

How Grid-Forming Power Converters are Solving the Stability Crisis of the Renewable Era

*Professor Khaled H. Ahmed
University of Strathclyde, Glasgow, UK*

The global energy transition is accelerating, with wind and solar photovoltaic installations breaking records year after year. Yet beneath this promising narrative lies a deeply unsettling technical reality: our power grids were never designed to operate without synchronous machines. For over a century, grid stability has been anchored by the physical inertia of large rotating generators. This stored kinetic energy acted as a natural buffer against disturbances, buying the system precious seconds to respond and recover. Today, that foundation is eroding. As synchronous generators are retired and replaced by converter-interfaced renewables, the grid is losing its mechanical inertia. Worse still, conventional “grid-following” converters are inherently dependent on a stable grid to function. They can inject power, but they cannot create voltage or frequency. They are followers, not leaders. We are dismantling the pillars of grid stability while adding more variable generation. The result is a looming stability crisis that threatens to slow down the clean energy transition.

This keynote presents the definitive solution: Grid-Forming (GFM) converters. Unlike grid-following converters, GFM converters operate as voltage sources. They do not follow the grid; they establish it. They can set voltage and frequency references, provide synthetic inertia, ride through disturbances, and enable black-start capabilities. In essence, they teach power electronics to behave like the synchronous machines they replace but with far greater speed, flexibility, and control. This talk will provide a comprehensive overview of grid-forming technology, covering:

- **The Stability Challenge:** Why grid-following inverters are insufficient for high-renewable grids, the concept of weak grids, and real-world examples of stability issues linked to declining system strength.
- **GFM Principles and Control:** Fundamental differences from grid-following converters, core control strategies including droop control, virtual synchronous machines (VSM), and virtual oscillator control (VOC), and how GFM converters provide synthetic inertia and fast frequency response.
- **Capabilities and Benefits:** Black-start capability, islanded operation, seamless mode transitions, enhanced resilience, and improved hosting capacity for renewables in weak grid areas.
- **Real-World Deployment:** Early adopters, pilot projects, lessons learned from field deployments in Europe, and North America, and evolving grid codes.
- **Challenges and the Road Ahead:** Technical challenges, standardisation efforts, the role of energy storage, and research gaps.
- **The Bigger Picture:** How GFM technology is transforming renewables from passive participants to active grid leaders and the path to a 100% inverter-based grid.