Editorial

Beyond Boundaries: Multidisciplinary Microgrids Empowered by Neuroscience and Artificial Intelligence

Josep M. Guerrero

Huanjiang Laboratory, Zhejiang University, Zhuji 311816, China; guerrero@ieee.org

As we unveil this new issue of the Journal of *Microgrids*, I am filled with a profound sense of pride and anticipation. The journey of microgrids from a specialized research niche to a cornerstone of the global energy transformation is nothing short of remarkable. Today, microgrids, which are distributed networks of any kind, are not only technical systems—they are enablers of sustainability, resilience, and innovation, bridging disciplines and continents, and empowering communities in ways previously unimaginable.

1. A Bold, Multidisciplinary Vision—"One Idea, Multiple Disciplines"

Microgrids was founded with the conviction that the future of energy will be shaped by multidisciplinary collaboration. Apart from energy, microgrids can also be designed for water management, biological and agricultural systems, transportation, telecommunications, healthcare, community infrastructure, digital networks, and space habitats, providing decentralized, resilient solutions across multiple critical sectors. Our mission is to provide a comprehensive, high-quality platform for the exchange of pioneering ideas, rigorous research, and transformative technologies. We are proud to publish work that spans the entire spectrum of microgrid science and engineering, including:

- Energy Microgrids:

Articles in this area address the design, modeling, control, and optimization of AC, DC, and hybrid microgrid systems. We highlight research on integrating distributed generation—such as solar photovoltaics, wind turbines, and fuel cells—alongside advanced storage technologies and demand-side management. The focus extends from urban smart grids to rural electrification, industrial parks, and off-grid communities.

- Hydrogen and Biomass Microgrids:

Our journal welcomes research on the use of hydrogen and biomass as clean, flexible, and renewable energy sources. This includes advances in hydrogen production, storage, and utilization within microgrids, the integration of fuel cells, and hybrid systems that combine multiple renewable resources for enhanced reliability and environmental performance.

- Water Microgrids and Micronets:

We are at the forefront of exploring microgrid concepts applied to water management, such as smart water distribution, renewable-powered desalination, and the water-energy nexus. These systems are crucial for sustainable water infrastructure, especially in regions facing water scarcity or extreme weather events.

- Closed Biological Systems:

The journal features research on closed-loop biological environments, including life-support systems for space missions, controlled agricultural and aquacultural systems, and bioenergy production. Here, the integration of biological and energy systems is key to developing autonomous, self-sustaining habitats.

- Maritime Microgrids:

Electrification and microgrid solutions for seaports, ships, and offshore platforms are increasingly important

for reducing emissions and improving operational resilience. We publish studies on all-electric and hybrid ships, renewable integration at ports, and energy management for offshore facilities.

- Aeronautic Microgrids:

The electrification of aviation is accelerating. Our scope includes microgrid technologies for airports, ground support systems, and more electric aircraft, focusing on reliability, efficiency, and sustainability.

- Space Microgrids:

Space exploration demands robust, autonomous power systems. We highlight research on microgrids for satellites, space stations, lunar and Martian bases, and life-support eco-systems, emphasizing redundancy, fault tolerance, and adaptability to extreme environments.

- Smart Medical Microgrid Systems:

Reliable and resilient energy is critical for healthcare. We encourage submissions on microgrids for hospitals, clinics, emergency response units, and telemedicine, especially in remote or disaster-prone areas.

- Digital Twins, Cybersecurity, and Quantum Computing:

The digitalization of microgrids is transforming the field. We publish research on digital twins for real-time monitoring and optimization, cybersecurity strategies to protect critical infrastructure, and the use of quantum computing for solving complex optimization problems in microgrid management.

- Neuroscience-Inspired Microgrid Control:

A rapidly emerging frontier is the application of neuroscience-inspired algorithms and cognitive models to microgrid control and protection. Techniques such as brain emotional learning, amygdala-inspired protection, and neural adaptation are enabling microgrids to become more adaptive, context-aware, and self-healing. These approaches draw from the remarkable capabilities of biological systems to learn, anticipate, and respond to changing environments.

- Artificial Intelligence for Microgrids:

AI is revolutionizing every aspect of microgrid operation. From deep learning and reinforcement learning to neuro-fuzzy systems and federated intelligence, AI enables advanced forecasting, optimization, predictive maintenance, and autonomous decision-making. These tools are essential for managing the growing complexity and scale of modern microgrids.

2. The State of the Art and Emerging Frontiers

The pace of innovation in microgrids is accelerating. Recent years have seen the deployment of increasingly sophisticated control architectures, seamless integration of renewable energy, and the adoption of digital technologies such as blockchain, digital twins, and AI. These advances are not only technical milestones—they are directly addressing real-world challenges: expanding energy access in remote regions, enhancing disaster resilience, decarbonizing critical infrastructure, and supporting the electrification of transportation, water, and healthcare systems.

Our journal is proud to feature pioneering studies on battery management for agricultural microgrids, active damping in power converters, multi-objective optimization for hybrid energy storage, and the deployment of microgrids in the most challenging environments—from isolated islands to deep space missions. The integration of neuroscience and AI is propelling the field forward, enabling microgrids to function as intelligent, adaptive, and self-healing systems.

3. Neuroscience and AI: The New Frontier

One of the most exciting developments is the convergence of neuroscience and artificial intelligence with microgrid engineering. Neuroscience-inspired algorithms, such as those modeling emotional learning or neural adaptation, are creating microgrids that can learn from their environment, anticipate disturbances, and autonomously adapt to changing conditions. These biologically inspired methods are particularly promising for protection relays, frequency and voltage stabilization, and real-time energy management.

Artificial intelligence, meanwhile, is transforming microgrid operation and management. AI-driven energy management systems can now perform real-time adaptation, predictive maintenance, and autonomous decision-making, making microgrids more efficient, reliable, and scalable. Neural networks and deep learning models are being used for renewable energy forecasting, resource allocation, and fault detection, while reinforcement learning is enabling microgrids to optimize performance in dynamic and uncertain environments.

4. Challenges and Opportunities

Despite these advances, significant challenges remain. Regulatory frameworks must evolve to accommodate new business models and technical realities. Ensuring cybersecurity, seamless islanding and reconnection, and interoperability with larger grid architectures are ongoing priorities. As neuroscience and AI become more integral to microgrid operation, issues of explainability, trust, and ethical deployment also rise to the forefront. Equally important are the economic, social, and environmental dimensions—ensuring that microgrid innovations are accessible, affordable, and beneficial to all communities.

5. Our Commitment

At *Microgrids*, we are dedicated to publishing research that advances both scientific understanding and practical solutions. We value interdisciplinary collaborations and contributions that bridge theory and practice. Our rigorous peer-review process ensures the highest standards of excellence and relevance.

As Editor-in-Chief, I draw upon my own experience—ranging from pioneering research in AC/DC microgrids and hierarchical control to recent work on maritime and space microgrids, and most recently going forward to neuroscience and medical applications—to guide our journal's vision. With over 1,500 journal publications and a deep commitment to global collaboration, I have seen firsthand the transformative power of microgrid innovation.

6. Looking Forward

The future of microgrids is bright and boundless. As we confront the challenges of climate change, urbanization, and energy equity, microgrids—empowered by neuroscience and artificial intelligence—will play an increasingly central role in building resilient, sustainable, and intelligent infrastructure for all. I invite researchers, practitioners, policymakers, and industry leaders to join us on this journey—sharing knowledge, driving innovation, and shaping the future of microgrids across every domain.

On behalf of the editorial board, I extend my deepest gratitude to all who contribute to our vibrant community. Together, we are redefining what is possible for microgrids and the world.

Conflicts of Interest

The author declares no conflict of interest.