Advanced control of industrial medium-voltage multi-phase wind power conversion systems

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

Ioannis Tsoumas
ABB Medium Voltage Drives
Austrasse, 5300
Untersiggenthal, Switzerland
ioannis.tsoumas@ch.abb.com
+41 79 5757827

Orcun Karaca
ABB Corporate Research
Segelhofstrasse 1K, 5405
Baden-Dättwil, Switzerland
orcun.karaca@ch.abb.com
+41 78 8230033

Tinus Dorfling
ABB Corporate Research
Segelhofstrasse 1K, 5405
Baden-Dättwil, Switzerland
martinus-david.dorfling@ch.abb.com
+41 79 8284723

Tutorial Objectives:

Multi-phase medium-voltage generators are increasingly employed in offshore wind parks in order to maximize the generated power per wind turbine and thus minimize the cost per MW of installed power. A characteristic example is the Dogger Bank wind farm, an offshore wind farm being developed at the Northeast coast of England. It will become the world's largest offshore wind farm with an installed capacity of 3.6 GW. Multi-phase medium-voltage generators with a rated power of 13–14 MW will be installed within the frame of the project. Often in such medium-voltage systems, a back-to-back converter configuration is used. One converter system is connected to the multi-phase generator and delivers power to the converter dc-link(s), whereas a second converter system delivers the power to grid via a multi-phase transformer. Control of these systems is more complicated than their conventional low voltage three-phase counterparts due to the low device switching frequencies.

This tutorial is intended to be a brief course on classical as well as on recently developed and deployed advanced control techniques for industrial medium-voltage multi-phase power conversion systems. The tutorial will focus on three closely related core topics, which are of major interest: generator-side control, grid-side control, and system related aspects. Regarding the generator and grid-side control topics, the attendees will get a strong grasp on control design requirements, traditional control techniques, and more recently developed model predictive control and optimization-based solutions in this area. Emphasis will be put on the requirements that need to be fulfilled in real industrial applications and the challenges related to them. In this regard, the shortcomings of state-of-the-art industrial control approaches and the benefits of the advanced ones will be assessed. Moreover, several important system-related aspects will be covered. In particular, the harmonic transfer mechanisms from the generator to the grid side will be analyzed. Characteristic examples of advanced control and modulation concepts for the suppression of the related harmonics are going to be presented. Furthermore, the topic of control stability at resonant

grids is going to be briefly covered.

Target Audience:

The tutorial targets a broad audience from the academia and the industry, including graduate students looking for a new active area of industrial research; control practitioners interested in novel control techniques and applications; and researchers in control and power electronics. The workshop audience is not expected have any advanced background in control theory or power electronics. A basic knowledge of control systems as well as power electronics and electrical machines is helpful but not a prerequisite.

Topical Outline:

Theme I: Control of medium-voltage generator-side converters (Estimated time: 150 min)

- Motivation for medium-voltage multi-phase generators in wind power conversion systems
- Modelling of medium-voltage multi-phase electrical machines
- Generator-side converter modulation and control fundamentals
- Shortcomings of classical control approaches
- Advanced flux and torque control approaches

Theme II: Control of medium-voltage grid-side converters (Estimated time: 120 min)

- Introduction to grid-connected conversion systems and their objectives
- System modelling fundamentals for grid-side converters
- Converter modulation techniques and classical grid-side control methods
- Grid-side requirements, objectives, and the shortcomings of classical control approaches
- Advanced current control approaches: Current-based model predictive pulse pattern control
- Open topics and ongoing research on advanced control on the grid-side: From robustness to weak grid operation

Theme III: System related aspects for power conversion control (Estimated time: 90 minutes)

- Grid-side harmonics due to generator-converter-induced dc-link ripple harmonics
- Grid-side harmonics due to back-EMF-induced dc-link ripple harmonics
- Grid-side performance against grid resonances
- Conclusion

Provisional Schedule of the Tutorial:

09:30 - 10:45 : Theme 1, Subject 1-3
10:45 - 11:15 : Coffee break
11:15 - 12:30 : Theme 1, Subject 3-5
12:30 - 13:30 : Lunch break
13:30 - 15:30 : Theme 2
15:30 - 16:00 : Coffee break
16:00 - 17:30 : Theme 3

About the Lecturers:

Ioannis P. Tsoumas received the Dipl.-Eng. and Dr.-Eng. degrees in electrical and computer engineering from the University of Patras, Greece, in 2000 and 2007 respectively. From 2008 to 2015 he was an

R&D engineer in the field of low voltage high power motor drive systems technology at Siemens AG, Nuremberg, Germany. From 2015 to 2019 he was with ABB Corporate Research in Baden-Dättwil, Switzerland. In 2019 he joined the ABB System Drives in Turgi, Switzerland, where he is currently a Principal R&D Engineer. His work focuses on control and modulation concepts as well as on system-oriented optimization of medium voltage power electronic converters for offshore wind energy applications. Dr. Tsoumas has more than 50 publications in international scientific journals and conferences and holds several international patents in the field of electric drive systems. He has been an IEEE Senior Member since 2017.

Orcun Karaca received the B.Sc. degree in electrical engineering from Bogazici University, Turkey, in 2014, and the M.Sc. degree in electrical engineering from ETH Zürich, Switzerland, in 2016. He obtained his Ph.D. degree at the Automatic Control Laboratory (IfA), ETH Zürich, in 2020. His PhD work was focused on developing optimization methods for power systems and electricity market coordination, and on designing controllers for large-scale networked systems. He collaborated on methods for nonconvex optimization problems, more recently, with applications to optimized pulse patterns. Since 2021, Dr. Karaca is a scientist at the ABB Corporate Research in Baden-Dättwil, Switzerland, where his research is on developing control methods and modulation techniques for medium-voltage power converters. He has published his research in top control and optimization journals. He was also the recipient of the Swiss National Science Foundation Mobility Award in 2020.

Tinus Dorfling received the B.Eng. degree in electrical and electronic engineering and the M.Eng. and Ph.D. degrees in electrical engineering from the University of Stellenbosch, South Africa, in 2015, 2018, and 2021, respectively. His Ph.D. focused on combining model predictive control and optimized pulse patterns to form a generalized model predictive pulse pattern controller that is appliable to high-order systems. In 2021, he joined ABB Corporate Research Centre, Baden-Dättwil, Switzerland, as a Scientist. Since then, he has been working on developing advanced grid-connected control methods for medium-voltage wind farms and calculating state-of-the-art optimized pulse patterns for industrial drives. His interests include modulation and control techniques for medium-voltage converter systems, with specific interests in optimized pulse patterns, model predictive control, and the implementation of control algorithms on FPGAs.