the complexity and cost of a solution. Quite often, as in the following case study, the reliability and some of the added features of the more expensive excitation system provide some justification for this added expense. Now, there is an integrated option that allows for customizing the excitation system to fit the project, instead of the other way around.

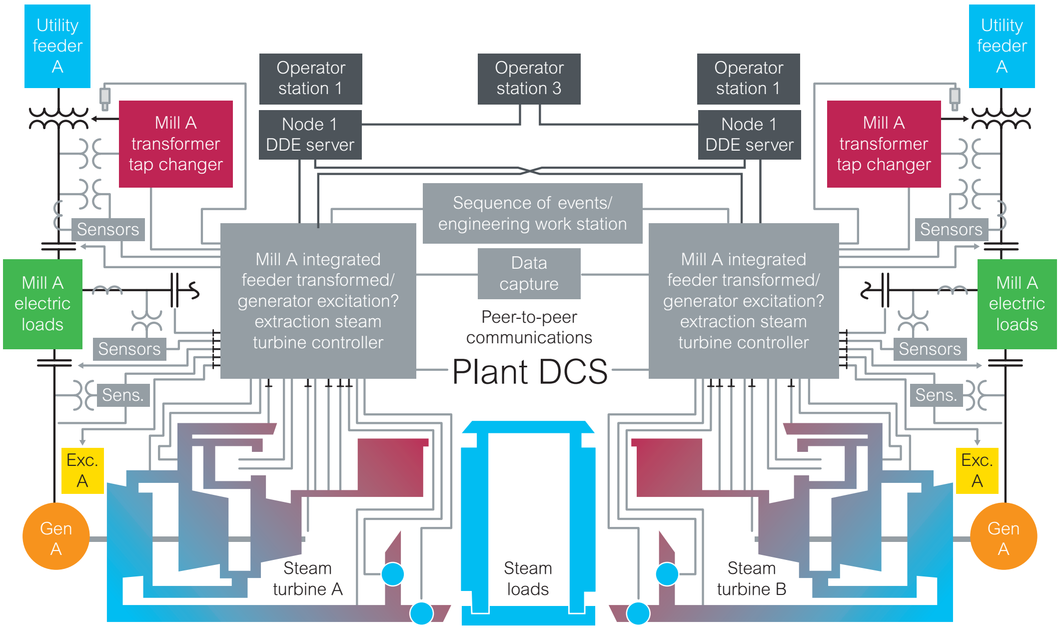

Figure 3

Integrated control system

Case study

Canadian pulp mill

A large pulp mill in western Canada had been experiencing many of the same challenges described above with its cogeneration turbines. The facility was running two steam turbines, each of which was capable of generating 47 MW of power or 87% of the total power required for the facility. In order to sustain the facility during a loss of utility power, the mill needed to replace the 1960s turbine control systems, which were supplied by the turbine generator OEM. The mill selected Schneider Electric to retrofit the control systems — specifically, the turbine governor, the excitation system, and generator protection systems.

A critical requirement of the new control system was that there could be no single point of failure for the overall system. If the steam plant were to suddenly lose power, then a cascade of issues would occur, severely impacting the facility:

- The recovery boilers' chemical processes would be upset, which has the potential for a safety hazard
- The reheating of the chemical process and cleaning of the smelt out of the boilers would take a considerable amount of time
- Other boilers would have to be purged

The intent was to keep the steam turbine generators on and continuously supplying the critical electrical loads required to keep all of the facility's steam production (boilers) processes continuously operating during the time the plant is not connected to the utility. When both the turbine-driven generators and the boiler systems are kept operating, most of the manufacturing processes can also be maintained; however, the actual manufacturing production rate level would understandable be decreased.

A total loss of those steam production (boilers) processes actually causes the facility a loss of product production time duration of at least several hours and often even a few days.

These and other technical objectives required that the controls be triple modular redundant (TMR). The mill also had five objectives for the project:

1. The turbine and generator controls would be replaced using modern and reliable digital control systems. Additionally, these controls were to use, to the greatest extent possible, standard components and would supply service and support within one day.
2. The turbine and generator controls were required to survive a loss of tie-line power and be able to re-synchronize when the local utility power was re-established.
3. The control system was required to manage both watt and VAR import to the required specifications of the utility contracted rate and also, when possible, minimize generator rotor heating.
4. The turbine and generator control systems were required to allow the dynamic load division between the two turbines for steam header pressure control and bus voltage control.
5. The turbines were required to recover the greatest possible power available by fully utilizing the mill process heatsink while accurately controlling header pressures.

The governor system

Modern turbines are supplied with separate lubrication and governor oil systems, which allows for different oil characteristics and filtering. The mill considered purchasing a separate high-pressure hydraulic power supply and actuators for each valve but decided to retain the low-pressure hydraulic power supply and actuator cylinders. The cost of replacing these parts seemed prohibitively high, especially given that the mill had good experience with the low-pressure system.

The new governor control system would replace the controls interfaces to the existing:

- Steam valves
- Emergency stop controls
- Throttle/overload controls
- Extraction valves
- Overflow (re-injection) valve
- Extraction non-return valve

In making the decision to use TMR controls, the mill gained the ability to physically remove any processor from operation for maintenance or replacement without disturbing the continuous operation of the system. This advantage comes from the dual redundant input/output systems with dual redundant field devices, ensuring no single point of failure can cause the system to cease operation.

The TMR designs of the systems are significantly reducing the number of single point failures, leading to increased safety, energy savings, and lower life cycle costs.

The excitation system

Originally, the mill had decided to purchase the most expensive excitation system from another supplier because they felt it offered the most robust option for all the requirements. Unfortunately, the system would have put the project significantly over budget as well as introduced a significant delay. Schneider Electric offered a nontraditional solution to the problem. The proposed solution would not have a separate control system for the excitation but would integrate the excitation system with the turbine governor and generator field control systems. At the time, this was a groundbreaking and untried solution that had the potential of significant cost reductions. Schneider Electric would also provide a single maintenance and engineering interface.

Power generation has increased on the average of 2 – 3 MW. This results in an energy savings of approximately $500,000 a year.

This very special and unique STAL-LAVAL two-piece counter rotating steam turbine generator rotors system application requires continuous field excitation through both exciter rotors at all times that the steam turbine shafts are rotating. The unique excitation system drive package does not require field flashing.

Generator protection

The mill additionally replaced the generator protection system that provides a complete electromechanical relay protection. The mill had several different types of relays and wanted to replace all of them with a single, digitally based generator protection system. The replacement of individual relays would allow for additional features, including oscillographic capture functions and 100% ground fault protection. In addition, the mill sought to replace the traditional and standard electromechanical metering functions with a digital networked metering package. This was not included within the Schneider Electric scope of supply.

Business benefits

The mill has been operating now for several years and has already seen significant improvements over the old system. Most importantly, because of the TMR design, the mill has realized a significant decrease in downtime. During testing, and then shortly after the completion, the mill suddenly lost utility power and successfully maintained a power and steam balance that avoided a shutdown. Almost as important, the turbine operators believe that the system is far superior, and they have greater confidence in the overall system. Complexity has been reduced for the operator and startup and synchronizing is usually a one-button operation. Additionally, during the normal operation, the mill is able to use both integrated control systems to dynamically share the steam pressure control functions. This has allowed the mill to the benefit of the process heatsink, and as a consequence, power generation has increased on the average of 2 – 3 MW. This change results in an energy savings of approximately $500,000 a year.

Conclusion

The advantages gained by improving turbine control systems can easily offset any cost associated with the upgrade, especially if a facility is seeing a significant rise in downtime and maintenance. Even a short amount of downtime can cause a dramatic revenue and production loss. Given the value of reliable and redundant digital controls, more facilities are replacing old analog systems. Turbine control upgrades are opportunities to integrate many pieces of control systems to reduce complexity and save on the costs of installation. The Schneider Electric local support also provides a fast response to any situation that may arise. Most importantly, the TMR designs of the systems significantly reduce the number of single point failures, leading to increased safety, energy savings, and lower life cycle costs.

About the author

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