EPE'23 ECCE Europe – Call for Tutorials

Grid-Forming Converters: Principles and Practices

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

Xiongfei Wang
KTH Royal Institute of Technology
Teknikringen 33
Stockholm, Sweden
xiongfei@kth.se
+46721486344

Heng Wu
Aalborg University
Pontoppidanstraede 111
Aalborg East, Denmark
hew@energy.aau.dk
+4593562219

Fangzhou Zhao
Aalborg University
Pontoppidanstraede 111
Aalborg East, Denmark
fzha@energy.aau.dk
+4550223559

Bo Fan
Aalborg University
Pontoppidanstraede 111
Aalborg East, Denmark
bof@energy.aau.dk
+4581913105

Teng Liu
China Southern Power Grid
No. 11 Kexiang Road
Guangzhou, China
tengliu1104@gmail.com
+86 136 5925 8297

Tutorial Objectives:

The grid-forming (GFM) technology is emerging as a promising approach for massive integration of inverter-based resources (IBRs) into electrical grids. Being controlled as a voltage source behind an impedance, GFM-IBRs can provide adequate services to enhance the reliability and resilience of the power network, and they also feature higher stability robustness against grid strength variation than conventional IBRs. In recent years, there is a growing consensus on the need of GFM-IBRs in the future power electronic dominated power systems. Many research and development (R&D) efforts have been initiated, by governments, power system operators, energy developers, and vendors of IBRS, on the technical specifications/grid codes, hardware and control solutions for GFM-IBRs.

This tutorial intends to cover both the basics and advances in GFM-IBRs that can fit the requirements of the evolving technical specifications/grid codes. The tutorial will start with the basic principles and typical control architectures of GFM-IBRs, which will be followed by the small-signal modeling, stability analysis, and damping control to guarantee the small-signal stability of GFM-IBRs under various grid strengths. Then, the dynamics analysis of GFM-IBRs under large grid disturbances, e.g., grid faults and phase jumps, will be performed, covering the transient stability analysis, current limitation strategies, as well as anti-islanding detection methods. In the end, perspectives on the prospects and challenges with the grid integration of GFM-IBRs will be shared.

Target Audience:

This tutorial will be beneficial for graduate students, researchers and practicing engineers, who are interested in GFM-IBRs and their integration into future power electronic dominated power systems.

Topical Outline:

1. **Basics of GFM-IBRs (Xiongfei Wang, 30 minutes)**
   1.1 Basic principle (10 min.)
   1.2 Control methods for GFM-IBRs (20 min.)

2. **Grid code requirements and technical specifications (Xiongfei Wang: 30 minutes)**
   2.1 General requirements from power system operators (5 min.)
   2.2 Recent updates on grid codes and technical specifications (15 min.)
   2.3 Challenges with grid-code compliance (10 min.)

3. **Small-signal stability and control of GFM-IBRs (Fangzhou Zhao and Heng Wu: 120 minutes)**
   3.1 Small-signal dynamics and control interaction analysis (Fangzhou Zhao: 30 min.)
   3.2 Advanced GFM controls with robust small-signal stability (Fangzhou Zhao: 60 min.)
   3.3 Consideration of small-signal dynamics under the current limitation mode (Heng Wu: 30 min.)

4. **Large-signal stability and control of GFM-IBRs under grid faults (Teng Liu, Bo Fan and Heng Wu: 150 minutes)**
   4.1 Transient stability analysis of GFM-IBRs without current limitation triggered (Heng Wu and Teng Liu: 60 min.)
   4.2 Current-limiting control of GFM-IBRs and its transient stability impact (Bo Fan: 50 min.)
   4.3 Anti-islanding detection (Teng Liu: 40 min.)

5. **Prospects and Challenges with GFM-IBRS (Xiongfei Wang: 30 minutes)**

Provisional Schedule of the Tutorial:

Schedule:

08:30 - 10:00: Part 1-2, Part 3.1

10:00 - 10:30: Coffee break

10:30 - 12:00: Part 3.2-3.3

12:00 - 13:00: Lunch break

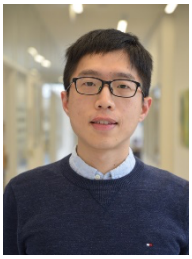
13:00 – 14:30: Part 4.1-4.2

14:30 - 15:00: Coffee break

15:00 - 16:30: Part 4.2-4.3, Part 5.

About the Lecturers:

Xiongfei Wang is a Professor at KTH Royal Institute of Technology, Sweden, and a part-time Professor with AAU Energy, Aalborg University, Denmark. He has been active tutorial instructors at IEEE conferences (e.g., PEDG, APEC, ECCE, EPE, eGrid) on stability and control of inverter-based resources and power systems. Dr. Wang is an IEEE Fellow and a recipient of the Richard M. Bass Outstanding Young Power Electronics Engineer Award, the IEEE PELS Sustainable Energy Systems Technical Achievement Award, the Isao Takahashi Power Electronics Award, and of the Clarivate Highly Cited Researcher during 2019-2021.



Heng Wu is currently an Assistant Professor with AAU Energy, Aalborg University, Denmark. His research interests include the modelling and stability analysis of the power electronic based power systems. He is the member of GB grid forming best practice expert group formed by national grid ESO, UK, and the subgroup leader of Cigre working group B4/C4.93 "Development of grid forming converters for secure and reliable operation of future electricity systems". He is identified as world's top 2% scientist by Stanford University from 2019.

Bo Fan is currently a Postdoctoral Researcher with AAU Energy, Aalborg University, Aalborg, Denmark. His research interests include power system stability, power electronics, smart grid, distributed control, and nonlinear systems. He was the recipient of the Best Reviewer Award of IEEE Trans. Smart Grid in 2019, the Outstanding Reviewer Awards of IEEE Trans. Power Syst. in 2019 and 2021, the Chinese Association of Automation (CAA) Excellent Doctoral Dissertation Award in 2020, and the Marie Skłodowska-Curie Individual Fellowship in 2021.

Fangzhou Zhao is currently an Assistant Professor with AAU Energy, Aalborg University, Denmark. His research interests include modeling, analysis and control of grid-following/grid-forming converters, modular multilevel converters, and grid emulation systems. He serves as a guest Associate Editor for the IEEE Journal of Emerging and Selected Topics in Power Electronics.

Teng Liu is currently a Senior Engineer with Electric Power Research Institute of China Southern Power Grid, Guangzhou, China. His research interests include modeling, control, and stability analysis of the power electronic-based power systems. He was the recipient of the MPCE Excellent Reviewer Award in 2020 and the Best Paper Award for COMPEL 2021.