Electrical & Computer Engineering

S E M I N A R

Louisiana State University

From Semantic to Physics-Structured Intelligence: Industrial Foundation Models for Power Systems

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Abstract—This talk introduces Physics-Structured Intelligence (PSI) as a next-generation large-scale foundation-model paradigm for resilient power systems, bridging the gap between today's semantic AI and the safety-critical realities of cyber-physical infrastructure. LLMs and LLM-style AI are indispensable for operator-facing intelligence, contextual understanding, and human-in-the-loop decision support, forming a key semantic layer for future grid operations. However, when the goal is high-fidelity simulation, trustworthy prediction, and verifiable control under highly uncertain renewables and complex grid dynamics, semantic models alone lack the physical grounding needed for assured performance. To address this gap, my new design follows a Large-Scale Small philosophy: it scales down to construct lawful tokens, i.e., compact, physics-consistent spatiotemporal modules with local feasibility and stability structure, and scales up through efficient intra- and inter-system attention that coordinates tokens across devices, time scales, and operating regimes. As a concrete example, LASS-ODE is presented to illustrate how tokenized physical structure and large-scale attention can support dynamic simulation and digital twin. Building on this example, a broader future direction is outlined toward an interoperable PSI ecosystem, together with validation pathways through digital twins, hardware-in-the-loop testing, and utility collaborations. The overarching message is that large-scale, physically grounded foundation models, working alongside LLM-style semantic AI, can move power-system intelligence from pattern recognition to assured, transferable capability.

Bio—Dr. Haoran Li received his B.S. in Electrical Engineering from Tsinghua University and his Ph.D. in Electrical, Computer and Energy Engineering from Arizona State University. He has been a visiting scholar at the University of Illinois Urbana-Champaign and the Massachusetts Institute of Technology Laboratory for Information and Decision Systems. His research interests focus on smart grids and cyber-physical systems, spanning power system estimation and control, renewable integration, physics-informed learning, and large-scale foundation models. His professional service includes IEEE PESGM panel chair/panelist, IEEE BigData Program Committee and reviewing roles for leading AI venues, including ICLR, NeurIPS, IEEE ICDM, as well as regular reviewing for major power and energy journals such as IEEE TPS and IEEE TSG.

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