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Natural Gas Conversions of Existing Coal-Fired Boilers

Authors:
F.J. Binkiewicz Jr., P.E.
R.J. Kleisley
B.E. McMahon
J.E. Monacelli
D.A. Roth
D.K. Wong

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

B&W babcock & wilcox power generation group

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Abstract

Electric utilities are always searching for ways to minimize costs, improve availability and reduce emissions. Recent changes in the price of natural gas have made that fuel economically attractive, with the added benefit of reduced emissions of sulfur dioxide (SO_2), nitrogen oxides (NO_x) and carbon dioxide (CO_2). For those utilities with existing coal-fired units, conversion from coal firing to natural gas firing might be an option worth considering.

This paper will consider the rationale for fuel switching, some of the options available for conversion of coal-fired units, technical considerations related to conversion, and some of the financial considerations that will impact the final decision.

Rationale for Considering Fuel Switching

The first step in the process is to identify the forces that drive the decision to convert from coal to gas. The key forces are regulatory (both in terms of emissions and as an offset for a new unit), fuel costs, the age of the plant and the need for plant output.

Regulatory forces are currently in a state of flux, with a wide range of proposed rules and legislative efforts that could have a far-reaching impact on coal-fired operation. What appears likely is that some form of CO_2 controls will be enacted in the near future. Those controls could be part of a cap-and-trade system (similar to previous allowance programs for SO_2 and NO_X) or they might take the form of gradual reductions to meet increasingly stricter goals. Regardless of the final form, the industry is reasonably certain that there will be some additional controls placed on power plant owners. Utilities must also factor in the future need for electrical power generation – either because of market demand projections or to replace a unit that might be approaching the limit of its useful service. There also may be regulatory issues to evaluate, such as New Source Review and offsets for other emissions regulated by state and federal laws.

The price of natural gas has recently become more attractive as a baseload fuel due to additional supply and reduced demand from general industry. There are many different projections of where gas prices might be in the near future, all of which are based on the forces of supply and demand. The current price of natural gas is relatively low and stable compared to previous years. Utilities should be aware that natural gas prices are much more sensitive than coal prices to short term changes in supply and demand. While current economic conditions favor natural gas usage, Babcock & Wilcox Power Generation Group, Inc. (B&W PGG) strongly advises its customers to evaluate potential price volatility as a key component in the decision making process.

A plant may be considered for fuel switching based on its age and how close it would be to a possible retirement or major rebuild. The timing for fuel switching may be ideal if the boiler in question is already under consideration for major projects like superheater replacement, burner modifications, air system changes and/or the addition of back-end emissions control equipment. B&W PGG can assist in comparing the costs and benefits of different scenarios to help make the best decision based on the specific needs of the plant.

One of the other key factors to consider is the need for plant output, including a potential for de-rate and/or increased turn-down capability. A unit's continued usefulness might involve its ability to operate or be on standby during periods of low load.

As utilities look at their long-term forecasts, plants that operate efficiently and with high availability will play a key role in meeting future demand. As such, these plants will need to be evaluated for projects that will extend their useful life. Those projects might be targeted for efficiency improvements with coal as a fuel (burner upgrades, emissions control equipment, etc.) or as fuel-switch projects that take advantage of the benefits of natural gas.

Options

B&W PGG can perform an engineering study to help determine the best options for your specific application. Among the many options to consider are:

1. Fuel switch with modifications to the existing boiler
2. Fuel switch for the existing boiler and the addition of a gas turbine to the existing boiler cycle
   a. addition of simple cycle to the existing system
   b. hot windbox repowering
   c. combined cycle repowering
3. New combined cycle plant (elemental review) with retirement of the existing coal plant

Each option has advantages and disadvantages, including cost and operational considerations, including:

- comparison of modification costs vs. capital cost of a new gas turbine
- impact of future changes in fuel prices and the potential risk associated with natural gas price volatility
- life expectancy of gas turbines and heat recovery steam generators (HRSG) compared to steam boilers
- amount of acceptable de-rate

Since no two plants are identical, it is important that utilities work with an experienced supplier like B&W PGG to evaluate the best solutions for their needs.

1. Fuel Switch with Modifications to the Existing Boiler

The most obvious change to a power plant that switches from coal to gas will be the modifications to the fuel handling, storage and distribution equipment. The plant must receive natural gas via a pipeline spur from the local main transmission line. If a spur does not currently exist, the plant will need to evaluate the costs and activities (permits, land rights, etc.) associated with constructing a new spur. Once inside the plant perimeter, the gas must be metered and piped to the boilers, where new gas burners will be required (or to a new gas turbine if applicable).

If the existing boiler is modified for gas-firing, the convection pass, ducting and windbox will likely need modifications. The extent of the modifications will be determined by an engineering study that will look at overall furnace absorption, furnace exit gas temperature, and tube bank arrangement/material changes (superheater, reheater and economizer). Other operational changes like sootblowing schedules, attemperator spray flows, air heater operation and operation of any back-end emissions control equipment will need to be adjusted for the switch from coal to gas.

Technical Considerations

As B&W PGG studies your plant, we will evaluate the impact of the following technical considerations:

- characteristics of natural gas vs. original or current fuel
- impact on boiler design and capacity
- impact on cycle efficiency
- boiler and environmental equipment modifications
- burner modifications
- convection pass modifications
- changes to fans, ductwork, fluework, etc.
- amount of acceptable de-rate

Financial Considerations

Any modification to an existing plant carries considerable cost implications. This is true when upgrading a coal plant with new components for higher efficiency and/or lower emissions. Likewise, there are financial considerations for switching fuel from coal to natural gas. Cost ranges for modifications for the units shown in the comparison table below are estimated to be in the range of $50 to $75/kW.

The unique conditions of each plant will necessitate a detailed study of the potential operational options and their corresponding costs. These costs include only modifications to the boiler island. Excluded are costs related to bringing natural gas supply to the boiler.

2. Fuel Switch for the Existing Boiler with Addition of a Gas Turbine

Technical Considerations

The concept of repowering existing power plants is currently viewed as an option to economically meet new demands for improved efficiency, power growth and stricter environmental regulations. Partial repowering is the conversion of an existing site to combined cycle where the boiler and steam cycle are retained to the greatest extent possible. There are several major partial repowering alternatives. Many of these alternatives have multiple possible equipment configurations that can be considered depending on the option. Low gas turbine exhaust oxygen concentrations (as low as 12%), and high exhaust temperatures (exceeding 1100F) can provide design challenges depending on the combustion turbine used for this configuration.

2a. Addition of Simple Cycle to the Existing System

This technology uses the existing boiler and steam turbine equipment in essentially its original configuration. In

Comparison Table -- Study Results of Typical Pulverized Coal to Natural Gas Conversions

Location	Ohio	Ohio	Oklahoma
Existing Unit Information			
-- Year built	1954	1956	1981
-- Original megawatts	152	103	390
-- Operating pressure (PSI)	2,050	1,480	2,640
-- Main steam temperature (F)	1,050	1,000	1,005
-- Reheat outlet temperature (F)	1,000	1,000	1,005
-- Original fuel	Pulverized bituminous coal	Pulverized coal	Pulverized coal
Target Performance Basis	100% NG with no pressure part changes	Minimize pressure part changes	Maintain 1005F w/excess air up to 87% MCR
Results and Limitations	Original maximum continuous rating; MCR (no limitations)	Maximum resulting SH temp = 950F; and Higher excesss air for steam temperature control at lower loads	Cannot maintain steam temperature above 87% MCR without modifications; and Unable to fire 100% gas without pressure part modifications
Recommended Burner Modifications	Add gas elements	New low NO_X burners + OFA ports	New burners + NO_X ports
Recommended Pressure Part Modifications	Minimal to none required	Minimal to none required	Minimal to none required
Attemperator Recommendations	No changes required	No changes required	SH changes required
Fan Recommendations			
-- Forced draft	Appears OK, evaluation by others	No changes required	Static capacity deficient
-- Induced draft	Appears OK, evaluation by others	No changes required	No changes required
-- Gas recirculation	Replace FGR fan and drive	No recommendations made	Removed from service
Air Heater Recommendations	No changes required	No changes required	Design static pressure deficient

this design, a gas turbine and feedwater heater are added in parallel to the existing boiler. Figure 1 provides a bullet summary and illustrates a typical equipment arrangement for this option. Depending on the specific plant configuration, balance-of-plant (BOP) material and erection services are required to complete this retrofit.

2b. Hot Windbox Repowering

In this configuration, a gas turbine is added to an existing plant and the exhaust from the turbine is ducted directly to the boiler windbox where it is used as combustion air for the boiler. The existing air heaters are typically retired with new stack gas coolers (or partial HRSG) added in parallel to the feedwater heaters to maximize cycle efficiency. Figure 2 provides a bullet summary and illustrates a typical equipment configuration for this technology.

Depending on the specific plant configuration, significant boiler and BOP material and erection services are required to complete these retrofits. This has been the repowering configuration of choice outside of the U.S. with Holland having more than 12 plants designed in this configuration (both retrofit and original). B&W PGG designed two new plants based on this cycle configuration in the early 1960s. Recent improvements in gas turbine technology have made integration of these machines with boilers more challenging than in the past.

2c. Combined Cycle Repowering

In this configuration, a gas turbine is added to an existing plant and the exhaust from the turbine is ducted to the boiler windbox where it is used as combustion air for the boiler. This configuration uses a supplemental heat exchanger (or partial HRSG) or mixes ambient air upstream of the boiler to cool the exhaust temperature to levels acceptable to existing windbox materials. The existing air heaters are typically retired with new stack gas coolers (or partial HRSG) added

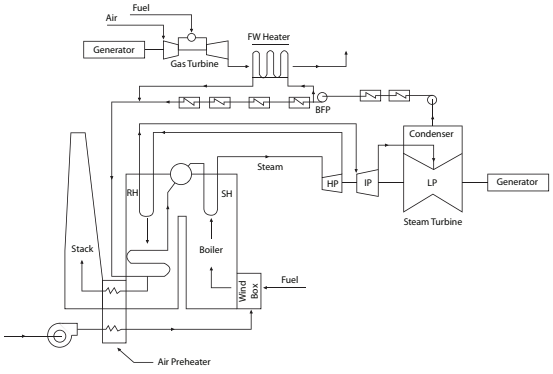

Fig. 1 Addition of Simple Cycle
- New gas turbine
- New recuperative feedwater heater(s)
- Retains steam system
  - » closes some extractions and feedwater heaters
- Advantages:
  - » low additional capital cost
- Disadvantages:
  - » small efficiency gain – 2% to 3%

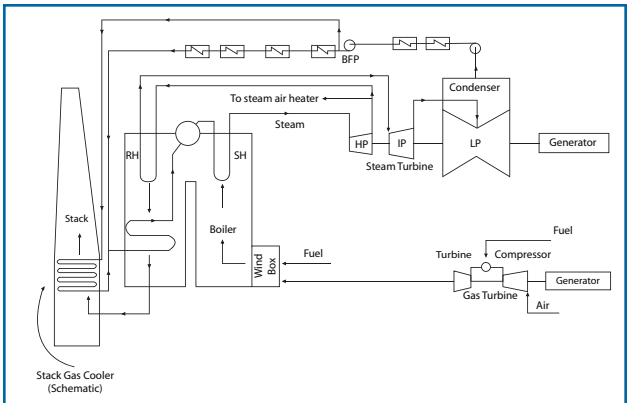

Fig. 2 Hot Windbox Repowering
- New gas turbine
- Retains boiler, steam turbine, generator, etc.
- Advantages:
  - » moderate power increase of up to 50%
  - » efficiency improvement of up to 15%
  - » retains current equipment and if desired, current fuel
  - » reduced emissions
- Disadvantages:
  - » requires new high temperature combustion air system
  - » may require boiler surface changes and/or de-rate
  - » requires special high temperature and low O_2 burners

in parallel to the feedwater heaters to maximize cycle efficiency.

Figure 3 provides a bullet summary and illustrates a typical equipment configuration for this technology. Depending on the specific plant configuration, significant boiler and BOP material and erection services are required to complete this retrofit.

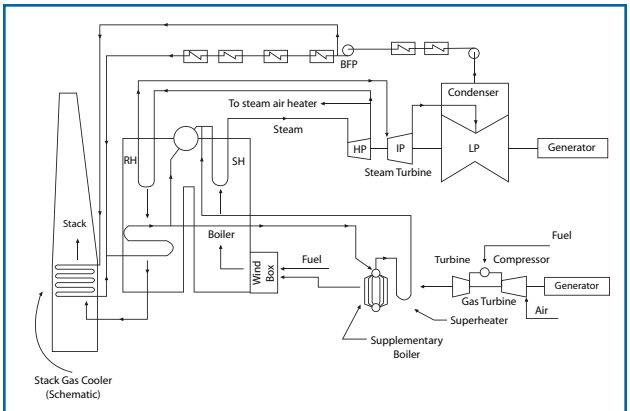

Fig. 3 Combined Cycle Repowering
- New gas turbine(s) and supplemental HRSGs or stack gas cooler
- Retains boiler, steam turbine, generator, etc.
- Advantages:
  - » moderate power increase of up to 70%
  - » efficiency improvement of up to 15%
  - » retains current equipment and if desired, current fuel
  - » reduced emissions
- Disadvantages:
  - » requires more complex steam system interface and piping systems
  - » may require boiler surface changes and/or de-rate
  - » requires special low O_2 burners

Financial Considerations

As the repowering configuration can vary significantly depending on the goals and constraints of a given system, cost for such a conversion can span a broad range. The combustion turbine will likely be the largest single component and cost. Estimates on retrofit costs range from $180 to $1,025 per unit kW increase in power.

3. New Combined Cycle Plant with Retirement of the Existing Coal Plant

A modern, highly efficient combined cycle plant is always a consideration when evaluating a fuel switch from coal to gas, especially when a considerable increase in power generation is needed. The higher capital cost of this option requires a careful analysis of its suitability to the unique needs of each utility.

This report is not intended to review every factor related to switching from coal to natural gas, but it is important for each prospective utility to consider the hidden costs associated with the retirement of a coal plant, including the cost of decommissioning or mothballing, as well as any site remediation costs. It is only when all the true costs are identified that the real savings from a fuel switch can be fully and properly evaluated.

Summary

Babcock & Wilcox Power Generation Group has the experience and expertise to help utility customers evaluate the operational, technical and financial considerations associated with a potential fuel switch from coal to natural gas. As plant owners consider their options, B&W PGG can assist in the evaluation of site-specific conditions and provide recommendations that represent the optimal balance of cost, schedule, performance and long-term availability.