TITLE: MODEL PREDICTIVE CONTROL OF INTEGRATED GASIFICATION COMBINED CYCLE (IGCC) POWER PLANTS

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1. ABSTRACT

Program Introduction: Rationale and Objective

Integrated Gasification Combined Cycle (IGCC) plants represent one of the most promising options for processing fossil fuels, such as coal or heavy refinery residues, to meet future CO_2 trading and more stringent environment regulations for NO_x, SO_2 or mercury emissions. The primary objectives of this project are to understand how the process design of an IGCC power plant affects the dynamic operability and controllability of the process. A dynamic simulation model will be developed to predict the process behavior during startup and shutdown. Advanced control strategies will be developed to improve the ability of the coal gasifier to follow changes in the power load demand, and to improve performance during process startup and shutdown and transition between power levels. Another objective of the proposed work is to educate graduate and undergraduate students in the application of process systems and control to coal technology. Educational materials will be developed for use in engineering courses to further broaden this exposure to many students.

Accomplishments Achieved During the Current Period of Performance

During the current period of performance, March 2007 – April 2008, a dynamic model (using ASPEN DYNAMICS) for a heat-integrated double column air separation unit (ASU) was developed to investigate feasibility and applicability of constrained multivariable control algorithms. The preliminary "flow-driven" model was extended to a "pressure-driven" simulation model to provide a better understanding of equipment level constraints and to describe the pressure dynamics responsible for mass-flow fluctuations. The process variables exhibited a large amount of interaction, which is responsible for difficulties with commonly used PID (proportional-integral-derivative)-based control schemes. A model predictive control strategy that handles rate-of-change constraints imposed by the process design of the air separations unit was developed.

Preliminary work on model development of pressure-driven dynamic model for gas turbine/gas compressor was performed to analyze integration with the ASU. These models incorporate internal surge and stonewall prevention controllers.

Steady-state operability analysis of individual unit modules/subsections (gasification island, ASU, gas combustion/turbine, Claus sulfur removal, syngas cleaning) and the integrated flowsheet, including achievable operating space, steady-state singular value decomposition and relative gain array analyses has been conducted.

An educational module on the control of an Alstom (air-blown) gasifier has been developed for use in undergraduate process control courses. In addition, an educational module on the Claus Sulfur Unit, for use in an undergraduate material and energy balances course has been developed.

Plans for the Remaining Period of Performance

The work planned for the remaining period of this research program includes the following tasks:

- Continue with development of detailed individual unit modules in AspenDynamics. This involves the development of custom models for specialized units
- Integrate unit modules into integrated dynamic flowsheet and confirm consistency with steady-state flowsheet.
- Analyze dynamic models, including linearization of models in state-space and input-output forms.
- Develop model predictive control strategies for individual unit operations as well as integrated plant. This involves the design of specific steady-state operating points, incorporating robustness and finally comparing block decoupling and integrated designs. Linear MPC will be extended to multiple model predictive control (MMPC) and performances of the different strategies will be compared.
- Publish the outcome of these investigations.

2. LIST OF PUBLISHED JOURNAL ARTICLES, COMPLETED PRESENTATIONS AND STUDENTS RECEIVING SUPPORT FROM THE GRANT

Conference Presentations

- P. Mahapatra, and B. W. Bequette "Modeling and Control of Air Separations Unit for IGCC power plants," AIChE Annual Meeting, Salt Lake City, 2007.
- P. Mahapatra, and B. W. Bequette "Effect of Gas-Turbine ASU Integration in Dynamics and Control of IGCC power plants,"Annual International Pittsburgh Coal Conference, 2008 (submitted).

Students Supported Under this Grant

- Priyadarshi Mahapatra, graduate student in the Department of Chemical and Biological Engineering, Rensselaer Polytechnic Institute.
- Hollie Leister, undergraduate student in the Department of Chemical and Biological Engineering, Rensselaer Polytechnic Institute.
- Forrest Churchill, undergraduate student in the Department of Chemical and Biological Engineering, Rensselaer Polytechnic Institute.