Periodic Control of Power Electronic Converters

Presenter(s):

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Brief description:

A key issue for power electronic converters is the ability to tackle periodic signals in electrical power processing (e.g. synchronous frame transformation, sinusoidal voltage/current regulation, power harmonics mitigation, and etc.) in such a way to precisely and flexibly convert and regulate electrical power. The Internal Model Principle (IMP) based periodic control has been found to provide power electronic converters with a superior control solution to the compensation of periodic signals with high accuracy, fast dynamic response, good robustness, and cost-effective implementation.

This seminar is to provide basic theory and some recent progress of IMP-based periodic control technology, complete analysis and synthesis of periodic control systems. It covers the control, compensation, and filtering of periodic signals in power electronic signal processing and proposes a unified framework for housing periodic control schemes for power converters, providing a perfect periodic control solution for power electronic conversion. This tutorial also consists of a number of demonstrative practical examples of the application of periodic control to: standalone/grid-connected PWM converters; CVCF High Frequency Link converters; shunt active power filters; and grid synchronizations.

This tutorial is intended for researchers and engineers in the field of power electronics and their applications, for control specialists exploring new applications of control theory in power electronics, and for advanced university students in these fields.

Outline:

- ***Power Electronics and Control*** ***(10 minutes)***
  - *Motivation and background*
  - *Power electronics technology development*
  - *General power converter control*
- ***Fundamentals and Synthesis of Periodic Control Systems*** ***(40 minutes)***
  - *Repetitive Control*
    - *Internal model principle based repetitive control*
    - *Discrete Fourier transform based repetitive control*
  - *Multiple Resonant Control*
  - *Application Examples*

Coffee Break (10 minutes)

- ***Advanced Periodic Control Systems*** ***(40 minutes)***
  - *Optimal Periodic Control for Harmonic Compensation*
    - *Internal model for power harmonics*
    - *Parallel structure internal model for harmonic compensation*
  - *Frequency Adaptive Periodic Control*
    - *Impact of frequency variations on periodic control systems*
    - *Fractional order periodic control*
  - *Application Examples*
- ***Continuing Developments of Periodic Control*** ***(20 minutes)***
  - *Periodic control for multi-period signal*
  - *Periodic signal filtering*
  - *Applications beyond power converters*

Relevant publications:

[1] Zhou, K., Wang D. Yang Y. and Blaabjerg, F. (2017) Periodic Control of Power Electronic Converters. IET Press, London, UK

[2] Y. Yang, K. Zhou, and F. Blaabjerg, "Virtual unit delay for digital frequency adaptive T/4 delay phase-locked loop system," in *Proc. IPEMC 2016*, pp. 2910-2916, Hefei, China, 22-25 May 2016.

[3] Yang, Y., Zhou, K., and Blaabjerg, F. (2016) Enhancing the frequency adaptability of periodic current controllers with a fixed sampling rate for grid-connected power converters. IEEE Trans. Power Ele., 31(10), pp. 7273-7285.

[4] Zou, Z.-X., Zhou, K., Wang, Z., and Cheng, M. (2015) Frequency adaptive fractional order repetitive control of shunt active power filters. IEEE Trans. Ind. Electronics, 62(3), pp. 1659-1668.

[5] Yang, Y., Zhou, K., Wang, H., Blaabjerg, F., and et al (2015) Frequency adaptive selective harmonic control for grid-connected inverters. IEEE Trans. Power Ele., 30(7), pp.3912-3924.

[6] Zhou, K., Yang, Y., Blaabjerg, F., and Wang, D. (2015) Optimal selective harmonic control for power harmonics mitigation. IEEE Trans. on Industrial Electronics, 62(2), pp. 1220-1230.

[7] Zhu, W., Zhou, K., and Cheng, M. (2014) A bidirectional high-frequency-link single-phase inverter: modulation, modeling, and control. IEEE Trans. Power Electronics, 29(8), pp. 4049-4057.

[8] Yang, Y., Zhou, K., Cheng, M., and Zhang, B. (2013) Phase compensation multiresonant control of CVCF PWM converters. IEEE Trans. on Power Electronics, 28(8), pp. 3923-3930.

[9] Lu, W., Zhou, K., and Wang, D. (2013) General parallel structure digital repetitive control. International Journal of Control, 86(1), pp. 70-83.

[10] Zhang, B., Wang, D., Zhou, K., and Wang, Y. (2008) Linear phase lead compensation repetitive control of a CVCF PWM inverter. IEEE Trans. Industrial Electronics, 55(4), pp. 1595-1602.

[11] Zhou, K., Wang, D., Zhang, B., Wang, Y., Ferreira, J.A., and de Haan, S.W.H. (2007) Dual-mode structure digital repetitive control. Automatica, 43(3), pp. 546-554.

[12] Zhou, K., and Wang, D. (2003) Digital repetitive controlled three-phase PWM rectifier. IEEE Transactions on Power Electronics, 18(1), pp. 309-316.

[13] Zhou, K., and Wang, D. (2001) Digital repetitive learning controller for three-phase CVCF PWM inverter. IEEE Trans. Industrial Electronics, 48(4), pp. 820-830.

Presenter's biography:

Keliang Zhou (M'04-SM'08) received his Ph.D. degree in Electrical and Electronics Engineering from Nanyang Technological University in Singapore in 2002, was conferred his B.Eng. and M.Eng. Degrees from Huazhong University of Science and Technology in China in 1992 and Wuhan Transportation University in China in 1995, respectively. Dr. Zhou is currently a Senior Lecturer in the School of Engineering at University of Glasgow in Scotland. He is currently active in the research areas of high‐frequency power conversion, modelling and control of power electronic based systems, renewable energy, distributed power generation systems, and smart grid technologies. He was one of the pioneering researchers in developing periodic control (especially repetitive control) technologies for power electronic conversion. He has published about 50 journal articles, over 50 refereed international conference papers and tens of patents in relevant fields. Several of his technical papers rank in the list of highly cited papers.

Yongheng Yang (S'12-M'15) received the B.Eng. degree in 2009 from Northwestern Polytechnical University, China and the Ph.D. degree in 2014 from Aalborg University, Denmark. He was a postgraduate with Southeast University, China, from 2009 to 2011. In 2013, he was a Visiting Scholar with Texas A&M University, USA. Since 2014, he has been with the Department of Energy Technology, Aalborg University, where currently he is an Assistant Professor. His research interests are focused on grid integration of renewable energy systems, power converter design, analysis and control, harmonics identification and mitigation, and reliability in power electronics. Dr. Yang has published more than 80 technical papers and co-authored a book – *Periodic Control of Power Electronic Converters* (London, UK: IET, 2017). Dr. Yang is a Member of the IEEE Power Electronics Society (PELS) Students and Young Professionals Committee, where he serves as the Global Strategy Chair and responsible for the IEEE PELS Students and Young Professionals Activities. He served as a Guest Associate Editor of IEEE Journal of Emerging and Selected Topics in Power Electronics, and has also been invited as a Guest Editor of *Applied Sciences*.

Frede Blaabjerg (F'03) is currently a Professor with the Department of Energy Technology and the Director of Center of Reliable Power Electronics (CORPE), Aalborg University, Denmark. He has intensive research work on power electronics and its applications in motor drives, wind turbines, PV systems, harmonics, and the reliability of power electronic systems. He has held more than 300 lectures national and international, most of them in the last decade are invited and as keynotes at conferences, covering various topics on power electronics, including the reliability. He was a Distinguished Lecturer for the IEEE Power Electronics Society from 2005 to 2007 and for the IEEE Industry Applications Society from 2010 to 2011. He has contributed more than 800 journal and conference papers, many of which in the last four years are relevant to the reliability of power electronic components, converters and systems. Dr. Blaabjerg received the IEEE William E. Newell Power Electronics Award in 2014, the IEEE PELS Distinguished Service Award in 2009, the Outstanding Young Power Electronics Engineer Award in 1998, and 15 IEEE Prize Paper Awards. He served the Editor-in-Chief of the IEEE Transactions on Power Electronics from 2006 to 2012.