Electrified Hydrogen Systems – Challenges and Opportunities

Name(s) and Affiliation(s) of the Lecturer(s):

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Tutorial Objectives:

Decarbonization of major energy-consuming sectors is a top priority of the 2015 Paris Agreement and the Intergovernmental Panel on Climate Change (IPCC) climate change 2022 report. Perhaps the most promising strategy for addressing this challenge is the implementation of hydrogen production technologies. These are seen to be a solution for many sectors, including so-called hard-to-abate areas in which it can be used as a feedstock or directly as a fuel.

Hydrogen is the world's cleanest energy source, with around 80 million tons currently being produced annually. Furthermore, production is expected to exceed 200 million tons by 2030, and 500 million tons by 2050, according to the Net Zero Scenario.

In this context, power electronics is expected to play an important role in the electrification of hydrogen systems, where different converter solutions, integration schemes, along with power management strategies and control methods can be properly utilized to accelerate the current and future plans for both hydrogen production and utilization.

The goal of this tutorial is to explore the power electronics-related challenges and opportunities in these electrified hydrogen systems. Such a goal will be reached by covering the following topics in this tutorial:

- Power electronics role in future hydrogen powertrains, in which both hydrogen production through water electrolysis and utilization in trains and vessels will be discussed.

- Considering one of the relevant applications for hydrogen as a feedstock, E-refineries will be explored, where the challenges and future trends in this industry using islanded micro-/nano-grids facilitated by multi-active-bridge converters will be discussed.
- This will then be enriched with some discussions around the control of renewable energy-fed hydrogen-based energy systems for isolated and grid connected applications.
- Finally, the safety-related aspects of hydrogen systems in a power electronics lab environment will be covered.

Target Audience:

Power electronics researchers from academia and industry, electrolyzers and fuel cell suppliers, and system engineers.

Topical Outline:

Introduction:
(Estimated time: 15 minutes)

- Introduction to the tutorial and motivation for hydrogen

Theme 1: Power electronics in hydrogen production and utilization
(Estimated time: 45 minutes)

- Introduction to hydrogen economy
- Hydrogen powertrain and the need for power electronics
- Power electronics in water electrolysis systems
- Power electronics in fuel cell vessels and trains

Theme 2: Large water electrolysis systems: challenges and future trends
(Estimated time: 45 minutes)

- Introduction to sustainable production of fuels and chemicals
- Power electronics requirements in large electrical refineries with water electrolysis
- Multi-active-bridge (MAB) utilization in microgrids

Theme 3: Control of renewable energy-fed hydrogen-based energy systems
(Estimated time: 45 minutes)

- Introduction of background and control requirement of renewable energy-hydrogen systems
- Renewable energy-hydrogen based microgrid for sustainable Arctic communities
- Using hydrogen electrolyzer power electronics to balance high share of wind power

Theme 4: Hydrogen safety in a power electronics lab environment
(Estimated time: 30 minutes)

- Safety concerning hydrogen storage
- Safety around the fuel cell module
- Safety aspects while running tests

Provisional Schedule of the Tutorial:

Schedule:

08:30 - 10:15 : Introduction / Theme 1 / Theme 2
10:15 - 10:30 : Coffee break
10:30 - 12:00 : Theme 3 / Theme 4 / Q&A

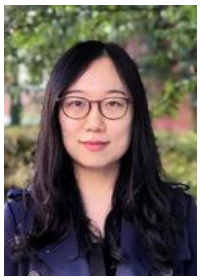
About the Lecturers:

Dr. Ahmed Abdelhakim (Senior Member, IEEE) was born in Egypt on April 1, 1990. He received the B.Sc. (Hons.) and M.Sc. (Hons.) degrees in electrical engineering from Alexandria University, Alexandria, Egypt, in 2011 and 2013, respectively, and the Ph.D. degree from the University of Padova, Padova, Italy, in 2019.
Since August 2018, he has been with ABB Research Sweden, Västerås, Sweden, where he held several roles and has been a Principal Scientist and R&D Project Manager since February 2022. In 2017, he was with the Department of Energy Technology, Aalborg University, Aalborg, Denmark, as a Visiting Scholar for ten months, where he was working on several research activities. From 2011 to 2014, he was a Demonstrator and then a Lecturer Assistant with Alexandria University. His research interests include power electronics converters and their applications for energy storage and hydrogen systems, investigation of new power converter topologies, and application of wide-bandgap semiconductor devices for high-frequency and high-power density power converters.
Dr. Abdelhakim has received the first classified excellent Ph.D. Dissertation Award from the Societa Italiana di Electronica among Italian universities in 2019. He is an Associate Editor for IEEE TRANSACTIONS ON INDUSTRIAL ELECTRONICS and IEEE TRANSACTIONS ON TRANSPORTATION ELECTRIFICATION.

Prof. Thiago Batista Soeiro (Senior Member, IEEE) received the B.Sc. (Hons.) and M.Sc. degrees in electrical engineering from the Federal University of Santa Catarina, Florianopolis, Brazil, in 2004 and 2007, respectively, and the Ph.D. degree from the Swiss Federal Institute of Technology, Zurich, Switzerland, in 2012. During the Master and Ph.D. studies, he was a Visiting Scholar at the Power Electronics and Energy Research Group, Concordia University, Montreal, QC, Canada, and at the Center for Power Electronics Systems, Blacksburg, VA, USA, respectively. From 2012 to 2013, he was a Researcher at the Power Electronics Institute, Federal University of Santa Catarina. From October 2013 to April 2018, he worked at the Corporate Research Center, ABB Switzerland Ltd., Baden-Dattwil, Switzerland, where he was a Senior Scientist. From May 2018 to January 2022, he worked at the DC Systems, Energy Conversion and Storage Group, Delft University of Technology, Delft, The Netherlands, where he was an Associate Professor. From January to

October 2022, he worked at the Power Management and Distribution Section (TEC-EPM) for the European Space Research and Technology Centre, Noordwijk, the Netherlands. Since October 2022 he became a full professor for power electronics at the Power Electronics and EMC group of the University of Twente, Enschede, The Netherlands. His research interests include advanced high power converters and DC system integration.

Prof. Dr. Soeiro was a recipient of the 2013 IEEE Industrial Electronics Society Best Conference Paper Award and the Best Paper Awards in the following IEEE conferences: International Conference on Power Electronics (ECCE Asia 2011), the International Conference on Industrial Technology (ICIT 2013), the Conference on Power Electronics and Applications EPE'15 (ECCE Europe 2015), and the International Conference on Power Electronics and Motion Control 2020 and 2022 (PEMC 2020 and 2022).



Assist. Prof. Qianwen Xu is Assistant Professor in Department of Electric Power and Energy Systems, KTH Royal Institute of Technology, Sweden. She is also the director of Intelligent Sustainable Grid (ISG) Lab @ KTH. Previously, she received the B.Sc. degree from Tianjin University, China, in 2014, and PhD degree from Nanyang Technological University, Singapore, in 2018, both in electrical engineering. Then she worked as a postdoc research fellow in Aalborg University in Denmark, a visiting researcher with Imperial College London, and a Wallenberg-NTU Presidential Postdoc Fellow in Nanyang Technological University in Singapore in 2018-2020.

Her research interests include advanced control, optimization and artificial intelligence application of sustainable power systems, microgrids and power converter systems. As the principal investigator, she has received research funding from Swedish Research Council (incl. VR Starting Grant), Swedish Energy Agency (incl. Future Electricity System program, Wind program, Building program E2B2), Sweden's Innovation Agency (Vinnova), STINT, C3.ai Digital Transformation Institute (C3.ai and Microsoft), ERA-NET, Digital Futures, StandUP for Energy, etc. She has published over 50 technical papers, with 15 first-authored journal papers in top IEEE Transactions. She is Vice Chair in IEEE Power and Energy Society & Power Electronics Society, Sweden, and an Associate Editor for IEEE Transactions on Smart Grid and IEEE Journal of Emerging and Selected Topics in Power Electronics. She is recipient of Humboldt Research Fellowship, Excellent Doctorate Research Work in Nanyang Technological University, Best paper award in IEEE PEDG 2020, etc. She is the winner of Nordic Energy Challenge 2022.

Dr. Sjoerd G. Bosga was born in 's-Hertogenbosch, Netherlands, in 1969. He received the M.Sc. and Ph.D. degrees in Electrical Engineering from Eindhoven University of Technology in 1993 resp. 1997. Since then he has been employed at ABB Corporate Research in Västerås, Sweden, where he currently holds the position of Principal Scientist. Since 2017 he is an affiliated faculty at the Division of Electric Power and Energy Systems, KTH Royal Institute of Technology, Stockholm, Sweden. His current research

interests include electric machines, power electronics, fuel cells and electrolyzers, control algorithms and their interaction for electric powertrains. Dr. Bosga is also the chairman of the EPE International Scientific Committee and Program Chair of the EPE Conference.