**146a The 'Value of Research' Methodology and Hybrid Power Plant Design**

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Policy-oriented problems are highly complex due to the multiplicity of conflicting objectives and the need to act with incomplete information that characterize many situations—combined with the computational and analytical demands of optimization [1]. This work is based on the utilization of optimization methods in policy analysis and research - in particular, on fuel cell hybrid power plants, which are designs that combine the fuel cell cycle with other thermodynamic cycles to provide higher efficiency. The power plant in focus is the High Pressure (HP)-Low Pressure (LP) Solid Oxide Fuel Cells (SOFC)/ Steam Turbine (ST)/ Gas Turbine (GT) [2] configuration which is a part of the FutureGen program - a new approach initiated by the U.S. Department of Energy's (DOE's) Office of Fossil Energy for developing 21st century energy plants that would have virtually no environmental impact. The overall goal is to effectively eliminate, at competitive costs, environmental concerns associated with the use of fossil fuels for producing electricity and transportation fuels [3]. In this design, coal is gasified in an entrained bed gasifier and the syngas produced is cleaned in a transport bed desulfurizer and passed over to cascaded SOFC modules (at two pressure levels). This module is integrated with a reheat GT cycle. The heat of the exhaust from the GT cycle is used to convert water to steam, which is eventually used in a steam bottoming cycle. There are multiple objectives: capital cost, CO2 and SO2 emissions, HP and LPSOFC current densities and overall efficiency to be optimized simultaneously. Since this hybrid technology is new and futuristic, the system level models used for predicting the fuel cells' performance and for other modules like the desulfurizer have significant uncertainties in them. Also, the performance curves of the SOFC would differ depending on the materials used for the anode, cathode and electrolyte. The accurate characterization and quantification of these uncertainties is crucial to the credibility of the model predictions. In a recent paper, we dealt with the characterization and quantification of uncertainties in the SOFC and the desulfurization modules for the SOFC/ST/GT hybrid power plant [4]. For the SOFC module, a two-level uncertainty analysis was performed, i.e. both material induced uncertainty and model uncertainty were considered. Next, the uncertainty in the pre-exponential factor and activation energy of the desulfurization reaction was characterized and quantified. The effect of uncertainties on the minimum capital cost design was examined and it was found that deterministic optimization under-predicted the capital cost value significantly emphasizing the fact that more research is needed in order to reduce these uncertainties. This work presents the policy aspect of hybrid fuel cell power plant design. It illustrates the concept of "Value of research" (VoR) which deals with the examination of trade-offs inherent in allocating scarce resources to reducing uncertainty [1]. A VoR framework is constructed through an augmented objective function based on weighted method. The trends for each objective based on uncertainty reduction are obtained. The average decision variable values are used to explain the reasons for these trends. The inferences derived from the trends are that: uncertainty in fuel cell materials have the most profound effect on the objectives, though not always negative. The capital cost was affected negatively while the SO2 emissions and overall efficiency were improved. The desulfurization reaction uncertainty had two components: frequency factor and activation energy uncertainties. Both affected the SO2 emission moderately, while the freq. factor uncertainty adversely affected the capital cost substantially. The fuel cell model uncertainty had the least impact on the objectives overall but it adversely affected the SO2 emissions moderately and impacted the overall efficiency positively. These trends give an idea to the decision maker about which uncertainties are important and where to leverage his resources for maximum impact.

Keywords: Policy oriented research, hybrid power plant, uncertainty, value of research, resource allocation, trade-offs

References:

1. Johnson, T.L.; Diwekar, U.M. Hanford Waste Blending and the Value of Research: Stochastic Optimization as a Policy Tool. Journal of Multi-Criteria Decision analysis. 2001, 10, 87-99. 2. National Energy Technology Laboratory (NETL). Vision 21 Concept Plants: Fuel Cell/Gas Turbine Configuration 1; U.S. Department of Energy: Morgantown, 1998 3. National Energy Technology Laboratory (NETL) Report to Congress FutureGen Integrated Hydrogen, Electric Power Production and Carbon Sequestration Research Initiative, March 2004 4. Subramanyan, K.; Diwekar, U. Characterization and quantification of uncertainty in solid oxide fuel cell hybrid power plants, Journal of Power Sources, 2005, 1-2, 103-116