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IECON 2023 Tutorial Proposal

Title of the Proposal: The Development, Applications and Challenges of Multi-level Converters in Flexible Traction Power Supply System

- Presenter(s):

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Assistant Professor, Lan Ma, Southwest Jiaotong University, China
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- Brief description:

Traction power supply system is one of the four core systems of railway. The existing traction power supply system is equipped with neutral sections, which is difficult to realize energy interconnection. In order to solve the problems existing in the traditional traction power supply system, the Flexible Traction Power Supply System(FTPSS) with Multi-Level Converter （MLC） as the core equipment of active power transmission has attracted wide attention in the industry.

The supply voltage of the traction power supply system is 27.5kV/55MVA. Limited to the voltage and current level of existing switching devices, flexible traction power supply system must rely on series and parallel converters to achieve full power operation. Therefore, how to design the topologic of MLC and study its control and modulation technology is the premise to ensure the stable operation of FTPSS. This tutorial will provide an overview of the FTPSS proposed by our research team.

Flexible traction power supply system can be regarded as a new type of power system which is composed of grid-forming converter. It can be seen that grid-connected control strategy is key technology to ensure the safe operation of FTPSS. Therefore, the grid-connected control strategy of FTPSS based on droop control and virtual synchronous machine control will be introduced in this tutorial. And the integrated coordinated control strategy of FTPSS which can reduce power losses is exhibited in this tutorial.

The FTPSS is composed of a variety of active and passive devices. Compared with the traditional traction transformer, the topologic, control method and reliability of the MLC is complexity because of its complex structure and many devices. However, the MLC has a higher degree of modularization, convenient data acquisition, controllability and adjustability, and its fault diagnosis and self-healing capabilities are strong. Therefore, this tutorial will provide the novel fault diagnosis, fault tolerance and protection strategy of the MLC. It is of great significance to carry out the research on the topologic, control method and reliability of the MLC.

To sum up, attendees will gain a comprehensive understanding of MLC and its development, potential applications and challenges in the FTPSS.

- Duration:

180 minutes

- Outline:

Part I: Introduction

- Development Status of Traction Power Supply System of High-speed Railway in the world
- Development Status of Multi-Level Converter (MLC)
- Outline of Flexible Traction Power Supply System

Part II: Structure, Modulation and Control Technology of Multi-level Converter for Flexible Traction Power Supply System

- Flexible Traction Power Supply System based on Cascaded-parallel Converter
- Flexible Traction Power Supply System based on Power Electronic Transformer
- Flexible Traction Power Supply System based on Modular Multi-level Converter

Part III: Grid-Connected and Integrated Coordinated Control Strategy of Flexible Traction Power Supply System

- Grid-Connected Control Strategy of Flexible Traction Power Supply System based on Droop Control
- Grid-Connected Control Strategy of Flexible Traction Power Supply System based on Virtual Synchronous Machine Control
- Integrated Coordinated Control Strategy of Flexible Traction Power Supply System

Part IV: Fault Diagnosis, Fault-tolerant Control and Protection Strategies of Flexible Traction Power Supply System

- Fault Diagnosis of Multi-Level Converter
- Fault-tolerant Control of Multi-Level Converter
- Protection Strategies of Flexible Traction Power Supply System

Part V: Conclusion

- Challenges of Flexible Traction Power Supply Systems in the future
- Summary and Questions

Brief CV:

Xiaoqiong He (hexq@swjtu.edu.cn) received the B.Sc. and D.Eng. degrees in electrical engineering from Southwest Jiaotong University(SWJTU), Chengdu, China, in 1998 and 2013, respectively. She joined SWJTU as a Teaching Assistant in 1999 and was a Lecturer from 2003 to 2008. She is currently a Professor with the School of Electrical Engineering, SWJTU. Her research interests include applications to power electronic converters, active power filters, and PWM rectifiers and control. She is the reviewer of IEEE TIE, IEEE TPE and IEEE TIA. Her paper Fault Diagnosis and System Reconfiguration Strategy of Single-phase Cascaded Inverter received the Best Paper Award of the IEEE ITEC Asia-Pacific by IEEE Industry Application Society, in 2017.

Lan Ma (mlan@swjtu.edu.cn) received the B.S. degree in automation and the Ph.D. degree in control science and engineering from the University of Electronic Science and Technology of China, Chengdu, China, in 2011 and 2018, respectively. From 2015 to 2017, she was a Visiting Scholar with Future Renewable Electric Energy Delivery and Management Systems Center, North Carolina State University, Raleigh, NC, USA. She is currently an Assistant Professor with the School of Electrical Engineering, Southwest Jiaotong University, Chengdu. Her research interests include energy storage and solar system control, power electronics converters.

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- Relevant publications:

[1] He Xiaoqiong, Shu Zeliang, Peng Xu, Zhou Qi, Zhou Yingying, Zhou Qijun, "Advanced cophase traction power supply system based on three-phase to single-phase converter," *IEEE Transactions on Power Electronics*, vol. 29, no. 10, pp. 5323-5333, Oct. 2014.

[2] He Xiaoqiong, Yu Haolun, Han Pengcheng, Zhao Zhiqin, Peng Xu, Shu Zeliang, Leonghai Koh, Wang Peng, "Fixed and Smooth-Switch-Sequence Modulation for Voltage Balancing Based on Single-Phase Three-Level Neutral Point Clamped Cascaded Rectifier," *IEEE Transactions on Industry Applications*, vol. 56, no. 4, pp. 3889-3903, July-Aug. 2020.

[3] Pengcheng Han, Xiaoqiong He, Haijun Ren, Yi Wang, Xu Peng, Zeliang Shu, Shibin Gao, Yanbo Wang, Zhe Chen, "Fault Diagnosis and System Reconfiguration Strategy of a Single-Phase Three-Level Neutral-Point-Clamped Cascaded Inverter," *IEEE Transactions on Industry Applications*, vol. 55, no. 4, pp. 3863-3876, July-Aug. 2019.

[4] Xu Peng, Xiaoqiong He, Pengcheng Han, Hongjian Lin, Zeliang Shu, Shibin Gao, " Opposite Vector Based Phase Shift Carrier Space Vector Pulse Width Modulation for Extending the Voltage Balance Region in Single-phase 3LNPC Cascaded Rectifier," *IEEE Transactions on Power Electronics*, vol. 32, no. 9, pp. 7381-7393, Sep. 2017.

[5] Shu Zeliang, He Xiaoqiong, Wang Zhiyong, Qiu Daqiang, Jing Yongzi, "Voltage Balancing Approaches for Diode-Clamped Multilevel Converters Using Auxiliary Capacitor-Based Circuits," *IEEE Transactions on Power Electronics*, vol. 28, no. 5, pp. 2111-2124, May 2013.

[6] Linghui Meng, Lan Ma, Weiwei Zhu, Han Yan, Tiangxiang Wang, Wenjun Mao, Xiaoqiong He, Zeliang Shu, "Control Strategy of Single-Phase UPQC for Suppressing the Influences of Low-Frequency DC-Link Voltage Ripple," *IEEE Transactions on Power Electronics*, vol. 37, no. 2, pp. 2113-2124, Feb. 2022.

[7] Shu Zeliang, Ding Na, Chen Jie, Zhu HaiFeng, He Xiaoqiong, "Multilevel SVPWM with DC-link capacitor voltage balancing control for diode-clamped multilevel converter based STATCOM," *IEEE Transactions on Industrial Electronics*, vol. 60, no. 5, pp. 1884-1896, May 2013.

[8] Linghui Meng, Zeliang Shu, Yuan Lei, Han Yan, Zuyong Li, Lan Ma, Xiaodong Yin, Xiaoqiong He, "Optimal Input and Output Power Quality Control of Single-Phase AC-DC-DC Converter With Significant DC-Link Voltage Ripple," *IEEE Transactions on Industrial Electronics*, vol. 67, no. 12, pp. 10366-10376, Dec. 2020.

[9] Hongjian Lin, Zeliang Shu, Jiaxuan Yao, Han Yan, Leilei Zhu, Deng Luo, Xiaoqiong He, "A Simplified 3-D NLM-Based SVPWM Technique with Voltage Balancing Capability for 3LNPC Cascaded Multilevel Converter," *IEEE Transactions on Power Electronics*, vol. 35, no. 4, pp. 3506-3518, April 2020.

[10] Jianglin Nie, Rui Fu, Chunjian Cai, Junyang Ma, Zeliang Shu, Lan Ma, "A High Efficiency Battery Equalizing Circuit Based on Half Bridge Topology with Multi-port Transformer," *IEEE Transactions on Industrial Electronics*, Early Access.