Tutorial Proposal

1. Tutorial Title

Artificial Intelligence for Next Generation Power Electronics – Challenges, Principles and Applications

2. Instructor Team: name(s), affiliation(s), and contact information

Huai Wang, Professor, AAU Energy, Denmark. Contact: hwa@energy.aau.dk

Subham Sahoo, Assistant Professor, AAU Energy, Denmark. Contact: sssa@energy.aau.dk

Shuai Zhao, Postdoc, AAU Energy, Denmark. Contact: szh@energy.aau.dk

3. Abstract (No more than 500 words. Accepted abstract will be published through the conference website, program, and proceedings.)

Artificial intelligence (AI) has been applied to control and condition monitoring of power electronic systems (PES) since the 1990s in the literature, including signal acquisition, stability assessment, fault detection, diagnostics, prognostics, etc. Due to the limitations on computation unit, data availability, and AI tools capability, the AI-based solutions are not quite competitive as expected and their implementations in the industry field are rare. Currently, these facts have drastically changed, considering that state-of-the-art AI tools like deep learning have been revolutionizing industrial areas such as computer vision and natural language processing. It is believed that these AI tools will deliver the overarching merits to power electronics as well since the PES are developing toward data-rich systems with the increasing awareness of data collection. Combining with the rapid development of computational platforms, they are forming solid foundations to tackle existing challenges in the field operation and accelerate industrial deployments. As a result, it is time to prepare for the paradigm shift to AI-assisted solutions, which will unleash the potentials of cutting-edge AI tools for control and condition monitoring in power electronics on various implementation levels.

The objective of this tutorial is to provide an overview of the latest development of AI-assisted condition monitoring on PES. As a synergy research field integrating data science and power electronics, this tutorial will firstly discuss three relevant aspects including the concepts, case studies, and outlooks. It starts with a systematic flowchart of data-driven condition monitoring for PES. Compared to other data-driven fields, the observations from these case studies and other latest research will be discussed. The specific features and requirements of PES when applying AI tools will be summarized. The second part of this tutorial will present the outlooks on the tailored AI techniques for condition monitoring of PES, e.g., data-light AI, computation-light AI, explainable AI, physics-informed AI. The open-access resources, identified challenges, and emerging opportunities in this field will be provided as well. Finally, the tutorial will sum up the faster growing challenges on control and uncertainties in power electronics. It will provide a basic summary of how the implementation of AI algorithms becomes a challenge for low end microprocessors and some easily deployable solutions to enhance data-driven controllability. It will also describe how the performances of the AI tools can be explained using an explainable machine learning framework for grid-tied inverters and identify qualitative data. In addition, the applicability of physics informed AI tools will be explained to delimit the amount of data for light data-driven control applications.

4. Tutorial Outline (Outline shall only define the topics and subtopics. No detailed descriptions please. Time allocation and instructor breakdown by topics is recommended.)

Overview of artificial intelligence in power electronics and emerging topics (60 minutes) – Huai Wang

- The synergy of AI and power electronics: a statistical point of view

- Essential AI tools in typical power electronic applications
- State-of-the-art example: data-driven early precursor discovery for battery
- Emerging topics of AI in power electronics

Coffee break (15 minutes)

AI-assisted condition monitoring and health assessment in power electronic systems (60 minutes) – Shuai Zhao

- Background and challenges in condition monitoring for power electronic systems
- Digital twin-based condition monitoring concept and implementation
- Physics-informed machine learning for parameter estimation of buck converter
- Outlooks and future work in condition monitoring for power electronics systems

Coffee break (15 minutes)

AI-assisted control and uncertainty quantification in power electronic converters (60 minutes) – Subham Sahoo

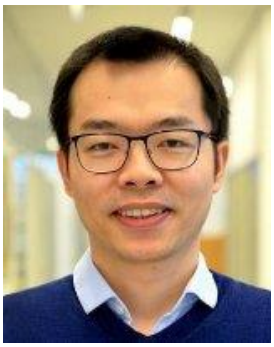
- Background and challenges in using existing AI techniques for control of power electronic converters
- Quantifying the uncertainty present in the training data via explainable AI for grid tied inverters
- Physics-informed neural network for control of grid-forming converter
- Physics-informed spline network for strengthening cybersecurity defense in grid-tied converter
- Outlooks and future work in control for power electronics

Final Q & A and wrap up (15 minutes)

5. Lecture Style and Requirements (Briefly describe the tutorial format, which may include traditional lecture, software/hardware demonstration, interactive audience polls/quizzes, worksheets, discussion, etc. Note any equipment or space requirements beyond a laptop and projector. Also list the targeted audience and tutorial difficulty level, including any pre-requisite knowledge.)

The tutorial is intended for intermediate and advanced audiences in the field of power electronics and power electronics-based power systems, who are looking for data-driven solutions to address the underlying challenges. Potential attendees are ranging from researchers who expect to get clicked to start this interdisciplinary research, to advanced ones who expect to be informed with the cutting-edge knowledge and frontiers in this field. Researchers and engineers who seek for the basic knowledge for the reliability engineering, health monitoring and control in power electronics converters are also welcomed. Prerequisite is basic power electronics and linear algebra fundamental theory.

6. Instructor Biography (No more than 200 words for each person. Each biography shall include the qualifications most relevant to the proposal. Past tutorial/teaching experience and outcome can be highlighted. External website link can be included but may not be reviewed.)



Huai Wang received BE degree in electrical engineering from Huazhong University of Science and Technology, Wuhan, China, in 2007 and Ph.D. degree in power electronics, from the City University of Hong Kong, Hong Kong, in 2012. He is currently Professor with the Center of Reliable Power Electronics (CORPE), Department of Energy Technology at Aalborg University, Denmark. He was a Visiting Scientist with the ETH Zurich, Switzerland, from Aug. to Sep. 2014, and with the Massachusetts Institute of Technology (MIT), USA, from Sep. to Nov. 2013. He was with the ABB Corporate Research Center, Switzerland, in 2009. His research addresses the fundamental challenges in modeling and validating power electronic component failure mechanisms and application issues in system-level predictability, condition monitoring, circuit architecture, and robustness design. He leads a project on Light-AI for Cognitive Power Electronics. Dr. Wang received the Richard M. Bass Outstanding Young Power Electronics Engineer Award from the IEEE Power Electronics Society in 2016, and the Green Talents Award from the German Federal Ministry of Education and Research in 2014. He is currently the Chair of the IEEE PELS/IAS/IES Chapter in Denmark. He serves as an Associate Editor of IEEE Journal of Emerging and Selected Topics in Power Electronics and IEEE Transactions on Power Electronics.

Subham Sahoo received his Ph.D. degree in Electrical Engineering at Indian Institute of Technology (IIT), Delhi, New Delhi, India in 2018. After the completion of his PhD, he worked as a postdoctoral researcher in the Department of Electrical and Computer Engineering in National University of Singapore during 2018-19 and in Aalborg University (AAU), Denmark during 2019-2020. He is currently an Assistant Professor in the Department of Energy, AAU, Denmark.

He is a recipient of the Indian National Academy of Engineering (INAE) Innovative Students Project Award for the best PhD thesis across all the institutes in India for the year 2019. He was also a distinguished reviewer for IEEE Transactions on Smart Grid in the year 2020. He is an active contributor and chairs the cybersecurity working group in the IEEE PELS Technical Committee (TC 10) on Design Methodologies. He has delivered 2 tutorials in IEEE APEC 2020 and IEEE IECON 2020. He has also organized the first Industrial/PhD course on Cybersecurity for power electronic systems in AAU in the year 2020.

His research interests are control, optimization, cybersecurity and stability of power electronic dominated grids, physics-informed machine learning tools for power electronic systems.

Shuai Zhao received the BE (Hons), ME, and Ph.D. degrees in information and communication engineering from Northwestern Polytechnical University, Xi'an, China, in 2011, 2014, and 2018, respectively. He is currently a postdoctoral researcher with the Center of Reliable Power Electronics (CORPE), Department of Energy Technology, Aalborg University, Denmark. From Sep. 2014 to Sep. 2016, he was a visiting Ph.D. student with the Department of Mechanical and Industrial Engineering at the University of Toronto, Toronto, ON, Canada, with a scholarship from China Scholarship Council (CSC). In Aug. 2018, he was a visiting scholar with the Power Electronics and Drives Laboratory, Department of Electrical and Computer Science at the University of Texas at Dallas, Richardson, TX, USA. His research interests include system informatics, intelligent condition monitoring, diagnostics & prognostics, and tailored AI tools for power electronic systems.