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

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ABSTRACT

An IGCC plant is an assimilation of operating units or subsections which share characteristics such as tight energy integration, similar process objectives and/or time scales. These subsections closely interact among themselves through material and energy flows which in turn provide natural hierarchy for high level control structure design. As a first step, rigorous dynamic process models (in AspenPlus™and AspenDynamics™) were developed for individual sub-sections of the plant; important ones being – the Air Separations Unit (ASU), Gasification Island and the Gas Turbine/Compressor (GT) sections. The preliminary "flow-driven" model has been extended to a "pressure-driven" simulation model to provide a better understanding of equipment level constraints also able to describe the pressure dynamics responsible for mass-flow fluctuations. Initially, simple PID-based controllers were implemented for regulating lower-level inventory levels. Later, a multilayer control architecture, where a centralized supervisory layer, based on model predictive control (MPC), keeps track of overall plant performance while coordinating among various sub-sections was designed. This is compared with a semi-centralized design where each sub-section is controlled by localized MPC, passing setpoint information among each other; and a fully decentralized IMC based PID controller design where each control loop remains oblivious to the other's presence.

The double–column cryogenic ASU is given significant focus in this work due to large operating costs and dynamically slower process times. In addition, large material interactions with the gasifier and GT sections and condenser–reboiler heat integration within the system, makes this process both interesting and challenging to control. A rigorous study involving many possible steady-state design configurations within a single flow-sheet using optimization and sensitivity tools is presented. Different process flowsheets corresponding to IGCC and non-IGCC scenarios are studied and compared in terms of structural design, energy requirements and process controllability. A rigorous heat-exchanger design is incorporated into the model to study the effect of thermal lags and wrong-way (inverse response) temperature ef-

fects due to feed-effluent heat exchange. Further, a model predictive control strategy that handles rate-of-change constraints imposed by the process design of the air separation unit has been studied and compared with performance using decentralized classical PID schemes.