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Tutorial Title:

Pulse energy modulation v.s. pulse width modulation for single-phase power inverters with power decoupling technologies

Organizer:

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Abstract:

As the power electronics industry has developed, various families of power electronic inverters and rectifiers have evolved, often linked by power level (single- or three- phase), switching devices, and topological origins. The process of switching the electronic devices in a power electronic converter from one state to another is called modulation. The most popular modulation strategy for controlling the ac output of bridge inverters is known as carrier-based pulse width modulation (PWM), which varies the duty cycle of the inverter switches at a high switching frequency to achieve a target average line-frequency output voltage or current. This tutorial provides a comprehensive overview of the evolution of single-phase converter topologies underlining power decoupling techniques and the development of various PWM techniques and pulse energy modulation (PEM). Different with most carrier-based PWM techniques, PEM employs energy reference rather than the voltage or current reference to compare with the carrier waveform to produce the triggering signals. Conventional passive power decoupling techniques paralleling a large electrolytic capacitor at the DC side were commonly used in single-phase power converters to buffer the second-order power mismatch. In recent years, as the active power decoupling technologies advance, it is promising to reduce the capacitance of the DC-link capacitor to enable the use of small film capacitors and extend the lifetime of the overall converter system, by employing independent power decoupling circuits such as bidirectional converters or dependent power decoupling circuits that share power electronic components with original converters. The active power decoupling topologies are evolved on three branches: current-reference, DC voltage-reference and AC voltage-reference. The tutorial presents benefits and drawbacks of each topology as compared with its predecessor in an underlying logic way enabling the audience to develop a systematic methodology to come up with new solutions for their own applications. In addition, a general comparison has also been made in terms of decoupling capacitance/inductance, additional cost, efficiency and complexity of control, providing a benchmark for future power decoupling topologies. Finally, a 10kW single-phase power inverter system is used as an example in the case study of power decoupling project at the Research Center for Photovoltaic System Engineering of Hefei University of Technology in China. The electrolytic capacitor of mF is replaced by a smaller film capacitor of ~200uF through topological and algorithmic designs, where a direct input current predictive control technique is used to achieve the power decoupling function.

Bio:

Shuang Xu received the B. Sc. E.E. in 2012 from Hefei University of Technology, Hefei, China, and the Ph.D. in Electrical Engineering in 2018 at the University of New Brunswick (UNB), Fredericton, Canada. He is currently a Post-Doctoral Associate at the Western University, London, Canada, and a Guesting Associate Professor at the North China University of Technology, Beijing, China. From 2018 to 2020, he was a Post-Doctoral Fellow at the Emera and NB Power Research Centre for Smart Grid Technologies at UNB. His research interests include renewable energy systems, energy storage technologies, multiple microgrids, power electronics, and power system support functions for distributed energy resources.

Dr. Xu was a recipient of the IEEE Applied Power Electronics Conference Outstanding Presentation Award in 2017. He was the tutorial speaker of the IEEE International Symposium on Power Electronics for Distributed Generation Systems (PEDG 2019) and the IEEE International Conference on High Voltage Direct Current (HVDC 2020). In addition, he has been teaching College Physics in The Princeton Review (TPR) from 2015 to 2019, where he got the year-end teaching evaluation of 5.0/5.0 in 2016 (<3% in Canada), featured in TPR Newsletter in Feb. 2017, and obtained the Instructor Bonus Earner of TPR North America in July 2017. He was also the session chair of PEDG 2019. He serves as the chair in 2019 and the vice chair in 2020 of IEEE UNB Power Electronics Society Student Branch Chapter.

Meiqin Mao (M'08-SM'14) received the B.Sc., M.Sc. and Ph.D. degrees in electrical engineering from Hefei University of Technology (HFUT) in 1983, 1988 and 2004 respectively. She is a Professor with the School of Electrical and Automation Engineering, HFUT, China. Her research interests and expertise include renewable energy generation technology, distributed power generation and microgrids, power electronics applied in power systems. She has published more than 190 papers. She serves as an Associate Editor for IEEE Journal of Emerging and Selected Topics in Power Electronics and the Committee Member of IEEE William E. Newell Power Electronics Award (2016-2018).

Liuchen Chang received B.S.E.E. from Northern Jiaotong University in 1982, M.Sc. from China Academy of Railway Sciences in 1984, and Ph.D. from Queen' University in 1991. He joined the University of New Brunswick in 1992 and is a Professor Emeritus at UNB. He was the NSERC Chair in Environmental Design Engineering during 2001-2007, and the Principal Investigator of Canadian Wind Energy Strategic Network (WESNet) during 2008-2014. He is president of the IEEE Power Electronics Society (2021-2022). Dr. Chang was a recipient of CanWEA R.J. Templin Award in 2010, Innovation Award for Excellence in Applied Research in New Brunswick in 2016, and PELS Sustainable Energy Systems Technical Achievement Award in 2018. He is a fellow of Canadian Academy of Engineering (FCAE). He has published more than 370 refereed papers in journals and conference proceedings. Dr. Chang has focused on research, development, demonstration and deployment of renewable energy based distributed energy systems and direct load control systems.