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Flexible Operation of Polygeneration Energy Systems with Renewable Energy

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Abstract

The design and operation of energy systems, specifically those driven by chemical processes such as gasification and coal combustion have long been associated with theoretical modelling studies done within chemical engineering. However, with the rising need to face challenges brought upon by a warming climate and increased emissions from fossil fuel sources, there is significant interest in being able to design and operate systems that can harness the power of renewable energy sources while also providing economic benefits derived from operating them in a flexible manner. Mathematical modelling of such systems will therefore need to borrow concepts from chemical process engineering as well as power systems engineering and energy economics. The project currently being undertaken involves the mathematical modeling and optimization of a polygeneration-based energy system. Existing research in the area of modeling and optimization of systems behaving as a polygeneration plant, have primarily included the use of coal or biomass gasification to obtain syngas. With this key unit operation as the foundation, the energy systems have been designed in a manner in which they depend on the syngas produced to drive both the production of power as well as value added chemicals and liquid fuels. In this project, the key difference in the design is the inclusion of renewable energy sources, specifically intermittent sources of renewable energy such as wind and solar power. Additionally, aside from the syngas derived from gasification unit, power derived from other established pathways are also included, namely natural gas combined cycle process as well direct coal combustion processes. The main contribution from this project would be to look closely into the behavior of these energy pathways and investigate how and to what extent the energy system can be made more flexible while also taking into account that we seek to maximize profitability from the perspective of the operator. The flexibility of the polygeneration optimization framework can be obtained by reformulating it into a stochastic optimization problem. By doing so, the uncertainty and intermittency of renewable energy sources, domestic electrical and chemicals demand can be accounted for and accordingly, operational and design decisions can enhance the flexibility of the system based on intermittence/uncertain data assumptions. The integration of these intermittent sources into polygeneration mathematical framework requires some electrical engineering (i.e. power system mathematical modelling) background. The resultant polygeneration system is expected to act as a smart tool with which the interactions between chemical process plants and power plants (i.e. either

renewable or conventional) can be harmonized to obtain optimal temporal decisions (when to produce power or chemicals or when to store power) and strategic decisions (e.g. what chemical plant should we design and what would their capacity be). This project represents an intersection where process engineering and power systems concepts meet to better design and operate flexible polygeneration systems as we look to transition to future energy systems.

Biography / Biographies

Tuhin Poddar is a PhD candidate at the University of Waterloo, Ontario, Canada. He has previous obtained his Master's degree from the Khalifa University's Petroleum Institute and BSc from Purdue University, USA. His research interests lie in applications of mathematical modelling and simulation in energy systems.

Ali Elkamel is a Professor of Chemical Engineering. He holds a BSc in Chemical Engineering and BSc in Mathematics from Colorado School of Mines, MSc in Chemical Engineering from the University of Colorado-Boulder, and PhD in Chemical Engineering from Purdue University – West Lafayette, Indiana. His specific research interests are in computer-aided modelling, optimization and simulation with applications to energy production planning, carbon management, sustainable operations and product design. Professor Elkamel is currently focusing on research projects related to energy systems, integration of renewable energy in process operations and energy production systems, and the utilization of data analytics (Digitalization), machine learning, and Artificial Intelligence (AI) to improve process and enterprise-wide efficiency and profitability.
Prof. Elkamel supervised over 90 graduate students (of which 35 are PhDs) and more than 30 post-doctoral fellows/research associates. Among his accomplishments are the Research Excellence Award, the Excellence in Graduate Supervision Award, the Outstanding Faculty Award, the Best teacher award, and the IEOM (Industrial engineering and Operations Management) Outstanding Service and Distinguished Educator Award. He has more than 280 journal articles, 141 proceedings, and 33 book chapters. He is also a co-author of four books; two recent books were published by Wiley and entitled Planning of Refinery and Petrochemical Operations and Environmentally Conscious Fossil Energy Production.

Peter Douglas is the Associate Dean of Engineering (Undergraduate Studies) and a Professor of Chemical Engineering at the University of Waterloo. He was previously the Director of the University of Waterloo United Arab Emirates Campus in Dubai from 2009 to 2013, the Associate Dean of Engineering (Computing), and the Associate Dean of Engineering (Graduate Studies). Professor Douglas was a founding member of WISE the Waterloo Institute for Sustainable Energy at UWaterloo. His primary research area of interest is in the development and application of PSE technology to industrial processes including process modelling, simulation, control and optimization. He is currently working on simulation and optimization issues related to the mitigation and capture of carbon dioxide from large scale emitters. Professor Douglas has consulted on a world-wide basis for many clients and has worked in Canada, Australia, Malaysia, Thailand, the UAE. Additionally, he is a co-inventor of the Dryer Master online measurement and control systems for the food processing industry; such systems are finding widespread use in Canada, USA, Europe and Asia. In addition to his research work, Professor Douglas has co-authored more than 200 related research publications and has supervised more than 80 postgraduate students

Ali Almansoori is Professor of Chemical Engineering at Khalifa University in Abu Dhabi. During his profession, Dr. Almansoori held several administrative positions including: the Coordinator of President's Duties, Dean of Engineering, and Chair and Deputy Chair of the Chemical Engineering Department. He also was the Interim Senior Vice President for Academic Affairs during the merge between PI, Masdar Institute, and Khalifa University of Science, Technology, and Research. His main research interest is in the area of Process Systems Engineering with the focus on energy systems design, simulation, modelling and optimization. He also conducts general research in the area of renewable energy and fuel cell technology with applications to the oil and gas industry. He has published numerous articles in renowned refereed journals and conference proceedings. He also delivered several presentations in international conferences and is the author of a few book chapters. Furthermore, he serves as a reviewer for reputable international journals in the area of energy and process systems.