IGCC pinch points

SYNGAS COMBUSTORS AND FEED AIR FOR THE AIR SEPARATION UNIT

I have been drawn to the concepts of IGCC and surrounding technologies lately. No surprise here, as "global warming" makes front page news almost every day now. IGCC stands for Integrated Gasification Combined Cycle, which is related to FutureGen, and there is some fascinating reading available to explain the concepts and to broaden understanding.

There is also more than a little "selling" going on, as well!

There are two important underlying issues that substantially affect plant design. The first is that syngas has only one-fourth the heat content of natural gas. It is a "low Btu fuel." And, as a hydrogen-rich fuel, syngas also exhibits high flame speeds, which limit the application of lean-premix combustor options. This necessitates some form of diluent addition to control emissions, adding to the increased "back-end" mass flow requirement.

I am a little conflicted on the combustor issue, so will leave it for others to explore, but these two syngas fuel characteristics do create a mass flow mismatch between the compressor and turbine sections of the existing gas turbines, and this topic does need some fresh air.

Air pressure requirement

The turbine OEMs don't really want to redesign their equipment for the obvious reasons that the requirements are still very unsettled and the market, if it materializes, is pretty far out there. The "work-around" is to bleed air off the gas turbine compressor to provide feed air for the Air Separation Unit (ASU), which conveniently reduces the air flow to the turbine and mitigates the added mass flow of the syngas and the diluent.

A critical design decision or trade-off is the so-called "degree of integration," which has been defined as the percent of Air Separation Unit (ASU) feed air that is provided by the compressor section of the main gas turbine.

A paper entitled "Gas Turbine Requirements for Integrated Gasification Combined Cycle (IGCC) Applications" was published at PowerGen International 2005. This is largely a combustor paper, but it states that, "Air extracted from the gas turbine cycle can also be used to supply all or a portion of compressed air needs of the air blown gasifier or air separation unit. This integration method reduces operating costs for process compressors, and can improve overall cycle efficiencies while providing gas turbine compressors margin to contend with increased fuel and diluent mass flow through the turbine."

A Massachusetts Institute of Technology study entitled "An Overview of Coal Based Integrated Gasification Combined Cycle," dated September 2005 states:

• By supplying a part or all of the ASU air from the gas turbine compressor outlet, less efficient compression in a separate compressor is reduced or avoided
• The point of maximum efficiency is found at 100% integration, based upon a much-referenced Foster Wheeler study
• It seems that the major effect which explains this is the compression energy saved by using a larger, more-efficient gas turbine compressor instead of a smaller, less-efficient ASU compressor

However, the report did state that an analysis of the effect of integration on efficiency was not included in the study, but, nonetheless, a conclusion was drawn that the current consensus seems to be that future IGCC plants should be built with partial air integration.

The report also included additional comments that seem more objective:

• Suggested gas turbine development improvements are compressor staging with intercooling
• The ASU process may also operate at elevated pressure such that the air fed to the ASU is at a pressure closer to that of the gas turbine compressor outlet
• Air integration may represent a solution to apply (existing) gas turbines, which would otherwise need redesign to work on syngas
• If the ASU is to be integrated with the gas turbine, a so-called elevated-pressure ASU has some benefits. It can use air compressed in the gas turbine (which is normally available at higher pressures than required by the ASU) more efficiently

Which is really my point. If the ASU operating pressure remains at 150 psig at a pressure ratio of 11.2:1, more or less, and the gas turbine pressure ratios remain at 18.5:1 for the GE 7FB, or 19.1:1 for the Siemens SGT6-5000F (W501F), then drawing feed air off the main gas turbine compressor, without the benefit of intercooling can't really be a good idea.

The numbers I have seen for the IGCC Reference Plant suggest a total feed air requirement of 230 lb/s for a power output of 400 MW; of which 272 MW is provided by the gas turbine. If all of this air were to be supplied by the main gas turbine at its rated compressor discharge pressure, the power consumption would be 71MW. If 50% of the ASU feed air were supplied by a 3-stage intercooled design, the power consumption would be 56 MW. If all the ASU feed air were supplied by separate compressors, the power consumption would be 42 MW.

About 60% of the 29 MW difference between 0% and 100% integration is due to the effect of compressing to the higher, but unnecessary pressure ratio of the gas turbine, and 40% is due to the effect of intercooling.

Two things can change this balance. The first is the development of cryogenic ASU systems that work at higher pressures, which might moderate the over compression penalty. Secondly, and most important, is the emergence of the high temperature and pressure membrane-based ASU that can substantially eliminate the ASU compression penalties and at which time the need for a dry low NO_X syngas combustor will have become more obvious *[1]*.

Footnote:

One of the better efforts is a National Energy Technology Laboratory (NETL) paper dated April 27, 2004, entitled "Integration of Gas Turbines Adapted for Syngas Fuel with Cryogenic and Membrane-Based Air Separation Units - Issues to Consider for System Studies." This paper has been published in the April 2006 issue of the Journal of Engineering for Gas Turbines and Power (Vol. 128, No. 2, pp. 271 - 280).

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