Technical Paper
BR-1903

Coordinated Sootblowing Optimization of Duke Energy's Miami Fort 7 and 8

Authors:
T.A. Fuller, L.R. Hyrne, and J.A. Brown

Babcock & Wilcox
Power Generation Group, Inc.
Barberton, Ohio, U.S.A.

K. Gutzwiller
Duke Energy
North Bend, Ohio, U.S.A.

Presented to:
Power-Gen International

Date:
November 12-14, 2013

Location:
Orlando, Florida, U.S.A.

Coordinated Sootblowing Optimization of Duke Energy's Miami Fort Units 7 and 8

T.A. Fuller, L.R. Hyrne, and J.A. Brown
Babcock & Wilcox Power Generation Group, Inc., Barberton, Ohio, U.S.A.

K. Gutzwiller
Duke Energy, North Bend, Ohio, U.S.A.

BR-1903
Presented to:
Power-Gen International
November 12-14, 2013
Orlando, Florida, U.S.A.

Abstract

Since 2008, Duke Energy's Miami Fort units 7 and 8 have been operating with Powerclean® intelligent sootblowing systems from Babcock & Wilcox Power Generation Group, Inc. (B&W PGG). These systems have been effective at reducing overall sootblower usage while improving the performance of each unit, but have been hampered periodically by limitations of the sootblowing system. In particular, Units 7 and 8 share a common sootblowing air header with Unit 6. This shared header arrangement can lead to a shortage of sootblowing air, especially if any of the air compressors are out of service. When this happens, operators take the Powerclean systems off line and coordinate a manual operation of the sootblowers.

B&W PGG approached Miami Fort with the concept of coordinating the sootblowing optimization on units 7 and 8 using the new Powerclean NX software which has the capability of multi-unit coordination. The concept was accepted and Miami Fort initiated a coordinated sootblowing optimization project with B&W PGG.

This paper presents initial results from the coordinated sootblowing optimization project on units 7 and 8 of Duke Energy's Miami Fort station. The goals of the project will be described and an overview of the Powerclean NX intelligent sootblowing system will be presented. The coordination logic developed for Miami Fort 7 and 8 will be discussed along with the constraints placed on the optimization. Finally, this paper will show how the coordinated sootblowing optimization has maintained the improved performance of both units while managing the use of the shared sootblowing medium.

Introduction

To achieve optimum boiler performance, operators must control the cleanliness and limit the fouling and slagging of heat transfer surfaces within the boiler. Historically, the heating surfaces were cleaned by sootblowers using air, steam or water with a simple time-based strategy initiated by the boiler operators. A scheduled cleaning approach, however, cannot address the regular changes in boiler operation caused by pressures such as load cycling and fuel switching/blending. Additionally, as power plant operators push to achieve greater efficiency and performance from their boilers, the ability to more effectively optimize cleaning cycles has become increasingly important. Sootblowing only when and where it is required to maintain unit performance can reduce unnecessary blowing, save on blowing medium utilization, and reduce tube erosion and wear.

Over the last decade, several companies have introduced intelligent sootblowing (ISB) systems in response to the need for improved boiler performance. These ISB systems automatically adjust the operation of the sootblowers in response to changing boiler conditions to keep the heating surfaces at the optimal cleanliness. The available ISB systems use different approaches for managing the sootblowing operations. Some ISB systems are goal based and use straightforward rules to determine sootblowing location and frequency. Other ISB systems use either data-driven (*i.e.*, neural network) or first-principles models of the heat transfer process coupled with rules or other decision logic to determine sootblowing location and frequency.

In 2008, Duke Energy's Miami Fort Station installed B&W PGG's Powerclean® intelligent sootblowing system on Units 7 and 8. The Powerclean system uses B&W PGG's highly detailed heat transfer model to monitor the performance of all heating surfaces within the boiler. The detailed boiler model is coupled with a rules-based expert system to determine sootblowing location and frequency. Since being brought into service, the Powerclean systems at Miami Fort have been effective at reducing overall sootblowing frequency while improving the performance of both units.

The success of the Powerclean systems at Miami Fort have been hampered by physical limitations of the existing sootblowing systems. The sootblowers on Unit 6, Unit 7 and Unit 8 share a common air supply header. One or more of the air compressors that service this supply header regularly go offline causing a reduction in available sootblowing medium. When this happens, the operators verbally coordinate the sootblowing operations to maintain enough air header supply pressure for proper sootblower operation. This usually results in the operators putting one or both of the Powerclean systems in manual mode until the air compressor issues can be resolved.

Recently, B&W PGG approached Miami Fort with the concept of automatically coordinating the sootblowing optimization on Units 7 and 8 using the new Powerclean NX software. Powerclean NX is the latest version of B&W PGG's Powerclean software and has the capability of multi-unit coordination. Miami Fort liked the concept and initiated a project to implement the proposed coordination control.

Miami Fort Unit Descriptions

Duke Energy's Miami Fort station has three operating coal-fired units. Unit 6 is an Alstom / CE tangentially fired boiler rated at 168 MW. Both Unit 7 and Unit 8 are B&W PGG Carolina-type RB boilers rated at 552 MW each. Unit 7 and Unit 8 each have 5 B&W Roll Wheel® pulverizers feeding 40 burners (8 per pulverizer) on each unit. Both units also have radiant platen heating surfaces. All three units fire an eastern bituminous coal. A side view of Unit 7 is shown in Figure 1 and a side view of Unit 8 is shown in Figure 2.

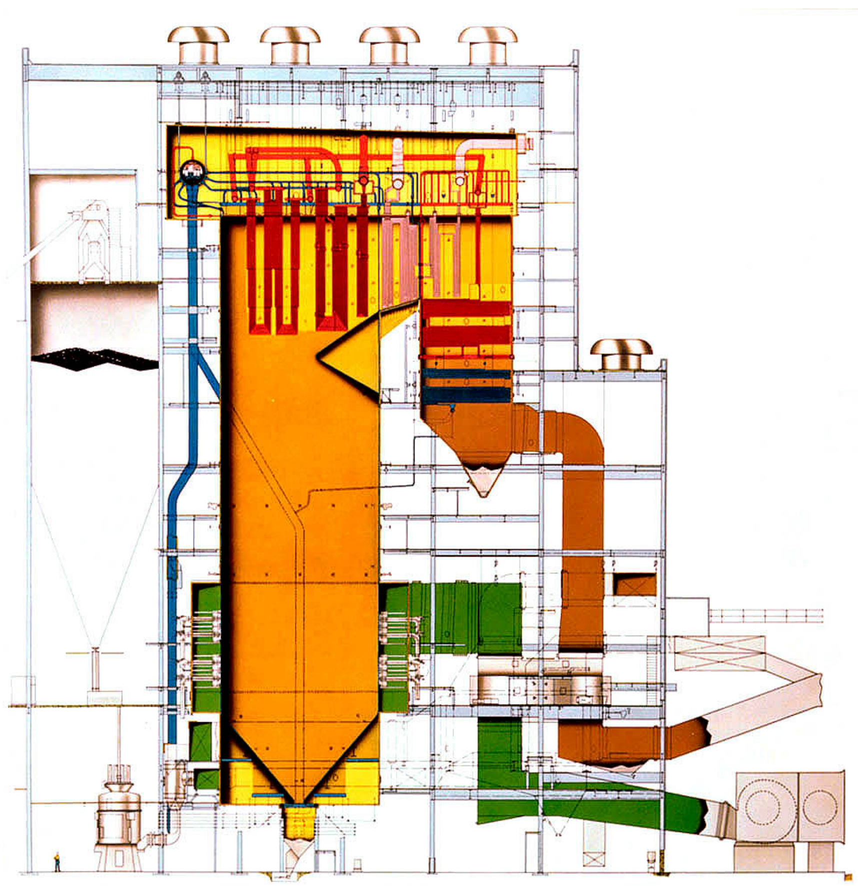

Figure 1 Duke Energy Miami Fort Unit 7

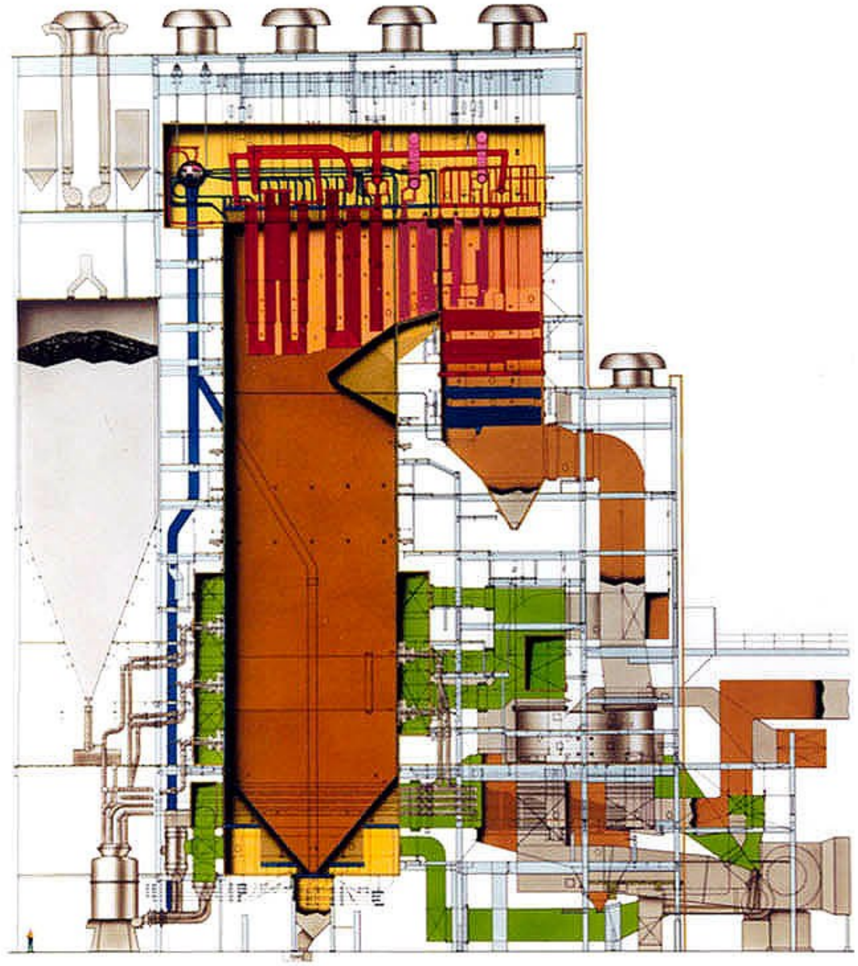

Figure 2 Duke Energy Miami Fort Unit 8

Diamond Power® sootblowers are used on all three units. Unit 6 has 40 IR sootblowers in the furnace and 30 IK sootblowers in the convection pass. Unit 7 has 58 IR sootblowers in the furnace and 54 IK sootblowers in the convection pass. Unit 8 has 58 IR sootblowers in the furnace and 52 IK sootblowers in the convection pass. The sootblowing controls on Unit 7 are handled by custom logic within a GE FANUC PLC system. The Unit 8 sootblowing controls are programmed into an ABB DCS. The Powerclean intelligent sootblowing system is installed only on units 7 and 8. The sootblowers on Unit 6 are operated manually.

Air is used as the sootblowing medium on all three units. The air is supplied by a common air header. Three Ingersoll Rand centrifugal air compressors, or Centacs, supply air to the common header. Each Centac is a high pressure device designed specifically for sootblowing applications.

Powerclean NX Software Coordination Features

Powerclean NX is the latest version of B&W PGG's intelligent sootblowing software. Among the numerous enhancements added into this version of the software are two features that allow multiple Powerclean NX systems to automatically coordinate the operation of sootblowers on different units. The first of these features is an improved queuing system for starting the sootblowers. When configured for coordination control, the sootblowing queue within a given Powerclean NX system requests permission to run the next blower in line by sending key information about the blower and the area to be cleaned to the coordination logic. The queue then waits for the coordination logic to grant permission to run the blower before sending a start command to the sootblower control system. The queue does this each time a blower is ready for operation.

The second feature that makes coordination control possible is the ability to run custom calculations and logic using *calculation sheets*. Calculation sheets are configured using a drag-and-drop, function-block-based editor. Powerclean NX software comes standard with a large number of function blocks that range from simple math and decision logic blocks to advanced modeling blocks such as fuzzy logic and neural networks. An example calculation sheet is shown in Figure 3.

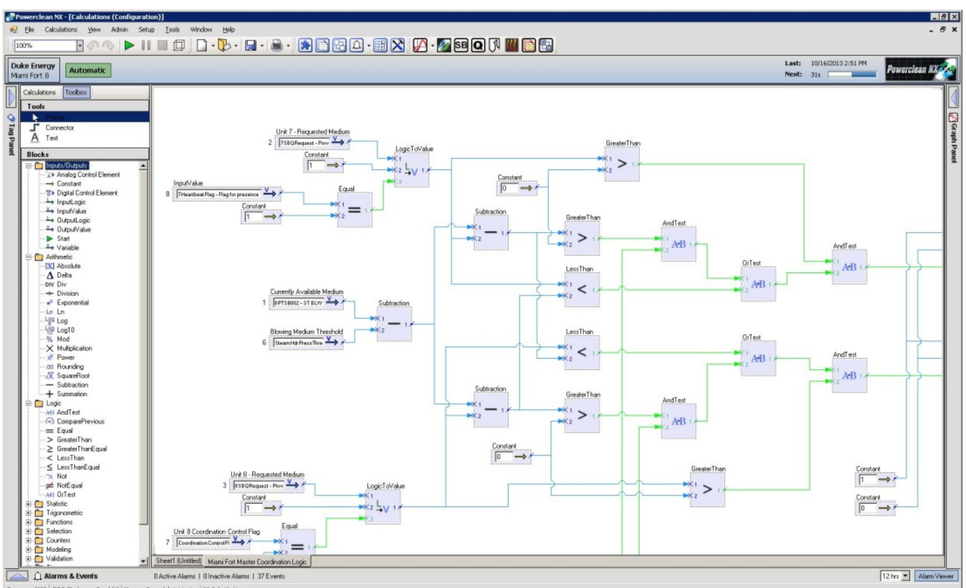

Figure 3 Powerclean NX Calculation Sheet

The calculation sheet system allows for the creation of master/slave coordination logic. Master logic is created on one of the Powerclean NX systems while slave logic is created on the remaining Powerclean NX systems. The master logic processes the dequeue (remove from the top of the queue) requests from all Powerclean NX systems and sets permission flags to allow sootblower operation. The slave logic checks status information from the master system to ensure that coordination control is still active.

Powerclean NX Software Coordination Setup

Communications

The two Powerclean NX systems on Miami Fort Units 7 and 8 were set up in a master/slave configuration using calculation sheets as described in the previous section. The Unit 8 Powerclean NX system was configured with master logic while the Unit 7 system was configured with slave logic. An OPC server was used to provide the communication link between the two systems. The OPC server was located on the Unit 8 Powerclean NX computer.

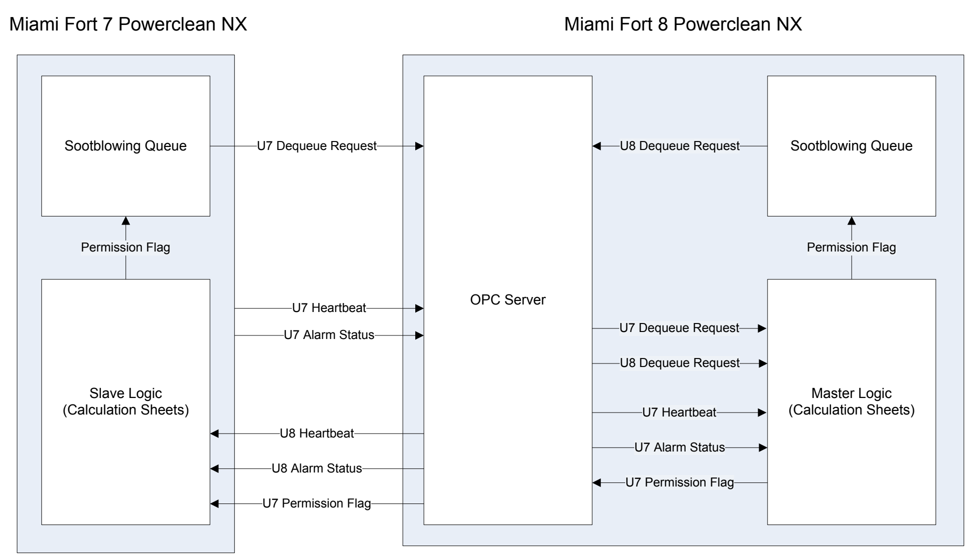

Figure 4 Coordination Logic Data Flow Diagram

The overall communications flow between the two Powerclean NX systems is shown in Figure 4. Both systems write dequeue requests to the OPC server. A dequeue request consists of: 1) the amount of air required by the target blower, 2) the cleanliness of the region to be cleaned, 3) the priority of the region to be cleaned, and 4) how long it has been since any cleaning has taken place on the unit. If a Powerclean NX system doesn't have a dequeue request on the current cycle, then zeros are passed to the master logic for the aforementioned items. In addition to the dequeue request, each system also writes a heartbeat and an alarm status value to the OPC server. The master logic reads all of this information and writes a permission flag back to the OPC server. Each system reads the permission flag and takes appropriate action. In addition to the permission flag, the Unit 7 system also reads the heartbeat and alarm values written by the Unit 8 system to determine if the permission flag should be applied to its own sootblowing queue.

Master Logic

The main purposes of the master logic are to enforce the minimum pressure requirement of the air header and to determine the order of operation when both units make simultaneous sootblowing requests. A flow diagram of the master logic is shown in Figure 5. The master logic first looks to see if there is a dequeue request from each unit. If a unit has a dequeue request, the logic then checks the heartbeat and alarm status of that unit. The dequeue request is marked as valid (true) if these checks pass; otherwise, the request is marked as invalid (false).

Once each unit has been checked for valid dequeue requests, the master logic prioritizes the valid requests. The prioritization takes into account the extent of cleaning required, how critical the region is to unit operation, and the length of time since any region was cleaned. After prioritizing the dequeue requests, the logic compares the required medium from the top dequeue request to the current air header pressure. If there is enough pressure to run the requested sootblower without dropping below a minimum threshold, then the permission flag for the requesting unit is set to true. If there is not enough pressure, the permission flag is set to false.

If the top unit was granted permission to operate, the logic will then look at the request from the other unit, if there is a request. The amount of medium required by the top unit is subtracted from the air header pressure to arrive at a new pressure. The required medium from the second unit is compared to this new pressure. If there is still enough pressure to run the blower from the second unit, then its permission flag is also set to true. If there is not enough pressure, then the second unit's permission flag is set to false.

Slave Logic

Compared to the master logic, the slave logic is very straightforward. First, the slave logic checks to see if the slave Powerclean NX system should participate in coordination control. Next, the logic checks the heartbeat tag from the master Powerclean NX system to ensure that it is still functioning. Finally, the logic checks for any alarms from the master Powerclean NX system. Certain alarms indicate problems with the master system that could influence the coordination logic. If all checks pass, the slave logic reads the permission flag set by the master logic and passes it on to the sootblowing queue. If any of the checks fail, the slave logic sets the permission flag to falsewhich effectively removes the slave Powerclean NX system from coordination control for that processing cycle. A flow diagram of the slave logic is shown in Figure 6.

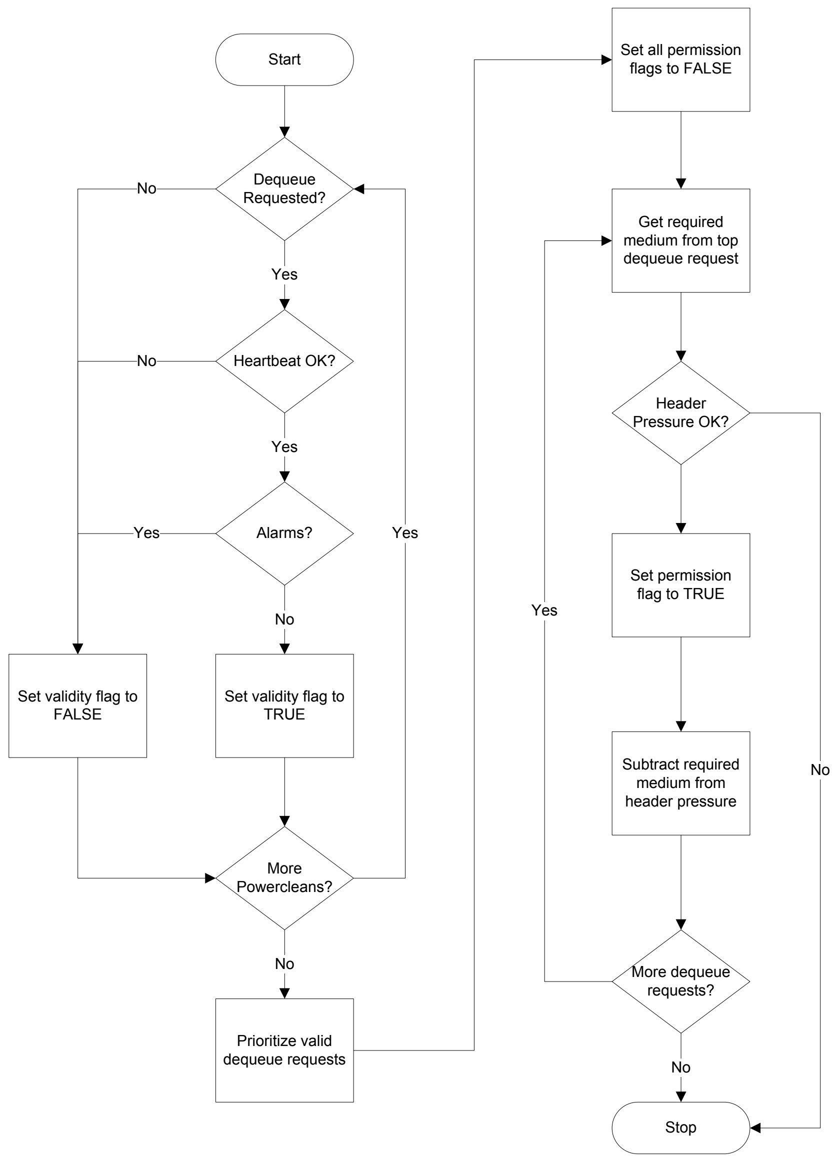

Figure 5 Master Logic Flow Chart

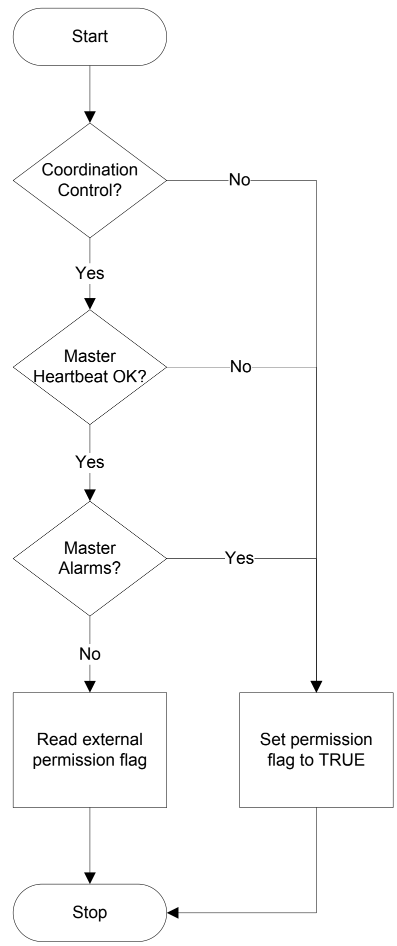

Figure 6 Slave Logic Flow Chart

Performance Results

The coordination control described in the previous sections was put in place after Unit 7 and Unit 8 were upgraded with Powerclean NX software. After the coordination control was placed in service, B&W PGG went through an initial fine tuning period where the master logic was adjusted based on observed operation. Once the logic was tuned, B&W PGG asked the operators to leave both systems in automatic operation even during periods when air compressors were out of service. The results presented below show the performance of the coordinated systems.

The first example of the coordination control at work is shown in Figure 7. In this figure, Unit 8 makes a request to start a sequence (solid red line) that will need 30 psi of air pressure. At the time of the initial request, the common sootblowing air header (solid blue line) cannot support a reduction of 30 psi. This would put the air header below its configured threshold (dashed gray line). Therefore, the permissive (solid green line) is not given to Unit 8 until adequate pressure is available.

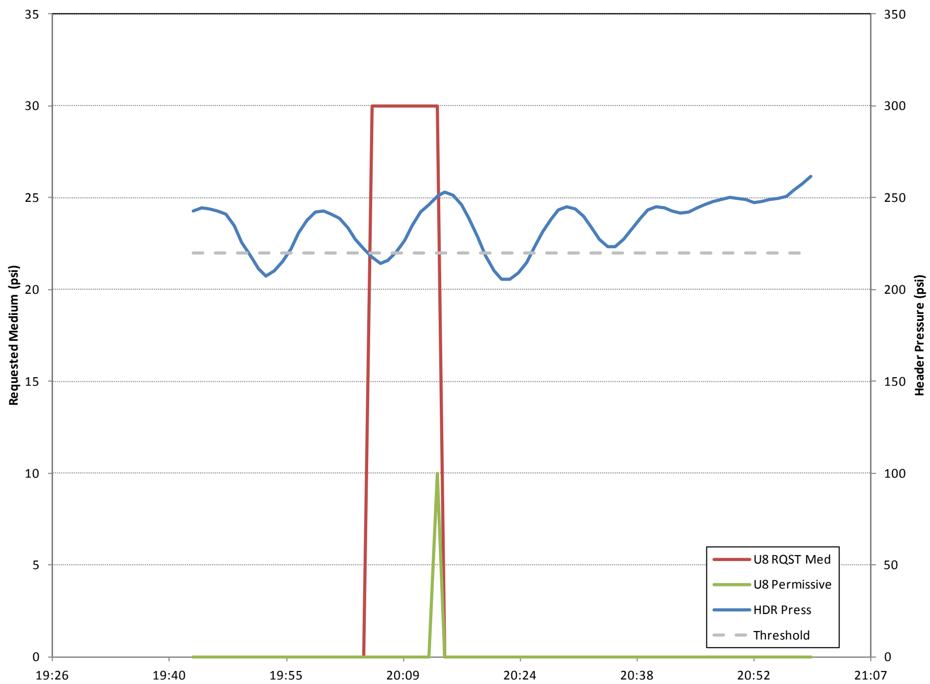

Figure 7 Unit 8 Blowing Request

Figure 8 shows a similar example of blowing requests made by Unit 7. In this figure, Unit 7 submits two separate start requests (solid red lines) to the master logic on Unit 8. Each of the requests requires 30 psi from the sootblowing air header. The first request does not receive a permissive for a few minutes because the header does not have enough capacity to run the Unit 7 blowers without lowering the available pressure below its threshold (dashed gray line). The second request from Unit 7 is granted immediately since the shared air header contains adequate pressure to meet the demand.

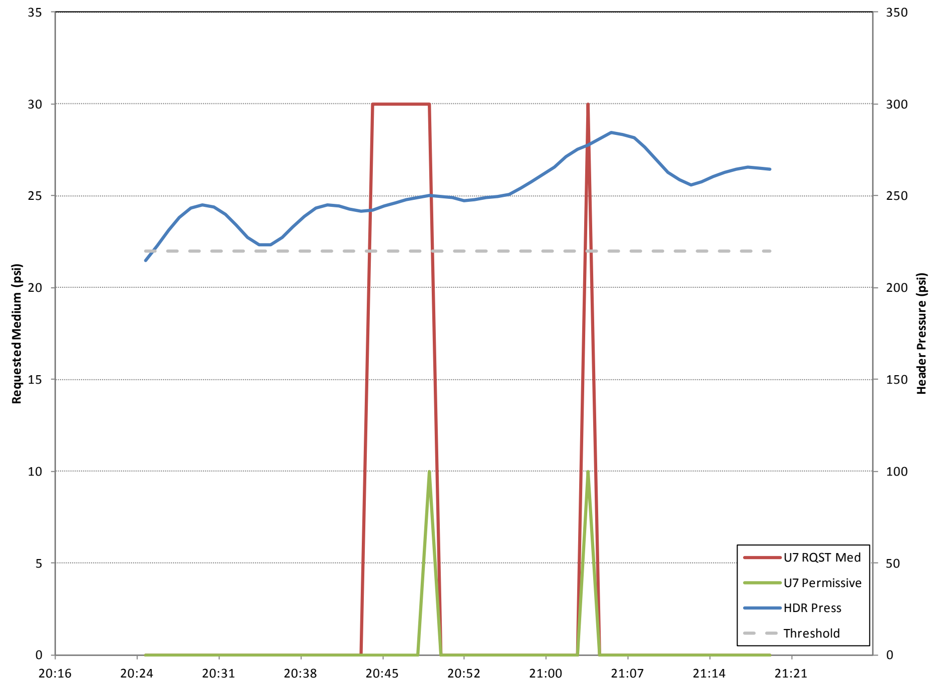

Figure 8 Unit 7 Blowing Request

An example of how the coordination control handles simultaneous sootblowing requests is shown in Figure 9. In this figure, multiple requests (solid red and solid purple lines) are submitted to the master logic over a period of approximately 2 hours. Of particular interest is the middle set of requests. Here, both Unit 7 and Unit 8 submit a dequeue request at the exact same time. Initially, both requests are not given permission due to lack of air header capacity. When the header has sufficient capacity, the master logic determines that Unit 7 has priority and grants it permission to run. Shortly after Unit 7 is permitted to operate, the header pressure is still high so Unit 8 is given permission to run.

Figure 9 Simultaneous Blowing Request

The results discussed thus far show how the coordination control delays blower operation to manage the common air supply header. Of particular interest, however, is how this type of control impacts the performance of each unit. One measure of performance is the cleanliness of each of the heating surfaces. Figures 10 and 11 show long-term averages of the cleanliness factors for the major boiler components on Unit 7 and Unit 8, respectively. These results were generated for similar high load timeframes. The blue bars in each figure represent a timeframe when the units were not participating in coordination control. The red bars represent when the units were submitting dequeue requests to the master coordination logic.

Generally speaking, the cleanliness factors were approximately the same with coordination control as without coordination control. Unit 7 actually tended to have slightly higher cleanliness factors when in coordination control. Unit 8, on the other hand, tended to be more of an even split between components with a slightly higher cleanliness factor and components with a slightly lower cleanliness factor.

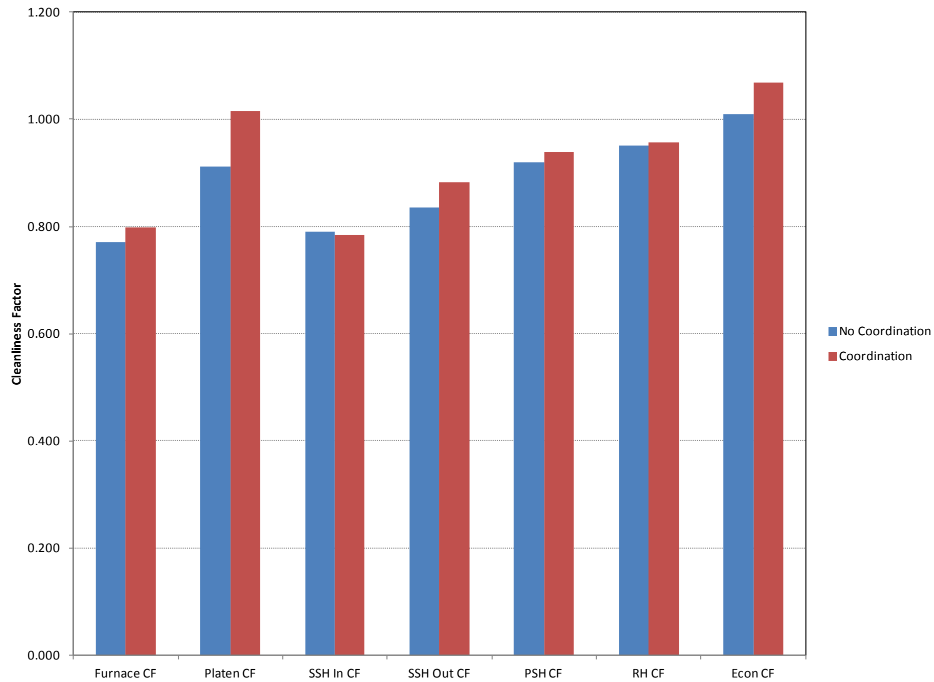

Figure 10 Unit 7 Cleanliness Factors

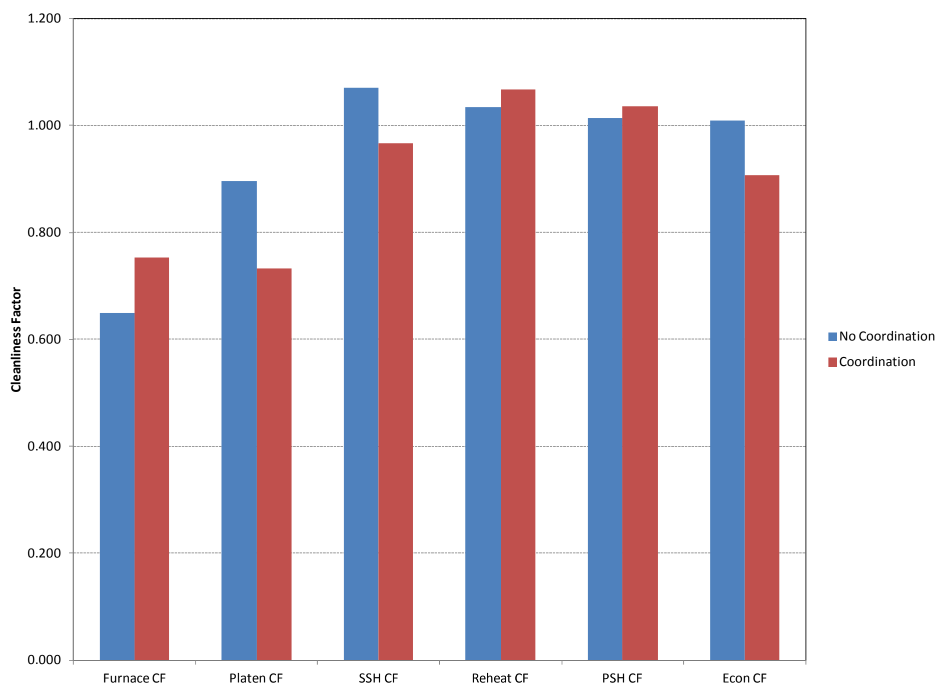

Figure 11 Unit 8 Cleanliness Factors

Conclusions

The coordinated Powerclean NX systems provide the Miami Fort units with a low cost, integrated method for providing a balanced, multi-unit approach to intelligent sootblowing. The results observed to date have shown that automated coordination control of Units 7 and 8 can provide similar or improved unit cleanliness while managing a potentially insufficient air supply. The success of the coordination control allows the operators to keep the Powerclean NX systems in automatic mode full time. This frees the operators to concentrate on other areas and allows for better overall management of the sootblowing activity on Miami Fort Units 7 and 8.

Future Work

While the results observed thus far have been very encouraging, B&W PGG has identified a few specific areas for future work. These include:

1. Continued operation under coordination control. This will help the plant assess the true long-term performance impacts and identify long-term benefits to Duke Energy.
2. Unit 6 does not currently participate in the coordination control. This adds an unpredictable element to the management of the common air supply header. Discussions with the plant are under way to find a solution which will allow Unit 6 to participate in coordination control.
3. Duke Energy has expressed an interest in running with fewer air compressors to save on operating costs. B&W PGG would like to conduct additional tests where air compressors are taken offline one at a time to more finely tune the coordination control logic for improved air header management.

the authors and contributors to this work are supplying general information and are not attempting to render or provide engineering or professional services. Neither B&W PGG nor any of its employees make any warranty, guarantee or representation, whether expressed or implied, with respect to the accuracy, completeness or usefulness of any information, product, process, method or apparatus discussed in this work, including warranties of merchantability and fitness for a particular or intended purpose. Neither B&W PGG nor any of its officers, directors or employees shall be liable for any losses or damages with respect to or resulting from the use of, or the inability to use, any information, product, process, method or apparatus discussed in this work.