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Power Electronics and Motion Control Conference | **PEMC**

Tutorial

Advanced DC Power Technologies for Mission-Critical Infrastructure Applications

Duration: 120 minutes

Abstract: DC power is increasingly attracting attention in mission-critical infrastructure, where uninterrupted operation, extremely high reliability, and fault tolerance are essential requirements. The primary motivation behind this trend is the potential for significant energy savings, achieved by eliminating losses associated with reactive power, multiple AC/DC conversion stages, and rectification processes inherent to traditional AC-based systems. As a result, DC systems can offer higher overall efficiency, simplified power architectures, improved controllability, and enhanced performance. The transition toward DC systems also closely aligns with the rapid growth of renewable energy sources and energy storage technologies. Since many distributed energy resources, such as photovoltaic (PV) systems and batteries, are inherently DC-based, DC distribution enables more direct integration, reduces the number of power conversion stages, and increases local self-consumption by allowing energy to be generated, stored, and utilized on-site. These features are particularly relevant for modern mission-critical systems that demand high flexibility, strong resilience, and sustainability, including lighting systems, IT installations such as data centers, and large-scale scientific and industrial facilities (e.g., particle accelerators). However, the widespread adoption of DC power systems also introduces new technical challenges and opportunities in power electronics and system design. These include the development of advanced DC–DC converter topologies, high-performance grid-interface converters to enable seamless interaction between AC and DC grids, and improved control, monitoring, and protection strategies. In particular, the absence of natural current zero-crossing in DC systems, combined with the requirement for fast fault detection and interruption, necessitates innovative protection solutions such as solid-state circuit breakers (SSCBs) and hybrid protection devices. This tutorial will explore the key innovations and emerging opportunities driving present and future DC power technologies for mission-critical infrastructure applications, incorporating both academic perspectives and an industrial viewpoint from *Eaton Corporation plc*, a global leader in power management solutions.

Content Outline

Duration	Topics covered
15 min	Introduction, system functionalities, technical requirements, and standardization aspects • Towards a decarbonized future • Shifting from purely AC distribution to DC power systems • The role of the *Current/OS Foundation* and the *Open DC Alliance (ODCA)* • **Mission-critical infrastructure applications**
20 min	DC technologies for lighting systems • Public street lighting and DC technologies • State of the art and emerging trends • DC lighting systems: case studies and practical experience • The ***LighLine*** project from the *FinEst Centre for Smart Cities* • Enabling technologies and outlook

20 min	IT installations with high flexibility, strong resilience, and sustainability • *AI* and *cloud computing*: implications for future power demand • Data center and IT system architecture solutions • The ***Shift2DC*** *Horizon Europe* project • ***PRISM:*** power-efficient, reliable, intelligent, and sustainable DC module for data centers
20 min	Large-scale scientific and industrial infrastructures • System design for the *Large Hadron Collider (LHC)* and the ***Future Circular Collider (FCC)*** • State-of-the-art commercial klystron solutions • DC powering solutions for the ***FCC****:* converter topologies, protection, and control • Requirements for two-stage multibeam klystrons and tristrons
30 min	Advanced DC circuit protection technologies • *Semiconductor Circuit Breakers (SCCBs)* and *Semiconductor Hybrid Circuit Breakers (SCHCBs)* in accordance with **IEC PT 60947-10** • DC *SCCB/SCHCB* circuit topologies, including current-commutation techniques and arc-free switching structures • Power semiconductor devices: comparison of switching characteristics, conduction and switching losses, and suitability for fast fault interruption • Voltage clamping circuits: operating principles, design trade-offs, transient performance, and comparative evaluation of different architectures • Practical insights from 100 A/800 V *SCCB/SCHCB* units deployed in the **Shift2DC** *Aachen Demonstrator:* grid topology, earthing concepts, and selectivity under DC fault conditions
5 min	Final considerations and general remarks
10 min	Q&A session

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