Innovation Description:

The Hopewell Cogeneration Facility (HCF) has always made a concerted effort to use our available resources to meet the needs of the community while trying to preserve the environment. This awareness of sustainable development principles has recently yielded a new startup procedure for our 3 Alstom GT11N gas turbines that not only reduces cost, but also significantly reduces our NO_x emission levels.

Prior to our innovation, the plant followed strict Original Equipment Manufacturer (OEM) procedures outlining the most efficient way to control NO_x produced by the gas turbines using its steam injection system. To begin, the first gas turbine must be started. Steam is produced by boiling water with heat recovered from this gas turbine using our Heat Recovery Steam Generators (HRSGs). All the steam is either released to atmosphere or bypassed until it achieves strict temperature and pressure limits; and once reached, is then piped from the HRSGs to the steam turbine. Here, some of it is diverted to the gas turbines to be used for NO_x control. Nitrous Oxide emissions produced by the gas turbine are controlled by 2 interconnected systems: the main NO_x steam injection system and each gas turbine's individual injection system. This dual layered process is designed to initiate automatic warm up of the individual injection system once the steam has reached 434°F at 255psig in the main NO_x steam injection system. Once the steam is at the necessary temperature, pressure, and the individual injection system has warmed up, steam is then released from the main NO_x system into the gas turbine by its individual injection system. Having done so, the NO_x emission level will immediately begin to fall below air permit limits. From start to finish this whole process usually takes about 60 minutes.

Simplistically stated, the gas turbines rely on steam produced by the HRSGs to control their emissions, and the HRSGs use heat from the gas turbines to produce the necessary steam. The problem arises from this circular relationship. The first gas turbine brought online must run unchecked for approximately 60 minutes until the steam required to regulate its emissions is produced. In the past, while following the proceeding OEM startup procedure, there would be an average of 600 lbs of NO_x produced during the start of the first gas turbine.

By watching the NO_x levels the Plant Engineer, Chuck Barnes, and a Technician, Mike Wargo, noted that one shift's startup emissions were significantly lower than the average on a consistent basis. When asked, the shift's Senior Operator, Joe Ennas[1], explained he was initiating warm up on the individual injection system prior to the automatic system operation. By taking manual control of the 2 steam injection systems he was warming both systems at the same time while the steam reached the necessary standards. Once this was achieved he returned the systems to automatic control and the steam was injected into the gas turbine. This resulted in the necessary steam injection parameters being reached faster, steam being injected into the gas turbine sooner, and a shorter period during which emission levels were uncontrolled. Mr. Barnes and Mr. Wargo formalized this new procedure and then distributed it to the other Senior Operators (i.e. Ken Blalock, Jeff Villines, Enrique Toro, and Chris Fegley) for their input and opinions. They streamlined the process into a more concise operation and sent their review back

to Mr. Barnes and Mr. Wargo for consolidation. Shortly thereafter the new NO_x Reduction Procedures began testing and Phase 1 of this experiment started.

After the team successfully demonstrated their NO_x Reduction Procedures, Mr. Wargo hypothesized that emissions could be further reduced if the gas turbines could be kept at a lower load until the main NO_x system was warmed and the individual injection system started. This line of questioning ended the first phase and ushered in Phase 2 of the experiment. Mr. Wargo's hypothesis was tested, proven to be true, and additional NO_x reduction procedures were written up by Mr. Fegley. Again, Mr. Toro, Mr. Villines, and Mr. Blalock lent their experience and expertise to the project and perfected the additional reduction procedure. Their input locked the most efficient reduced load rating in at 12MW until the steam injection system was ready.

The refinement continued through 2009. HCF was able to have the plant in compliance within an hour of startup as opposed to the three hours required by the manufacture. The procedure worked very well; however, there were some out of compliance issues. It seemed that it was more difficult to start one gas turbine over another. After accidence in January of 2010, Mr. Wargo went through each NOx skid to see what could be the problem. This could be considered the third phase. A very formal in depth Root Cause Analysis was launched. The results required that each NOx skid be recorded, analyzed, calibrated, and setup such that the valve sequencing would not trip the skid. In addition Mr. Wargo held training with all of the operators to be sure they understood the temperature – pressure relationship required by the NOx skid. Additional notes were added to the procedure to help the operation run even smoother. The work took about three months to complete. After 129 starts there have not been any accidences or problems.

NO_x Reductions:

Phase 1 of the reduction procedure was initiated in the summer of 2006. Emission data kept over the next year clearly shows a 5% reduction in NO_x levels. This translates to 16 tons less NO_x released into the atmosphere each year when compared to levels when the OEM procedure was used. Since then emission levels have continued to fall. On June 27th, 2008 Phase 2 was initiated and resulted in another significant drop in NO_x emission levels. Using the July 2008 value and the number of starts for our last contract year, 198, we have estimated the reduction in our NO_x emission to be about 40 tons, when compared to the original OEM startup procedures. The Phase 3 made the NOx skids more efficient. This translated into about 65 ton reduction based on a 200 start year.

Cost Reduction:

The current market price for 1 ton of NO_x varies with the annual rates vs the Ozone rates. The startup reduction is the same for both summer and winter and therefore it is more important that the reduction be as much as possible. If the average cost were about $1,000 a ton then there would be $65,000 in savings.

New NO_x Reduction Procedures:

1. **START** the preferred startup order is GT3, GT1, and then GT2. This is due to the inherent characteristics of the NOx emissions during initial firing of the units.

2. **AFTER** the first set of HP/LP steam header valves open at 1500 RPMs, and then place the NO_x bypass valve in "AUTO" to start warming up the main NO_x steam injection header and downstream individual NOx steam injection skids.

3. **WHEN** NO_x steam pressure is ≈150 PSI, shut the GT Blow-off Valves, and turn on the NO_x Function Group. *Note: 150 PSI of pressure and the blow off valves shut are permissive to turn on the function group, additionally, the conditional statement is the release criteria for the individual NOx steam injection control valve to be placed in AUTO. Control valve will not open until steam pressure is 250 PSIG and a temperature of 434 deg F.*

4. **AFTER** the GT is on the grid, select the load SP to manual twice.

5. **HOLD** the GT at about 12MW and observe the NO_x ppm on the CEMS computer analog channels page.

6. **ADJUST** the MW set point using increments ≤3MWs on the GT to maintain NO_x ppm <120. *Note; the NOx analyzer maximum range is 120 ppm.*

7. **TAKE** manual control of NO_x bypass valve (valve will be approximately 10% open) and keep NO_x steam pressure between 310 and 330 PSI to speed warm-up. *Note; This pressure should enable the NOx steam header to warm-up at the same rate as the HRSG HP/LP Steam Header.*

8. **WHEN** NO_x steam temp at the GT goes above 435° deg F., place NO_x bypass back in auto to lower pressure, or you can lower the pressure with the valve in manual but place it in auto as soon as GT NO_x comes on. *Note; NOx steam pressure NOP at the individual NOx steam injection skid is 255-300 PSIG.*

9. **WHEN** NO_x steam is flowing to the GT, raise MW up to 65MW. Keep NO_x attemperator isolation (Big Blue) closed until NO_x steam temperature reaches 500° to prevent tripping it off due to leakage past the attemperator control valve.

10. **BEFORE OPENING** the NOx attemperator isolation valve; place the NOx attemperator valve in MANUAL.

11. **WHEN** the isolation valve is open place the attemperator back in AUTO.

12. **WHEN** starting the second and third GTs hold their MW set points at 12MW or less while warming up the NO_x. Observe the NO_x ppm on the CEMS computer analog channels page, it should be <120ppm.

13. **ADJUST** the MW set point using increments ≤3MW on the GT to maintain NO_x ppm <120. *Note; The NOx analyzer maximum range is 120 ppm.*

14. **WHEN** NO_x steam injection is ON, raise the load to the MW set point.