Luxembourg distributed energy systems

Power electronics has the capacity to disrupt electrical distribution systems and propel us towards a more sustainable future. This technological advancement paves the way for a greener future by enhancing the efficiency and reliability of power grids, integrating renewable energy sources, and facilitating the deployment of innovative energy storage solutions.

At the forefront of this transformative journey is the Luxembourg Institute of Science and Technology (LIST), home to the Intelligent Clean Energy Systems research unit. It recently organised the 15th IEEE International Symposium on Power Electronics for Distributed Generation Systems (PEDG 2024).

PEDG 2024, which drew +200 participants from across the globe, delved deep into the theory, analysis, design, and deployment of power electronics, focusing on distributed generation, energy storage, and sustainable energy sources. It cast a compelling light on emergent configurations, controls, applications, and tests in the renewable energy domain, emphasizing the critical steps required to achieve carbon peaking and neutrality goals. This international scientific conference tackled an array of topics, each pivotal in steering us towards a greener future.

A segment of PEDG 2024 explored advancements in power converters and controls for various sustainable sources, including hydrogen technologies. Efficient power conversion using innovative technologies and the application of inverter based resources (IBR) was highlighted. Discussions also covered the monitoring and protection standards of distributed generation systems, underscoring the importance of robust frameworks in fostering sustainable energy adoption.

The role of power electronics in energy storage systems and electric vehicles was another focal point. Topics included applications in batteries, supercapacitors, hybrid storage systems, and electrical vehicle fleet charging infrastructures. Energy management strategies for system planning, sizing, and diverse case solutions were examined, showcasing how power electronics can enhance the efficiency and reliability of energy storage, pivotal for the integration of renewable energy sources.

The symposium also addressed the impact of power electronics on microgrids and distributed generation. Discussions ranged from grid interconnection and islanded operation to electric power quality impacts and mitigation strategies. With a focus on grid-forming, demand response, and strategies for high distributed generation penetration, the sessions highlighted the transformative potential of power electronics in modern power systems.

Emerging topics such as new power semiconductors, cybersecurity, artificial intelligence, big data, policy issues, and real-time simulation in renewable energy systems were also in the spotlight. These discussions emphasized the roles of these advanced technologies in power electronics-based distributed and sustainable

generation systems, illustrating the intersection of innovation and sustainability.

At the heart of these advancements is LIST"s Power Lab, a state-of-the-art facility dedicated to the experimental validation of complex energy systems. Divided into two distinct areas--real-time system simulation and power conversion experimentation--this lab rigorously tests hardware performance in complex real-world scenarios under controlled operating conditions before deployment in pilot settings.

In this setup, real hardware is integrated into the real-time simulation loop using advanced measurement systems and power amplifiers, ensuring compatibility between digital signals and real-world power signals. The lab also integrates communication networks into real-time testing, evaluating the impact of contingencies and cyberattacks on system performance. This comprehensive approach allows for thorough testing and validation, essential for the reliability and effectiveness of new energy systems.

Within the framework of the Horizon Europe projects i-STENTORE, WeForming and EnerTEF, LIST"s Power Lab is working on a multi-port converter connected to the power grid, fuel cells, EV chargers, and PV panels. This solution promises to bring flexibility to the distribution grid, adding numerous functionalities to power electronics. The lab employs real hardware devices such as power converters, power amplifiers, and AC sources, communicating with real-time hardware through fieldbuses to control devices, bridging the gap between the physical and virtual worlds.

In the context of the lab, several battery energy storage systems have been deployed throughout Luxembourg. These systems provide ancillary services to the grid, including peak shaving, congestion management, and flexibility services. The lab offers manufacturers the opportunity to test their hardware performance in real-world complex scenarios under controlled conditions, demonstrating not only technical and economic viability but also reliability under demanding operating conditions.

Pedro Rodr?guez, Head of the Intelligent Clean Energy Systems unit at LIST, stated: "While technologies like photovoltaics have become mature, others, such as energy storage and hydrogen, still require significant practical development. The lab"s ability to develop, operate, and control new energy systems under practical conditions is vital for demonstrating their performance and meeting user needs."

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