The Frequency Range 2-150 kHz (Supraharmonics): Challenges for Distribution Networks due to Modern Power Electronics

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

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Scope and Benefits:

This course focuses on the challenges in the frequency range 2-150 kHz (i.e., supraharmonics), which became more and more important in recent years, particular due to the increasing amount of power electronics. The extensive penetration of power electronic converters has significantly elevated the disturbance levels and coordination of EMC (electromagnetic compatibility) in this frequency range becomes increasingly challenging. At present, virtually no emission limit standards exist for nonintentional emissions in the frequency range 2 – 150 kHz and no normative method is yet available to measure grid disturbance levels. Only little is known about summation and propagation of supraharmonic emission as well as the immunity of equipment, which is essential for a successful EMC coordination in order to ensure a virtual disturbance free and reliable operation of present and future distribution networks. Due to disturbances reported within the 2 – 150 kHz range, the world leading International Electrotechnical Commission (IEC) has requested international experts to develop a comprehensive standardization framework for this frequency range.

In order to manage supraharmonics and consequently to ensure EMC, the respective emissions, their summation and their propagation need to be identified and analyzed, both from the perspective of equipment and the distribution network. Thereby, this course presents the recent developments in measuring disturbance levels and impedance characteristics of the power network within 2 – 150 kHz. Beside the measurement techniques also results of several measurement campaigns are presented and discussed including the summation of emission from multiple devices and their propagation in the network. Furthermore, the course covers recent findings in predicting and modeling of supraharmonics with respect to the single-phase and three-phase power electronic converters utilizing analytical and black-box modeling techniques as effective approaches in comparison with real-time supraharmonics measurements. Moreover, possible strategies in mitigating supraharmonics and adapting to the new upcoming standard emission limits will be discussed.

Contents:

The outline of the half-day tutorial is as follows:

Part 1:

Introduction

- Definitions and principles
- Disturbance sources and effects
- General emission characteristics
- Present status of standardization

Measurement of grid disturbance levels

- Needs and requirements
- Limitations of CISPR method for grid measurements
- Alternative approaches
- Example measurements (sites with PV inverter, EV chargers, …)

Frequency-dependent impedances of network and equipment

- Definitions and measurement methods
- Survey of network impedance in residential LV networks in central Europe and comparison with normative AMNs (IEC 61000-4-7, CISPR LISN)
- Input impedance characteristics of mass-market equipment
- Impact of network impedance on equipment emission characteristics

Case studies with high penetration of power electronic equipment

- Propagation in case of high penetration of PV inverters
- Supraharmonic amplification due to resonance caused by an EV fast charger
- Emission characteristic and interactions in a central EV charging infrastructure

Part 2:

Supraharmonics emission prediction in power electronic converters

- Noise source and impedance modeling
- AMN and EMI receiver model
- Black-box modeling approach
- Prediction and validation

Suitable filtering techniques

- DM Passive filtering and optimization
- Active spectral shaping methods
- Stability consideration

Conclusions

- Further aspects beyond the scope of the tutorial
- Advantages of prediction method as an effective tool
- Discussion

Schedule:

Monday, 5 September 2022 - 1st Tutorial Day - Afternoon

14:00 - 15:30	**Part 1:** Introduction / Measurement of grid disturbance levels / Frequency-dependent impedances of network and equipment / Case studies with high penetration of power electronic equipment
15:30 - 16:00	Coffee break
16:00 - 17:30	**Part 2:** Supraharmonics emission prediction in power electronic converters / Suitable filtering techniques / Conclusions

Who should attend:

This course is intended for intermediate researchers and engineers in the field of power electronics and its applications, for EMC specialists and advanced university students exploring new distortion phenomena and EMI challenges in power electronics-based power system. General knowledge in power electronics converters operation modes, passive components and basic control theory are preferred.

About the Lecturers:

Jan Meyer (M'12-SM'17) received the Dipl.-Ing. and Ph.D. degrees in electrical power engineering as well as the postdoctoral qualification in Power Quality from Technische Universitaet Dresden, Dresden, Germany, in 1994, 2004 and 2018 respectively. He is currently with Technische Universität Dresden as Senior Lecturer and Leader of the Power Quality Research Team.

His research interests include network disturbances and their assessment, especially for distortion below and above 2 kHz, accuracy of Power Quality measurements as well as analysis of big data amounts from Power Quality measurement campaigns. He is member of several national and international working groups on EMC standardization, vice chair of the German EMC committee in DKE, several CIGRE working groups and the CIRED technical committee. He gives regular speeches on recent topics in the field of Power Quality and is organizer of seminars in the field of network disturbances and its assessment.

Pooya Davari (S'11–M'13-SM'19) received the B.Sc. and M.Sc. degrees in electronic engineering in 2004 and 2008, respectively, and the Ph.D. degree in power electronics from QUT, Australia, in 2013. From 2005 to 2010, he was involved in several electronics and power electronics projects as a Development Engineer. From 2013 to 2014, he was with QUT, as a Lecturer. He joined Aalborg University, in 2014, as a Postdoc, where he is currently an Associate Professor.

He has been focusing on EMI, power quality and harmonic mitigation analysis and control in power electronic systems. He has published more than 160 technical papers. Dr. Davari served as a Guest Associate Editor of IET journal of Power Electronics, IEEE Access Journal, Journal of Electronics and Journal of Applied Sciences. He is an Associate Editor of Journal of Power Electronics, Associate Editor of IET Electronics, Power Electronic Devices and Systems, Editorial board member of Journal of Applied Sciences and Journal of Magnetics. He is member of the International Scientific Committee (ISC) of EPE (ECCE Europe) and a member of Joint Working Group six and Working Group eight at the IEC standardization TC77A. Dr. Davari is the recipient of Equinor 2022 Prize and 2020 IEEE EMC Society Young Professional Award for his contribution to EMI and Harmonic Mitigation and Modeling in Power Electronic Applications. He is currently Editor-in-Chief of Circuit World Journal. He is founder and chair of IEEE EMC SOCIETY CHAPTER DENMARK.