



IEEE IECON 2025

Impedance Modelling and Passivity Design for Power Electronics-Dominated Power Systems

With rising renewable energy integration, power electronics significantly impact power system stability. This GreenTech tutorial introduces impedance theory and its applications in power electronics-based systems. Topics include historical context, high- and low-frequency modeling, and damping strategies. It targets researchers, engineers, and graduate students focused on converter- and system-level modeling and control.

Instructor Team:

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Abstract:

With the increasing penetration of renewable energy, the power system is experiencing a transition, and the effect of power electronics should be considered for the stability analysis. This tutorial is closely aligned with the GreenTech subtopic of IECON 2025, focusing on impedance theory and its applications in power electronics-based power systems. It comprises five sections: Section 1 offers historical insights into impedance theory; Sections 2 and 3 cover high-frequency modeling and damping strategies, while Sections 4 and 5 address low-frequency modeling and damping techniques. The tutorial is intended for researchers, engineers, and graduate students interested in modeling and control at both the converter and system levels.

Schedule:

1. Introduction of Impedance Theory

Presenter: Marta Molinas

- Fundamentals of Impedance-Based Stability Analysis: A Historical Perspective
- AC impedance models and basics of impedance-based analysis

2. Cost-effective high-frequency passivity design

Presenter: Chuan Xie, Shan He

- Damping design through observers and passive filters
- Damping design through multi-sampling

3. Passivity design for infinite gain controllers

Presenter: Chuan Xie, Shan He

- Repetitive controller design
- Resonant controller design

4. Impedance modeling and stability control

Presenter: Chen Zhang

- Impedance modeling, property and measurement
- Adaptive grid-connected oscillation control

5. Wideband passivity design

Presenter: Zhiqing Yang

- Low-frequency damping design
- Wideband damping design

6. Summary and discussion

7. Wideband passivity design

Presenter: Zhiqing Yang

- Low-frequency damping design
- Wideband damping design

Instructor Biography:



Shan He (Senior Member, IEEE) received the B.S. degree from Northeast Electric Power University, Jilin, China, in 2015, the M.S. degree from Zhejiang University, Hangzhou, China, in 2018, and the Ph.D. from Aalborg University, Aalborg, Denmark, in 2022, all in electrical engineering.

Since 2022, he is with Aalborg University working as a Postdoc. In 2021, he was a visiting researcher with Institute for Power Generation and Storage Systems, RWTH Aachen University, Aachen, Germany. In 2023, he was a Postdoc with Chair of Power Electronics, Kiel University, Kiel, Germany. In 2025, he is a visiting researcher with Department of Engineering Cybernetics, Norwegian University of Science, Trondheim, Norway. He is the Associate Editor of Protection and Control of Modern Power Systems and the Guest Editor of IEEE Transactions on Power Electronics. His research interests include grid-connected renewable system, Power to X, and battery system.



Zhiqing Yang (Member, IEEE) received the B.S. degree from Southwest Jiaotong University, Chengdu, China, in 2013, and the M.S. and Dr.-Ing. degrees from RWTH Aachen University, Aachen, Germany, in 2017 and 2021, respectively, all in electrical engineering.

He was a Research Intern with the Advanced Technology Research and Development Center, Mitsubishi Electric, Amagasaki, Japan, from April 2016 to September 2016, and a Research Associate with the Institute for Power Generation and Storage Systems, RWTH Aachen University, from October 2017 to September 2021. Since 2022, he has been an Associate Professor with the School of Electrical Engineering and Automation, Hefei University of Technology, Hefei, China, and a Researcher in the Institute of Energy, Hefei Comprehensive National Science Center, Hefei. His research interests include power electronics in renewable generations and automobile applications, and power converters with wide bandgap semiconductors. Dr. Yang serves as a Guest Editor for CPSS Transactions on Power Electronics and Applications.

	<p>Chuan Xie (Senior Member, IEEE) received the B.S. degree in automation engineering from the University of Electronic Science and Technology of China(UESTC), Chengdu, China, and the Ph.D. degree in power electronics from Zhejiang University (ZJU), Hangzhou, China, in 2007 and 2012, respectively. Since 2012, he has been a Lecturer with the School of Automation Engineering, UESTC, where he was promoted to an Associate Professor in 2019. Since 2022, he has been a part-time Professor with Shenzhen Institute for Advanced Study at UESTC. From 2015 to 2016, he was a Visiting Scholar with the Department of Energy Technology, Aalborg University. His main research interests include digital control of power electronics, grid synchronization technology, distributed generation systems, microgrids and power quality.</p>
	<p>Chen Zhang (Member, IEEE) received the B.Eng. degree in automation from the China University of Mining and Technology, Xuzhou, China, and Ph.D. degree in electrical engineering from Shanghai Jiao Tong University (SJTU), Shanghai, China, in 2011 and 2018, respectively.</p> <p>He was a Postdoc with Department of Engineering Cybernetics, Norwegian University of Science and Technology, Trondheim, Norway, from March 2018 to July 2020; and a Postdoc with Department of Electrical Engineering, Technical University of Denmark, Lyngby, Denmark, from October 2020 to August 2021. Since 2021, he is a Tenure-Track Associate Professor with the Department of Electrical Engineering, SJTU. His research interests include the time/frequency domain modelling and analysis of power electronics-dominated systems. Dr. Zhang also serves as an Associate Editor for IEEE Transactions on Energy Conversion.</p>
	<p>Marta Molinas (Fellow, IEEE) received the Doctor of Engineering degree from Tokyo Institute of Technology, Tokyo, Japan, in 2000. In 1998, she was a Guest Researcher with the University of Padova, Padua, Italy. From 2008 to 2014, she was a Professor with the Department of Electric Power Engineering, Norwegian University of Science and Technology (NTNU), Trondheim, Norway, and since 2014, she has been a Professor with the Department of Engineering Cybernetics, NTNU. She was a Visiting Scholar with Columbia University, New York, NY, USA, in 2014, and invited Fellow in Japan with a JSPS Invitational Fellowship in 2008 and in 2022. Her research interests include stability of power electronics systems and harmonics and nonstationary signals from the human and the machine. Dr. Molinas is an Editor of the IEEE JOURNAL OF EMERGING AND SELECTED TOPICS IN POWER ELECTRONICS, IEEE JESTIE, IEEE TRANSACTIONS ON ENERGY CONVERSION AND SCIENTIFIC REPORTS and an Associate Editor of the IEEE Transaction on Power Electronics.</p>