Environmental and Water Resources Engineering and Center for Water and the Environment Seminar Series:

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Optimal Operation and Control of Interconnected Cyber-Physical Infrastructural Systems

Dr. Farrah Moazeni, Assistant Professor, Lehigh University

Ph.D. in Civil and Environmental Engineering from the University of Nevada, Las Vegas; B.S. and M.S. in Chemical Engineering from Sharif University of Technology (Tehran, Iran)

Abstract

The digital transformation of critical infrastructures has intensified the interdependencies between water, energy, and cyber systems, creating both unprecedented opportunities for optimization and new challenges in resilience and security. This talk presents a unified framework for the modeling, control, and cybersecurity of interconnected cyber-physical infrastructural systems (CPIS). We begin with a data-driven system identification approach that reconstructs nonlinear system dynamics from limited sensing data while preserving physical structure and uncertainty information. Building on this foundation, the presentation introduces hierarchical control strategies, from open-loop water-energy co-optimization to closed-loop model predictive control (MPC) formulations, that achieve economic efficiency, stability, and operational feasibility across interlinked networks. We then extend these methods toward automation-driven and resilience-informed control. Recent advances from the CONCISE Laboratory, including neural predictive controllers for shipboard and islanded microgrids, stability-guaranteed nonlinear MPC for water systems, and resilience-aware MPC integrating real-time resilience metrics, demonstrate how data, physics, and learning can jointly enhance the adaptability and trustworthiness of infrastructure control systems. The talk concludes with ongoing experimental validation on hardware-in-the-loop water testbeds and highlights pathways for deploying secure, adaptive, and energy-efficient control frameworks across critical infrastructures.

Background

Dr. Faegheh (Farrah) Moazeni is an Assistant Professor and Director of the Ph.D. Program in the Department of Civil and Environmental Engineering at Lehigh University, where she also directs the Inter**CoN**nected **C**ritical **I**nfrastructure **S**ystems **E**ngineering (**CONCISE**) Laboratory. She is also a core faculty member of the Center for Advancing Community Electrification Solutions (ACES) University Research Center.

Her research focuses on the cybersecurity, optimization, and control of interconnected water and energy systems, with particular emphasis on the water-energy nexus and mathematical optimization/control frameworks for resilient and efficient infrastructure operations. Dr. Moazeni currently serves as Secretary of the ASCE-EWRI Water Distribution Systems Analysis (WDSA) Council and Chair of the Efficient Combined Operation of Water-Energy Systems (ECO-WES) Task Committee.

EWRE Seminar Committee Members: Abby Chapman, Becky Cantrell, Connor Coolidge, Julia Barkelew, Tzu-An Lee