Registration Seminar

Seminar Title	: Global Synchronization of Stochastic Inverter Based Resources (IBR's)
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Venue	: EE 205
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Abstract	: Abstract

The rapid proliferation of inverter-based resources (IBR&rsquos), such as solar photovoltaic systems, wind turbines, and battery storage, is fundamentally transforming the dynamics of modern power grids. Unlike traditional synchronous machines, IBR&rsquos lack natural inertia and require sophisticated control strategies to maintain phase and frequency synchronization. As these systems increasingly operate under stochastic conditions arising from renewable variability, communication delays, and measurement noise, achieving reliable global synchronization becomes a central challenge.

This research investigates three advanced nonlinear control frameworks - Immersion and Invariance (I&I), Passivity Based Control (PBC), and Cohomology Based Methods for ensuring global synchronization of stochastic inverter networks modeled using an extended Kuramoto framework. The Kuramoto model, widely recognized for its ability to describe synchronization in coupled oscillator systems, serves as a powerful abstraction for modeling phase dynamics of IBR&rsquos in power systems. Its stochastic variant is particularly suited to capturing uncertainties inherent in renewable generation and decentralized control.

The study aims to analyze the efficacy, robustness, and scalability of each control strategy in achieving synchronization across networks with diverse topologies and parameter variations. The I&I method offers global convergence guarantees by designing invariant manifolds tailored to the synchronization objective. The PBC framework exploits the passive structure of inverter dynamics, leveraging energy shaping and damping injection for stability. Meanwhile, cohomology-based methods provide a topological lens to identify and resolve global phase inconsistencies, especially in nontrivial network structures.

By conducting comparative simulations and theoretical analysis, the research seeks to uncover trade-offs among these approaches, such as convergence speed, robustness to noise, and implementation feasibility. The outcomes are expected to guide the design of scalable, resilient synchronization controllers for future grid architectures dominated by stochastic IBR&rsquos, contributing to the broader goal of maintaining power system stability in the face of growing renewable integration.