GRIFFIN MILESTONE REPORT

U2 STEP NOx NEURAL NETWORK PROJECT

October 4, 2018

Introduction

Since its installation, Griffin in its two forms (COS and KSB) has been used for three major purposes at Huntington Unit 2: NOx reduction, sootblower control, and temperature control. The following report displays how the system has done at achieving its goals of reducing NOx, improving sootblower control, reducing the amount of time tubes are at extremely high temperatures, and maintaining adequate steam temperature control. Also reported are the usage statistics of the two applications since their most recent major configurations.

Usage Statistics

The COS system has been fully active with only minor attention since April 13, 2018. At this time, the system was reconfigured back to the standard Griffin base installation. As it has been online, minor changes have been made as improvements have been identified. However, the system has never had to be taken offline for these changes to be made.

Recently, there have been a couple of instances where the neural network communication failure alarm has become active and has caused the Griffin system to turn off automatically. Initially, it was believed that this was due to an unknown issue on the DCS side of the communication link, as a number of the failures occurred at exactly midnight every few days. However, the issue ceased for a number of weeks, until becoming more prominent. A dedicated application for the heartbeat signal between DCS and Griffin was created, and the scan rate reduced on this application, and no failures have occurred since.

The sootblowing system has had a high degree of operator acceptance, and its percent usage reflects this, with both systems (retract and wall blowers) being active more than 80% of the time since it became available on July 13, 2018. This system will be discussed further later in this report.

The overall usage statistics are available in the table below.

Table 1: Griffin Application Usage Statistics

	Percent of Time Active
Damper Control	77.78%
O2 Control	65.91%
Wall Blower Control	80.14%
Retract Control	83.76%

As can be seen here, the O2 control is active much less often than any of the other systems. In many cases, this is due to the necessity to turn O2 control off to complete O2 sensor calibration, and the operator forgetting to turn it back on after the test is complete. This has a direct impact on NOx, as the system loses ability to control one of the main NOx influencers. It is recommended that an alarm be added to DCS to inform the operators that Griffin O2 control is not active if it has been off for longer than 1 hour.

NOx Emissions across Unit Load Range

Steady improvement in the average NOx emissions across the unit's load range has been realized since the beginning of the project. Compared against pre-installation performance, NOx as of the most recent quarter (QIII 2018) has been reduced an average of 13% across all load ranges. This progression can be seen in the figure below.

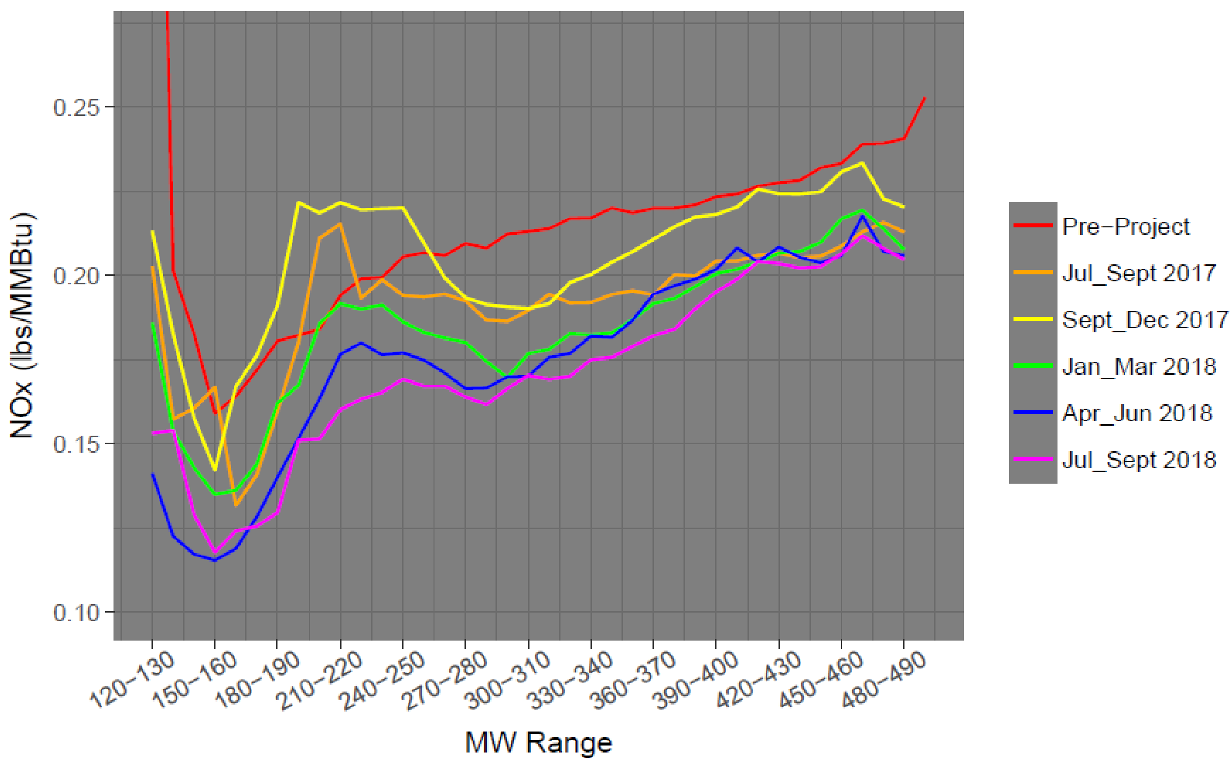

Figure 1: Quarterly NOx emissions since Project Beginning

Two observations from this plot are the sharp increase in emissions at the current minimum load (~120 gross MWs) and the large jump in NOx centered at around 220 gross MWs. The minimum load value is due to the control limits currently in place on total air flow. On May 21st, the total air flow limit was reduced from 30% to 29% and was again stepped down on June 21st to 28%. These changes are directly reflected by the decreased NOx emissions at the lowest load ranges.

The second observation, that of the high NOx emissions at about 220 MWs likely comes from this being near the common mill point. Putting the 4th mill in and out of service has a severe effect on NOx. On May 18th, logic was implemented to allow large biasing of the aux air dampers as mills come in and of service. It is probable that the improvements that have been realized in this area are due to this logic.

Since the first Griffin implementation, the overall trend of NOx is decreasing, while load is increasing. As NOx emissions are heavily dependent on load, to see the two divert from one another in this matter suggests emissions are truly improving.

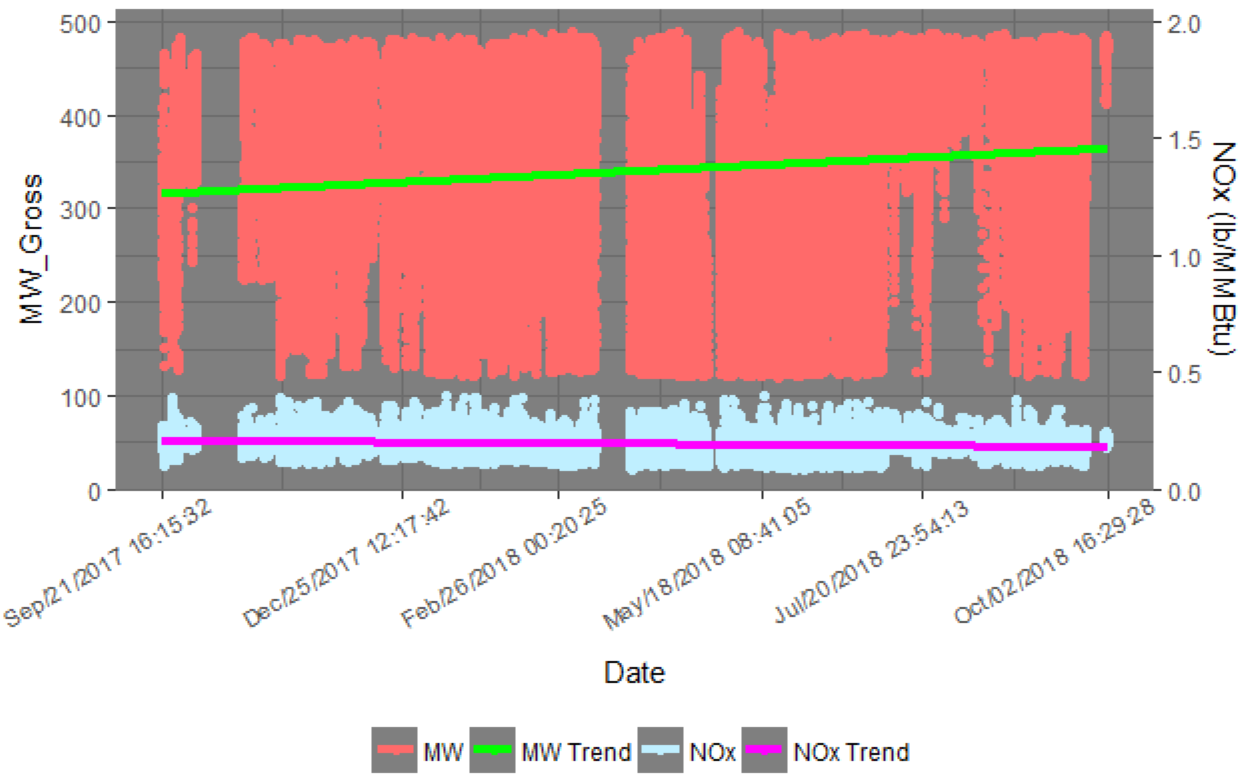

Figure 2: Trends of NOx and Load since first Griffin implementation

The immediate benefits that Griffin has on the unit have been portrayed through a number of on/off tests. After letting the unit operate as guided by the DCS for a period of time, the Griffin system is fully activated (all available parameters are put into Griffin control) and the effects on NOx are observed. From these tests, it has been seen that NOx may immediately improve by as much as 19% from Griffin being activated. Some of these instances are displayed in the following figures.

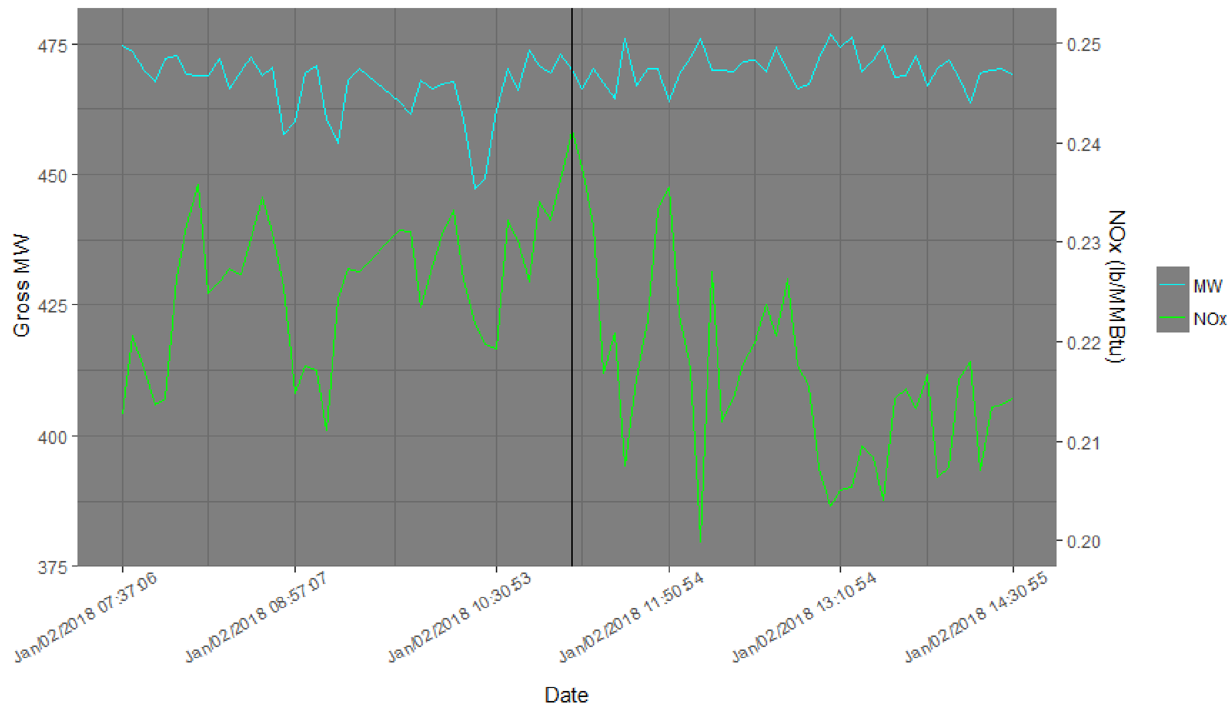

Figure 3: Jan 2, 2018 On/Off Test, NOx decrease of 13%

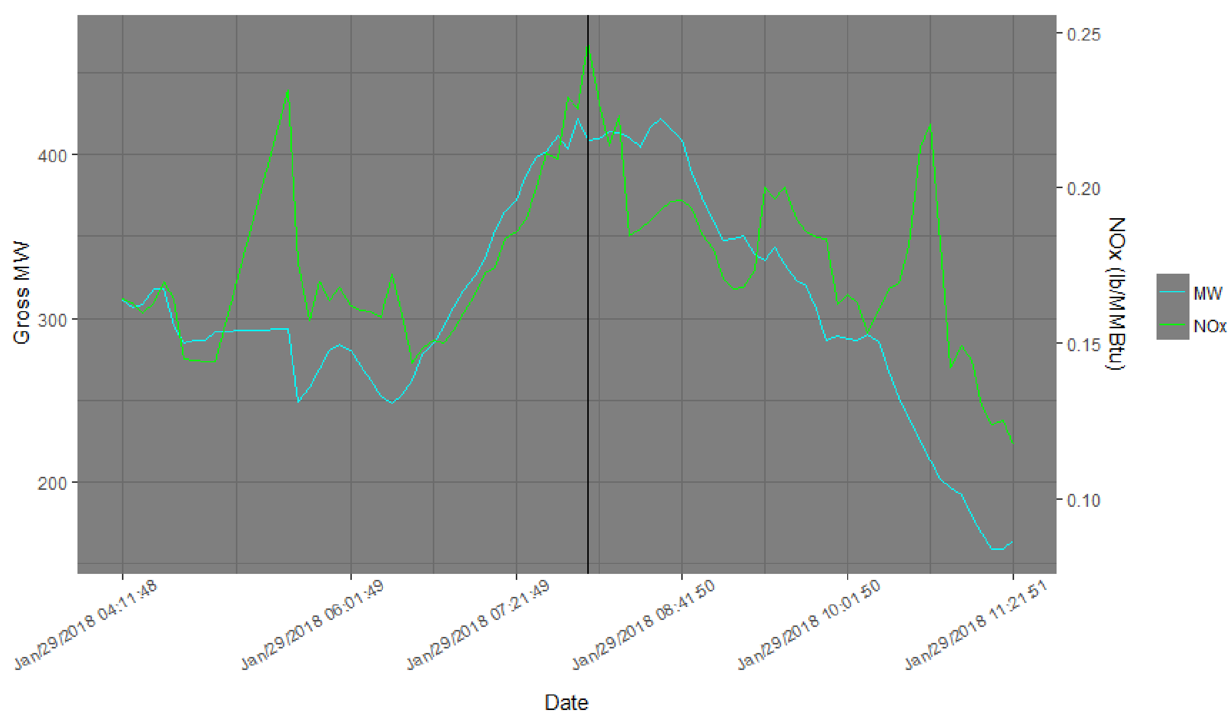

Figure 4: Jan 29, 2018 On/Off Test, NOx decrease of 19%

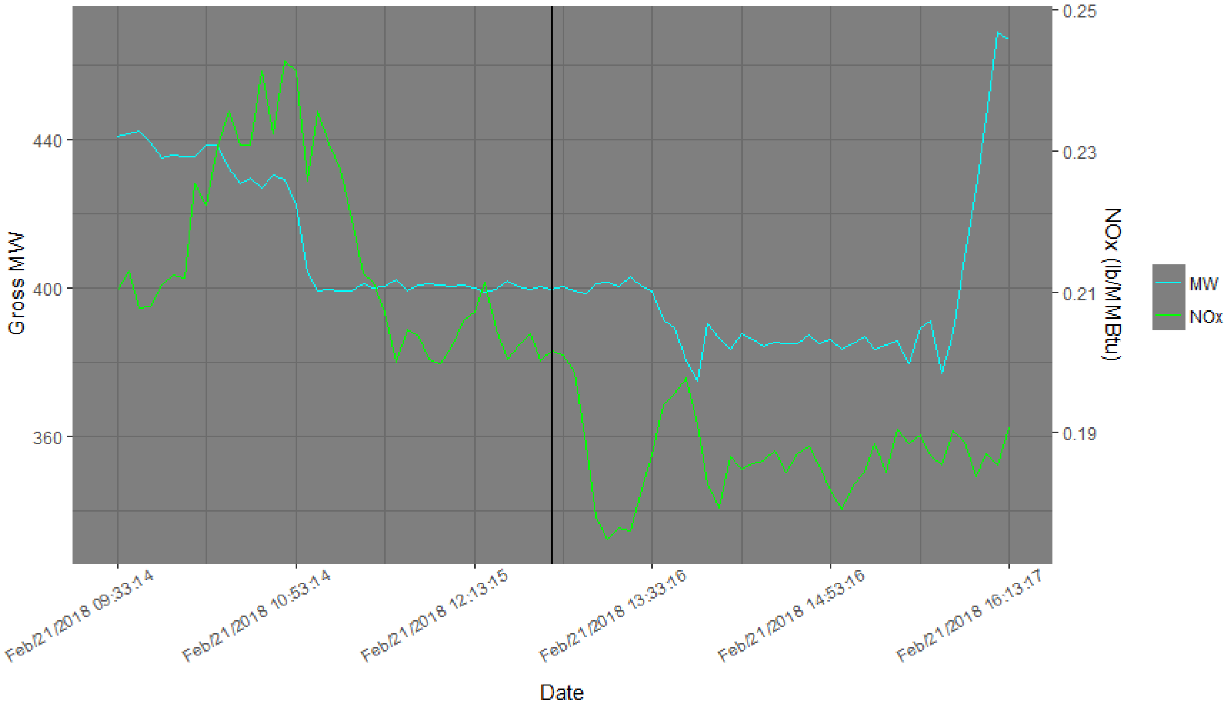

Figure 5: Feb 21, 2018 On/Off Test, NOx decrease of 13%

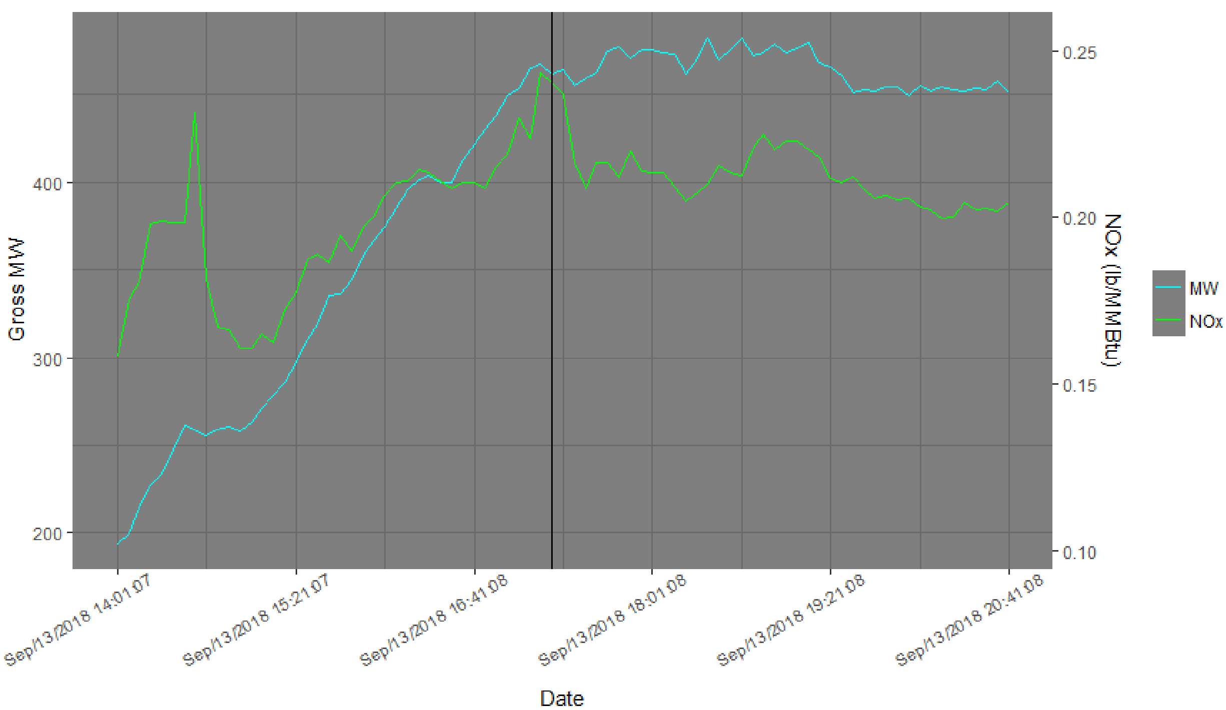

Figure 6: Sept 13, 2018 On/Off Test, NOx decrease of 12%

Of the different tests performed, some of the most telling data is the result of a communication failure which caused the system to be offline for a full week. The following plots show NOx emissions for the week before the communication failure (Griffin System On, blue dots), and the week without Griffin available (orange dots). The trend of NOx for each week is displayed on the actual NOx records as a solid line, and the corresponding load profile is shown for reference.

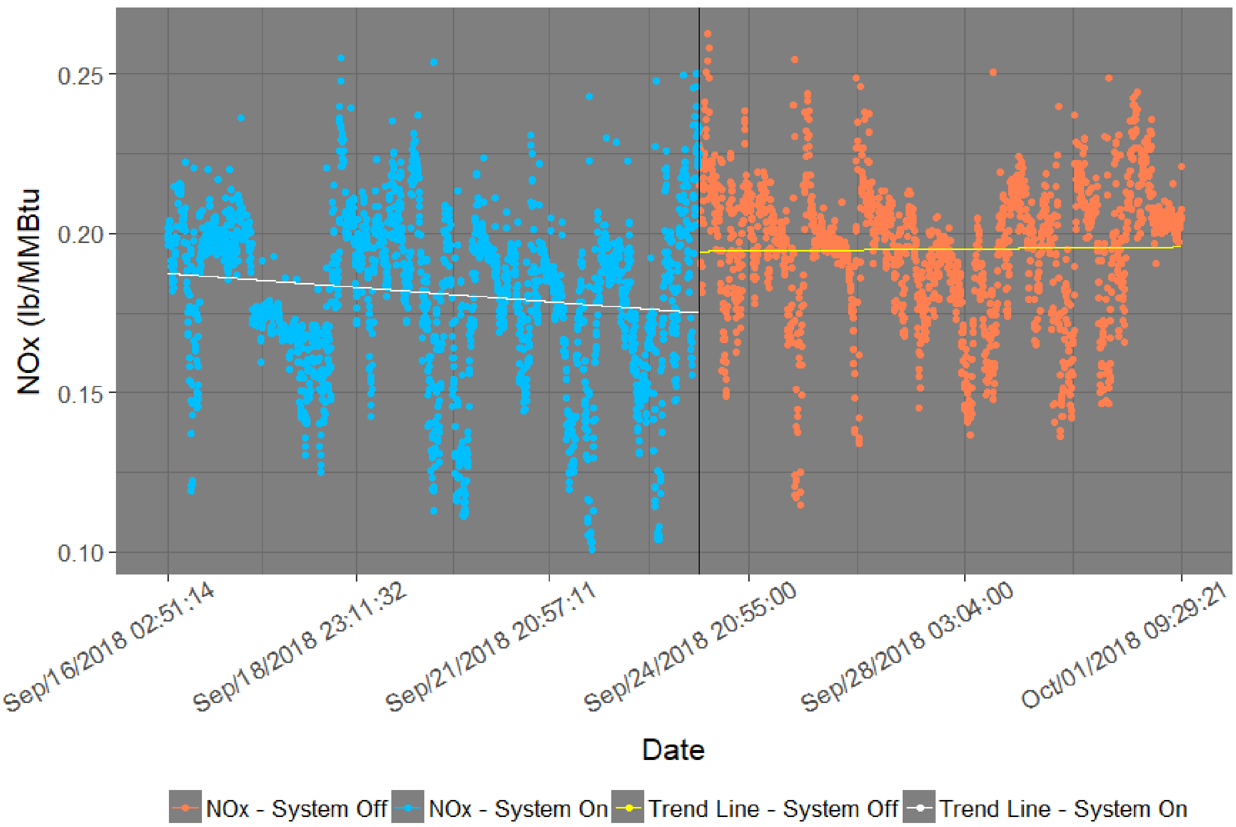

Figure 7: NOx and Trend for week with Griffin active (blue) and not active (orange)

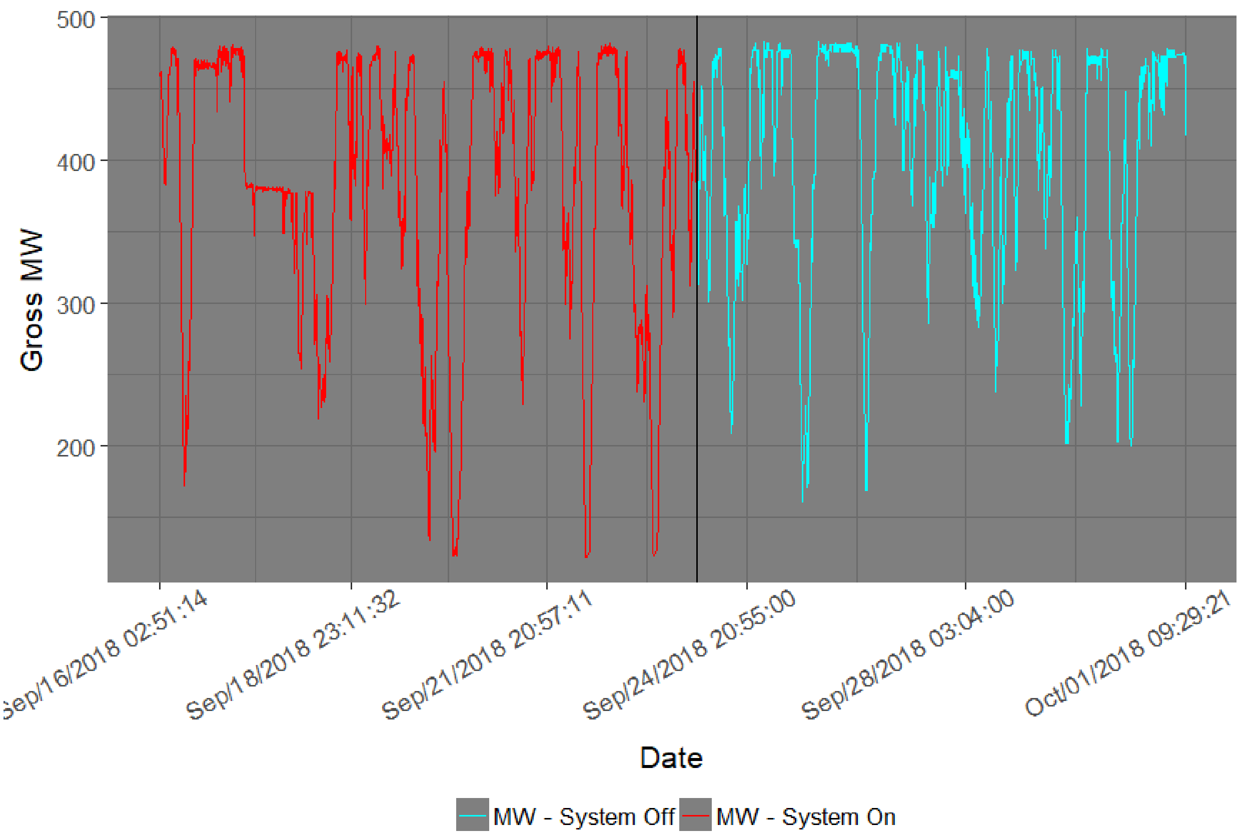

Figure 8: Corresponding load profile to Figure 7

The average observed NOx of the two periods is 0.181 while Griffin is active, and 0.195 when Griffin is not active. This is a 7% difference, with Griffin resulting in reduced emissions. There is also a significant difference in the observed trend of NOx during the two periods. While Griffin is on, although load is highly variable, NOx is trending decidedly down. When Griffin is off, NOx emissions quickly rise, and the trend actually starts to come up slightly.

KSB Performance

The sootblowing system has been well accepted by operations. It is a relatively simple system, but contains within it specific logic created to capture the expert knowledge of the operators. Engagement of the system is a seamless process, with no observable negative effects on performance.

The system has resulted in sootblowers being activated less often, while maintaining adequate control of ash and slag within the boiler. One of the key attributes of the system has been its ability to assist with steam temperature control. This being in automatic control has helped to reduce the need for operators to focus on temperatures, allowing them to focus on other tasks. The amount of time that has been recorded during which steam temperatures have been greater than 1030°F has declined by 24.4%.

The change in average sootblower activations is displayed in Table 2.

Table 2: Average Daily Sootblower Activations

	Before KSB	Active KSB	Percent Change
Wall Blowers	99	79	-20%
Retract Blowers	39	38	0%

Temperature Control

High tube temperatures have been a constant issue faced by this unit. Particularly when ramping, tube temperatures rise at a rapid rate and have been observed to reach levels as high as 1175°F. A number of methods have been attempted by operators and within the evolving Griffin system. Of the methods tried, for a period of time Griffin had logic in place which bumped up the O2 bias in response to high temperatures, and also closed upper SOFA dampers to help cool off the unit. These methods were satisfactory in most instances, but also caused a direct NOx penalty to be incurred. Additionally, there were times when it was observed that these measures would actually **increase** temperatures, and thus further compound the problem.

On August 3, 2018, a new method was implemented. The method consists entirely of using the lower SOFA tilts to control tube temperature excursions. This has proven remarkably effective at reducing the number of times tube temperatures exceed 1100 °F and has also resulted in more uniform temperature control across the unit. The following figures display the hottest tube temperatures as the action of the lower SOFA tilts before and after this logic update. The value associated with the SOFA tilt is not to scale, but it does allow its behavior to be visualized.

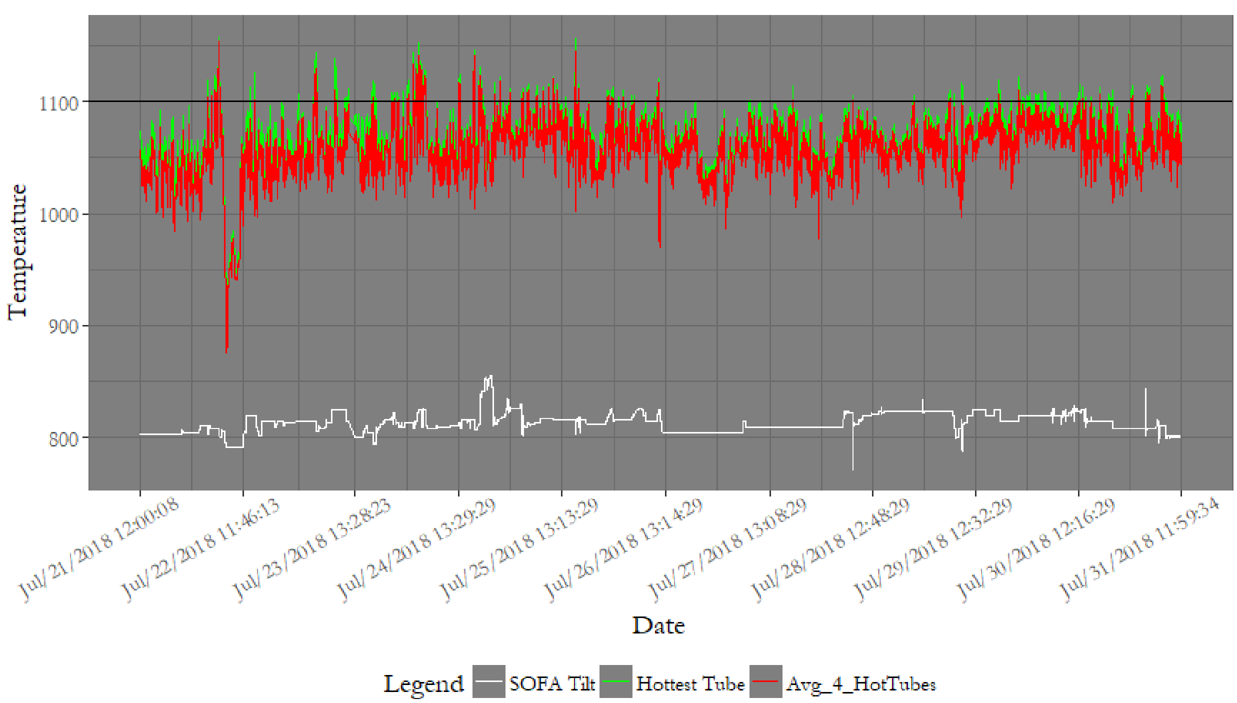

Figure 7: Tube temperature excursions and lower SOFA tilt behavior before SOFA tilt control

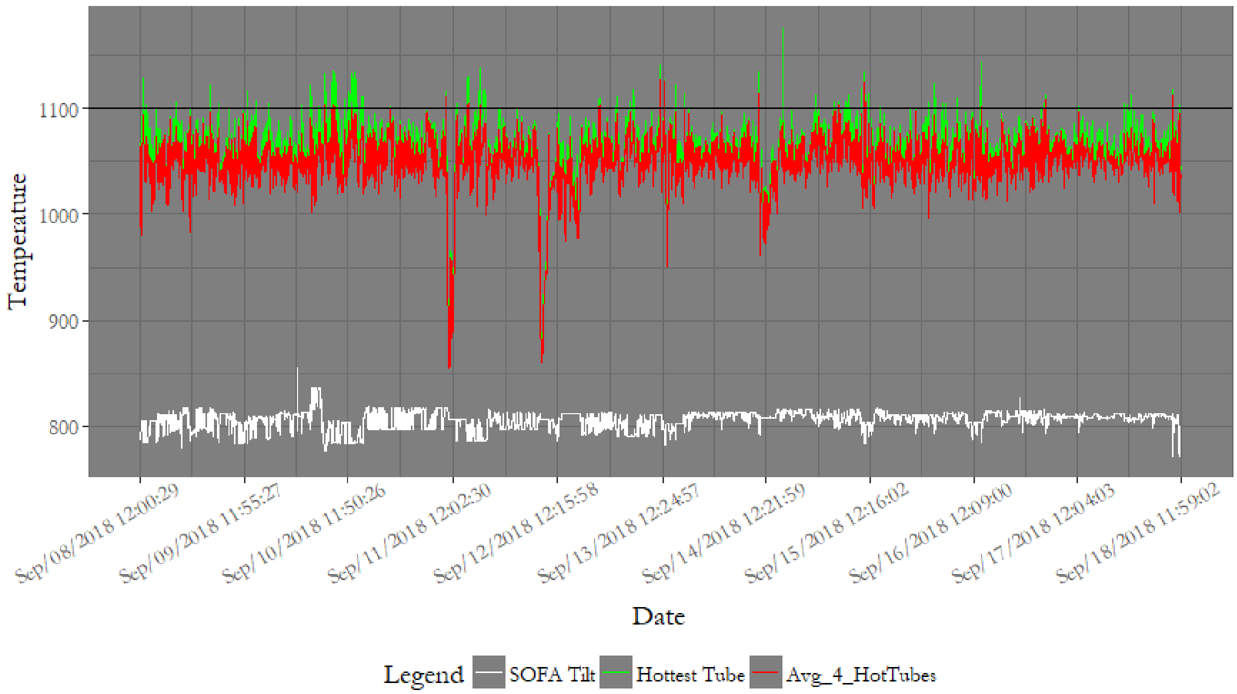

Figure 8: Tube temperature excursions and lower SOFA tilt behavior after SOFA tilt control

From the plots, it can be seen that the SOFA tilts are far more active since the controller has been put into place. As well, the number and severity of tube temperature excursions has been reduced. Each plot shown here represents a ten-day period. The number of temperature violations and the change caused by the SOFA tilt controller are summarized in Table 3.

Table 3: Summary of tube temperature violations and effect of SOFA tilt control

	Before Control	Active Control	Percent Change
Hottest Tube Violations	741	491	-33.7%
Average 4 Hottest Tube Violations	377	52	-86.2%

Closing Remarks

The Griffin system is continually evolving and improving, as evidenced by the results displayed within his plot. It is clear that the controls implemented within the system have had an effect on the operation of the unit. Both systems, the combustion optimization system (COS) and the knowledge-based sootblowing system (KSB) are currently active the majority of operating time, and function robustly.

Current evaluations show that NOx has been decreased across all load ranges an average of 13%. In addition to NOx benefits, tube temperatures are in greater control and the unit is experiencing significantly less alarms related to this. The sootblowing system has enabled better steam temperature control, and total sootblower activations have been significantly reduced. These metrics will continue to improve as models within the system continue to develop and more systems are integrated into automatic control (e.g. burner tilts, fan speeds, coal quality).