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NEW TECHNOLOGY FOR ENABLING AGING GENERATION ASSETS TO COEXIST WITH WIND GENERATION

Renewable electrical generation resources are a welcome addition to the generation portfolio to meet the needs of the market in a reduced carbon footprint fashion. The disruption to the electrical stability of the transmission and distribution network is a concern with these highly unpredictable generation resources, especially considering wind farm generation assets. The ability to effectively utilize the maximum amount of the wind farm production, while preventing transmission voltage surges, was a concern for Minnkota Power Cooperative. Conversely, when the wind would slow, the conventional assets are required to respond to prevent voltage sags. Minnkota M.R.Young power station is the primary source of electric generation for more than 110,000 customers. For many years prior to the wind farm additions Young station was base-load operated to meet the generation needs of the area. The main factors requiring a revised operational mode for the plant generation are twofold. The market was being deregulated by the creation of the Midwest Independent System Operator (MISO) of the transmission grid. Also new wind farms were put into operation nearby, causing additional load demand regulation issues and voltage problems with the electrical transmission lines.

When Minnkota started participating in the deregulated electricity market (MISO), the units were required to change to cycling operations and quickly and efficiently responding to daily demand changes. This presented several challenges. First, reaction of the units to set point load variations caused lagging load response and overshoots in megawatt control. Second, recently added wind farms required the Young units to immediately offset megawatts to meet generation demands and permit utilization of this green power source.

Working with together Minnkota and Emerson created a Unit Response Optimization (URO) solution to help overcome these operational challenges at the power plant. Individual process models were developed for the steam generation response (coal fired cyclonic furnace boiler), and the prime mover (steam turbo-generator). These process models we integrated seamlessly into the existing DCS coordinated control modes of operation. The integration effort, system response and operator impacts will be discussed in this paper. We will also show the results, which were dramatic and included:

- A 70% improvement in ramp rate
- 2 MW reduction in over/undershoot in meeting grid (ISO) demand

The URO project required significant changes to the Young Station operations to allow Minnkota to capture available wind generated electricity by efficiently cycling the Young Station to meet constant changes in the wind generated electrical output.

Minnkota Power Cooperative, Inc. (MPC) is a regional generation and transmission cooperative serving 11 member-owner distribution cooperatives. Minnkota's service area of 34,500 square miles is located in eastern North Dakota and northwestern Minnesota. Through its generation resources, Minnkota has one of the lowest average wholesale electrical rates in the country, approximately 3.6 cents per kilowatt-hour (kWh).

Minnkota's Young power station is the primary source of electric generation for more than 110,000 customers. For years the Young station was base-load operated to meet stable regulation demands. When Minnkota started participating in the MidWest ISO, the units were required to change to cycling operations and quickly and efficiently responding to daily demand changes. This presented several challenges. First, reaction of the units to set point load variations caused lagging load response and overshoots in megawatt control. Second, recently added wind farms required the Young units to immediately offset megawatts to meet generation demands.

Unit #1 consists of a Babcock and Wilcox lignite fired boiler rated at 1,714,000 lbs./hr., 1970 psig, 1010deg.F/1010deg.F outlet steam conditions. The seven cyclone single wall fired boiler is a drum type, natural circulation, balanced draft unit with two motor driven forced draft centrifugal fans and two motor driven induced draft centrifugal fans. It is equipped with a tubular style air heater and an electrostatic precipitator. The boiler supplies steam to a tandem compound double flow General Electric/Alstom turbine-generator rated at 256,200 KW, 1801 psig, 1000deg.F/1000deg.F with a design backpressure of 1.5" HgA. The unit has two 60% capacity motor driven boiler feed pumps. The feedwater train consists of two stages of low pressure feedwater heaters, a deaerator, and three stages of high pressure feedwater heaters.

Unit #2 consists of a Babcock & Wilcox cyclone fired boiler rated at 3,200,000 lbs./hr., 2620 psig, 1005deg.F/1005deg.F outlet steam conditions. The twelve cyclone opposed wall fired boiler is a drum type, assisted circulation, balanced draft unit with two motor driven forced draft centrifugal fans and two motor driven induced draft axial flow fans. Two gas recirculation fans circulate gas from the economizer to the upper furnace (gas tempering). The boiler is equipped with a tubular style air heater, electrostatic precipitator, and wet sulfur dioxide scrubber (two open spray towers). The boiler supplies steam to a tandem compound quadruple flow Westinghouse turbine-generator rated at 441,439 KW, 2400 psig, 1000deg.F/1000deg.F with a design back pressure of 2.0" HgA. The turbine will be upgraded in fall 2007 by Siemens Power and the expected a gain of approximately 25 MW with no additional heat input from the boiler. The new HP turbine will be a full arc design expected to be operated in single valve or sliding pressure control modes. This unit has one 100% capacity turbine driven boiler feed pump. The same turbine also drives a booster pump through a gear reducer. The feedwater train consists of four stages of low pressure feedwater heaters, a deaerator, one intermediate pressure feedwater heater, and one high pressure feedwater heater.

For years, Young Unit 1 has been operated as a base-load unit in which megawatt production levels remained relatively constant. This changed when Minnkota recently started participating in the Midwest ISO (MISO), an operating environment in which revenue is dependent on a station's ability to quickly and efficiently respond to constantly changing market demand. This environment was particularly challenging for Young Unit 1, which was now also required to offset megawatts whenever recently added wind farms are unable to meet demand.

Unit 1 was upgraded to Emerson's Ovation expert control system in 2003 to cover boiler, turbine generator and other plant controls. This modern system uses widely recognized, commercially available hardware, software, networking and communication interfaces that provide an easy upgrade path which allow the facility to keep pace with changing technology and market conditions. The with the MISO participation load ramping was not a key aspect of the new "open" market aspect of operation.

This regulation fine-tuning typically involved small load swings – ramping up or down by 10 megawatts. However, the unit's response to load set point changes often resulted in over/undershoot and lagging load response, both of which contributed to lost revenue.

Rapid ramping rates are critical to power utilities - the faster the ramp rate, the better the performance. With optimized ramping capabilities, generating units are able to maintain heat rate at a lower capacity, and are able to avoid heat degradation, even when operating significantly below generating capacity. Increased ramp rates, achieved through balanced coordination of boiler and turbine controls, improve operational flexibility, maneuverability and, ultimately, profitability of generating units.

The prior inability of Young Unit 1 to respond efficiently to the changing demand conditions meant that Minnkota had to seek a solution which would improve the unit's operational response and could be easily integrated into its existing control system.

Minnkota had fuel that does vary quite a bit (minute by minute) and they were looking for ways to improve pressure control with this variability. The severe fouling characteristics of the fuel also require us to blow our sootblowers continually with some large swings in steam temperature.

They had normally operated U1 at constant pressure and U2 in a sliding pressure mode (valves wide open).

The current and desired rates are 1 to 7.5 MW/Min. By the end of 2007 Minnkota was required to do regulation on Unit 1 at +/- 7MW. Unit 2 is presently required to follow MISO. The controls system plan was to support being capable of operating at ± 10 MW.

A key aspect of following market demands is the steam temperatures behavior both during ramps and at steady state. Minnkota had large variations in steam temperature during steady state conditions due to sootblowing. There can be extremely large swings in steam temperature during load ramps (depends on operator). Minnkota had seen 35-40 °F swings during U2 valve tests.

The Emerson URO project required significant changes to the Young Station operations to allow Minnkota to capture available wind generated electricity by efficiently cycling the Young Station to meet constant changes in the wind generated output. The scope of the URO project was to create new fully coordinated closed loop control strategies via the following method:

1. Capture detailed unit operating data via parametric testing by cycling the units through various power ranges.
2. Using that data to develop dynamic models of the unit's operating characteristics at various load ranges.
3. Testing and verifying those models under actual operating conditions.
4. Modification of existing control settings and benchmarking the new strategy vs. the base strategy.

Challenges

A key requirement of the project was to implement the new Unit Response Optimization solution seamlessly into the existing control system without adding new tasks or additional complications for plant operators.

Control system suppliers have recognized the need to develop software that will help utilities achieve optimized equipment performance for emissions compliance, temperature control, efficiency, and overall continuous operational improvement. For example, Emerson's SmartProcess® plant optimization software incorporates fuzzy logic, neural networks, predictive control, and other tools to optimize performance.

By building plant-specific models to simulate process variations and changing load levels, these software systems identify the precise control settings for continuous optimal performance. The plant model incorporates self-learning features that allow the software to adapt to long-term changes in the plant, regardless of plant size or configuration.

The software can also operate in advisory-only mode, alerting operators to changing settings and taking actions to achieve targeted objectives. They can be integrated with any suppliers' control system or deployed using other technologies, such as historians or the open industry standard OPC protocol, and its non-invasive implementation process is conducted without any outage.

The URO module was designed to dynamically optimizes its targeted processes, sending new set points and biases directly to the control system - even as the plant ramps to meet market and grid demands.

When Minnkota upgraded the systems at Young Unit 1, the optimization software was embedded within the unit's control system. Using non-linear dynamic feedforward and model predictive control, the optimization technology builds upon the existing coordinated control capability to further enhance the boiler and turbine response for tighter overall control and more efficient operation. This translates into additional revenue opportunities for power generators like Minnkota.

The tailored solution uses actual plant operating data to create an accurate model of dynamic boiler and turbine responses and other unit characteristics. When developing the system, the Emerson engineers worked alongside Young Unit 1 operators to collect unit-specific data. After observing normal unit operation, the operators ramped the unit up and down – typically in 20-MW intervals – to capture dynamic response characteristics. Parameters measured included steam temperature and pressure, throttle pressure, valve positioning, megawatts, fuel flow, drum levels, air flow, boiler master output and turbine master output.

The data collected was analyzed and used to design models that accurately reflected the unique process dynamics of Young Unit 1. Control modifications were designed to support the new operational philosophies and their seamless integration into the existing control structure. As part of this integration process, there were several sheets of control logic modifications, and additions.

In most cases, optimization technology can be installed while a plant is in normal operation, with no downtime required. However, because Young Unit 1 was performing a software upgrade during a scheduled outage in the autumn of 2007, it made sense to install the new technology at the same time.

Figure 2 -

Once the unit was back in service following the outage, engineers from the software supplier were onsite for final commissioning of the optimization technology. Initially, the new software ran in advisory mode a few hours each day. Based on an analysis of the unit's performance, the models, control logic and PID loops were fine-tuned. After two days of advisory-mode operation, the software was put into service in closed-loop mode – in which it runs automatically and without operator intervention – and has been running continuously ever since.

New Technology Provides Many Benefits

The upgraded software has provided many benefits. The unit is now able to hit targeted set points accurately and with minimal megawatt overshoot, thereby contributing to reduced fuel costs. The unit is also able to ramp to the targeted set point much quicker, enabling revenue to be generated more quickly. Because the unit is able to follow load demand it is now possible for MPC to compete in the ancillary power services market. In addition, the use of optimization technology can also translate into less stress on critical equipment, further enhancing unit reliability and availability

Innovation

Developing a new mode of operating the units completely inside the existing control system with no addition hardware requirements. The URO is 'one button' operation and requires no operator intervention.

Operational Excellence

With the addition of the URO, the Young Station can now better meet ISO demands via a vastly improved ramp rate and less MW overshoot. The results have been dramatic: a 70 percent improvement in ramp rate, from 2 MW/min. to 7 MW/min.; a 2-megawatt reduction in over/undershoot; and a 4 PSI average decrease in throttle pressure, contributing to overall machinery health. As an additional benefit, the URO solution has also been instrumental in helping Young Station pass its routine ISO (turbine steam inlet valve) tests.

Financial Results

Use of the URO has translated into additional revenue opportunities for Minnkota. This is accomplished by:

- Enabling units to more accurately hit targeted set points with minimal megawatt overshoot, thereby contributing to reduced fuel costs;
- Helping units quickly ramp to targeted set points and allowing them to generate revenue as quickly as possible; and,
- Enabling units to follow load demand, making it possible for them to compete in the ancillary power services market.
- Less stress on critical equipment, further enhancing unit reliability and availability.