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Module Specification

University/Department: Technical University of Denmark, DTU
Module name: Fuel Cells Energy
Programme (Energy/ICT): Energy
[Existing example - DTU:
Technological specialization course, MSc. Eng., Advanced and Applied Chemistry
Technological specialization course, MSc. Eng., Chemical and Biochemical Engineering
Technological specialization course, MSc. Eng., Sustainable Energy]
ECTS: 6
Type Bachelor/Master : Master
Scope and form: Lectures, class discussions, homework
Duration (weeks; Hours/week): 15 weeks of lectures, labs and simulations.
Type of assessment: Evaluation of exercises/reports
Qualified Prerequisites: Basis course in fuel cells.

General module objectives:

Fossil fuels are depleting. Carbon dioxide is accumulating in the atmosphere. Global warming is accelerating at an increasing rate. These ever growing concerns stimulate worldwide research activities within technologies of high fuel efficiency, low air emissions, and renewable energy for the 21st century. Hydrogen and fuel cells are expected to play central roles in this context. The course presents a comprehensive and up-to-date understanding of the hydrogen energy and fuel cell technologies in order to provide (1) an introductory overview to students that are new in the field, (2) a detailed explanation and further understanding to those familiar with the subject, and (3) a discussion platform for the newest innovations and future improvements to those involved or to be involved in the development.

Topics and short description:
Hydrogen as an energy carrier, fundamentals of fuel cells, electrochemical principles, thermodynamics, ion conductors, catalysts and electrodes, types of fuel cells (proton exchange membrane fuel cell, alkaline fuel cell, phosphoric acid fuel cell, molten carbonate fuel cell, solid oxide fuel cell), hydrogen storage, metal hydrides, fuel processing, hydrogen production (reforming and electrolysis), system integration, balance of plant, applications. Optional lab tours will be arranged. If possible, build the system in whole or in part, in the laboratory and make measurements in order to examine the functionality of the system and to verify the set up models.

Learning outcomes:

Knowledge	Skills	Competences
About how to apply hydrogen as an energy carrier	To assess advantages and limitations of different techniques for hydrogen storage	To describe the mode of operation of a fuel cell as well as the function of the individual components
To present the most important techniques for production of hydrogen	To assess the differences in function and application of different types of fuel cells	To explain the shape of a polarization curve and calculate ohmic resistance and conversion efficiency on that background

Module recommended literature:

1. Textbook (T1): *Fuel Cell Systems Explained*, by J. Larminie and A. Dicks, Publisher: SAE International; 2nd edition (May 1, 2003), pp.406, ISBN-10: 0768012597, ISBN-13: 978-0768012590.
2. Textbook (T2): *Fuel Cells: Principles, Design, and Analysis*, by Shripad T. Revankar, Pradip Majumdar, May 28, 2014 by CRC Press, pp.748, ISBN 9781420089684 - CAT# 89684.
3. References (R1): *Handbook of Fuel Cells, Fundamentals, Technology& Applications*. Volumes 1-4, by W. Vielstich, A. Lamm and H. A. Gasteiger; Publisher: Wiley, Chichester, UK (2003).

Special Considerations: Generically none for this module but should be commented on by the institution delivering the module.