NO_X EMISSIONS SOLUTIONS FOR GAS TURBINES

Kevin A. Carpenter
Siemens Westinghouse Power Corporation, 4400 Alafaya Trail, MC 250, Orlando, FL 32826-2399
E-mail: kevin.carpenter@siemens.com; Telephone: (407) 736-7335; Fax: (407) 736-5025

Summary

SELECTING THE OPTIMAL EMISSION CONTROL FOR GAS TURBINES

Site and unit specific conditions largely determine the optimal NO_x emissions solutions available for a particular gas turbine. The three primary approaches to achieving emission control on gas turbines are: 1) Gas turbine engine modifications to prevent NOx formation. 2) Addition of post combustion controls to remove NOx from the exhaust gas being released into the atmosphere; and 3) Application of a synergistic combination of methods (1) and (2).

Design Approaches

Water/Steam Injection

Water and steam injection have been known to provide a reduction of NO_x up to 60%, depending on the application. Water (or steam) injection can also be used to increase power.

Dry Low NOx (DLN) Burner Technology

Although generally not available for mature frames, DLN is employed primarily to control NOx emissions.

Fuel Conversion

Simply converting from oil firing operation to natural gas can reduce NOx emissions by up to 40%.

Wet Compression

In wet compression, water is injected into the inlet to increase power and it also may reduce NOx.

Post Combustion Control

Selective Catalytic Reduction (SCR) Technology

An SCR System consists of catalyst, a reactor, an ammonia injection grid (AIG), an ammonia storage and supply system, as well as instrumentation and control. In the SCR system, Ammonia is injected into the turbine exhaust gas, which then passes through the catalyst reactor where Nitrogen and Water are the products of the NO_x – Ammonia reaction.

UPGRADING GAS TURBINES WITH SCR TECHNOLOGY

Combined Cycle Gas Turbine Units

In general, combined cycle gas turbines are better candidates for SCR retrofits than simple cycle units. The main challenge in a combined cycle SCR retrofit is to find enough space to house the SCR reactor within the HRSG in the proper temperature regime. Since HRSG designs may be unique to each manufacturer, the retrofit must be considered on a case-by-case basis. The catalyst is usually located within an inner section of the HRSG, since this is where the ideal gas temperature window for SCR operation is found and the AIG is installed upstream of the catalyst. Locating the catalyst within the HRSG ensures good ammonia distribution enhanced by extra mixing around the boiler tubes.

Simple Cycle Gas Turbine Units

Depending on the exhaust temperatures, simple cycle gas turbines can be candidates for upgrading. The lower exhaust temperature of some mature frame gas turbines, which is usually well below 450°C (842°F) is within the operating capability of state-of-the-art SCR technology.

In a simple cycle gas turbine configuration, the SCR reactor is located immediately downstream of the gas turbine and requires an expansion from the gas turbine outlet exhaust duct to the SCR reactor. The ammonia reducing agent must be injected into the exhaust gas stream as homogeneously as possible to avoid unbalanced distribution of ammonia, which would result in increased slip downstream of the catalyst.

SYSTEMS APPROACH TO NOx COMPLIANCE:

With some areas of the country requiring NOx emissions as low single digit ppm NOx, a systems approach to NOx control is imperative. Although SCR systems are very capable of 95% reductions and even 99%

reductions in theory, when the efficiency of the SCR system is pushed beyond 80%, NO_x conversion is no longer stoichiometric. This non-stoichiometric condition leads to the following issues:

Increased Quantity of Catalyst Required = INCREASED COST
Increased Back-pressure = POWER LOSSES = LOST REVENUE
Increased Quantity of Reducing Agent Required = INCREASED COST
Increased Ammonia Slip = ENVIRONMENTAL COMPLIANCE ISSUE

For both simple cycle and combined cycle turbines, a system consisting of an SCR, integrated with an appropriate front-end engine modification or upgrade will achieve NOx emissions goals in the most cost-effective manner.

OPERATING EXPERIENCE

CASE 1-Example of Integrated Approach
Based on an actual Texas-based power plant.
Design Considerations:
Engine type: Gas Turbine rated at approximately 100 MW
Configuration: Combined Cycle
NOx inlet: 38 ppmvd
Available upgrades: Burner Modification (DF42)
Outlet NOx target: 4 ppmv
Ammonia slip limit: 10 ppmv
The HRSG was densely packed with tubes and there was no room inside the HRSG for the addition of catalyst. The only areas for catalyst were either at the front of the HRSG, which presented a high temperature limit problem for the catalyst and the rear of the HRSG, which presented a low temperature limit problem for the catalyst. The plant was providing process steam to an adjacent plant and could not afford to lose steam production

The solution was to upgrade the combustion system to achieve NOx emissions of 25 ppmvd at the turbine exhaust, which allowed for construction of a “smaller” SCR requiring the least amount of catalyst, also limiting back-pressure.

A low temperature SCR reactor with an expanded cross-section fanning out wider and taller than the HRSG was required. In combination with placement of AIG, the new cross section allowed for proper mixing of ammonia with exhaust gases without the use of flow modification devices which would increase back-pressure.

CASE 2-Example of Simple Cycle Plant Retrofitted with an SCR
Based on an actual Ohio-based simple cycle power plant.
Design Considerations:
Engine type: Gas Turbine, rated at approximately 20MW
Configuration: Simple Cycle
NOx inlet: 140 ppmvd
Available upgrades: None
Outlet NOx target: 9 ppmv
Ammonia slip limit: 10 ppmv
For this application, a high efficiency SCR was installed without the need for gas cooling. Initial testing indicated NOx emissions of 4ppmvd with 7ppmvd ammonia slip.

CONCLUSION
Owners of mature gas turbines are being required to reduce their NOx emissions dramatically while maintaining profitability. As described in this paper, an optimal approach has been demonstrated which simultaneously reduces NOx emissions below 10 ppm, holds ammonia slip below 10 ppm and mitigates deleterious power/steam output effects.