1. Tutorial Title

Emerging Power Electronics Technologies for Green Data Center

2. Instructor Team:

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3. Abstract

The world's data centers currently consume more than 500 billion kilowatt-hours of electricity annually. Traditional power delivery architectures in data centers are bulky and inefficient. About 40% of the data center energy consumption comes from the losses in power conversion. There is a long process to convert electricity from the utility grid, to 5V DC or lower on the motherboards including multiple AC-DC, DC-AC, DC-DC stages. This tutorial will provide an overview of the state-of-the-art of power delivery architecture and topology in data centers, and discuss the key principles on designing and implementing these power electronics technologies for green data centers. Three emerging and important power electronics technologies covering the power delivery from utility grid to CPU will be discussed: zero-voltage-switching (ZVS) three-phase/single-phase AC-DC converters, modular multiport DC energy router, and 48V-to-1V hybrid switched-capacitor point-of-load (48V-PoL) converters.

The ZVS AC-DC converters aim to solve the switching loss issue and improve the efficiency and power density of the grid interface of data centers. Traditional AC-DC converters suffer from the switching loss of semiconductor devices, which limit the switching frequency and further reduce the efficiency and power density. Based on the resonant dc link concept, a family of three-phase/single-phase ZVS AC-DC converters and the corresponding modulation strategies (ZVS-SVM and ZVS-SPWM) will be introduced. The engineering challenges, practical details of this approach, and the impact of wide bandgap (WBG) devices tech will be discussed.

The modular multiport DC energy router is suitable for applications with large scale modular units such as photovoltaic (PV) energy system, battery management system, and data centers. The modular design couples a large number of cells with a single magnetic core which processes multiway bidirectional power flow, decouples the voltage rating and current rating of the basic cells, and offers much lower device stress than traditional wide-operation range multiport dc-dc converters. The power flow control of the modular multiport DC energy router and its application in data centers will be presented in detail in this tutorial.

The 48V architecture is now becoming the mainstream choice for data center power delivery system due to lower conduction loss and cost. Meanwhile the power consumption and transient current of microprocessor is also increasing with the improvement of performance. The 48V-PoL

aims to address the challenge of very high voltage conversion ratio for high performance microprocessors. A family of hybrid switched-capacitor topologies leveraging the low voltage device, the high energy density of capacitor, and precise regulation of inductor will be introduced. Soft charging techniques for hybrid switched-capacitor circuit will be reviewed, with key principles provided to guide the design of resonant soft-charging and PWM soft-charging.

4. Tutorial Outline

1. Challenges and Opportunities of Data Center Power Delivery (10 min)
2. ZVS AC-DC Technology (45 min)
    a. Soft-switching AC-DC topologies overview
    b. Three-phase ZVS AC-DC converters
    c. Single-phase ZVS AC-DC converters

   Break (10 min)
3. Modular Multiport DC Energy Router (45 min)
    a. Review of multiport power conversion architecture
    b. Power flow control of the modular multiport DC energy router
    c. Data center application

   Break (10 min)
4. 48V-1V Point of Load Architecture (45 min)
    a. Review of high step-down ratio power conversion architecture
    b. Hybrid switched-capacitor approach for 48V-1V PoL Design
    c. Principles of soft charging technique

   Break (10 min)
5. Summary and Future Discussions (15 min)

5. Lecture Style and Requirements

Traditional lecture

6. Instructor Biography

Mark Dehong Xu received B.S., M.S. Ph.D. degrees from the Department of Electrical Engineering, Zhejiang University, China. He used to be a visiting professor in University of Tokyo of Japan, Virginia Tech in United State, and ETH in Zurich. He has been a professor in Zhejiang University since 1996. His current research interests include power electronic converter modeling, control and design, high-power-density converters and systems applied to renewable energy, datacenters and charging stations etc. He has authored ten books and more than 270 IEEE Journal or Conference papers. He holds over 50 patents. Dr. Xu was a recipient of seven IEEE journal and conference paper awards. He became an IEEE Fellow in 2013. He was an IEEE PELS Distinguish Lecturer from 2015 to 2018. He received IEEE PELS R. D. Middlebrook Achievement Award in 2016.

He is an At-Large Adcom Member of the IEEE Power Electronics Society and vice-president of Power Electronics Society. He is Co-Editor in Chief of IEEE Open Journal of Power Electronics. He is a past President of China Power Supply Society. He is general chairs of IEEE international conferences such as IEEE ISIE2012, IEEE PEDG2012, IEEE PEAC2018 etc.

Yenan Chen received his honors degree of engineering from the Chu Kochen College, Zhejiang University in 2010, the bachelor's degree and Ph.D. degree from the College of Electrical Engineering, Zhejiang University, Hangzhou, China, in 2010 and 2018 respectively, both in Electrical Engineering. He was a Postdoctoral Research Associate with the Department of Electrical Engineering, Princeton University, NJ, USA, from 2018 to 2021. In December 2021, he joined Hangzhou Global Scientific and Technological Innovation Center, Zhejiang University, China, where he is currently a Research Scientist and Principal Investigator with the Advanced Semiconductor Research Institute. He holds four issued Chinese patents. His research interests include high frequency power converters, advanced power electronics architecture, grid-interface power electronics and renewable energy systems. Dr. Chen was the recipient of the Second Place Prize Paper Award of the IEEE Transactions on Power Electronics in 2020, the Best Paper Award in IEEE COMPEL 2020, the IEEE APEC Outstanding Presentation Award in 2019, and the First Place Award from the Innovation Forum of Princeton University in 2019.