WASHINGTON STATE UNIVERSITY
School of Electrical Engineering and Computer Science

Modeling and analysis of energy networks: System-theoretic solutions to fundamental challenges

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OVERVIEW

Driven by sustainability aspirations, tremendous progress has been made in the past decade towards synthesis and solution of complex problems in management of energy networks. Targeting theoretical footings for these algorithmic developments, this talk answers fundamental questions on energy-system modeling and analysis using classical constructs from linear algebra and graph theory. The first part of the talk will focus on model reduction to manage complexity in large-scale power networks. A classical method in this domain is Kron reduction, a well-known pedagogical instance of which is the wye-delta equivalence. We present an exact time-domain generalization of Kron reduction that is developed using a linear-subspace representation of current flows in generalized settings. This facilitates the development of reduced-network representations that apply beyond steady-state sinusoidal analysis. Increasing interdependencies of power systems with natural gas and water networks has brought to notice fundamental analysis gaps for these sister networks. In the second part, we present a result on uniqueness of solutions to water and natural-gas flow problems. The analysis builds on monotonicity properties of governing physics alongside algebraic properties of network-graph matrices. Applications of these foundational modeling and analysis results to the formulation of operations and control algorithms for interconnected energy networks will be outlined.

BIO

Manish K. Singh is a postdoctoral associate with the Department of Electrical and Computer Engineering at the University of Minnesota, Minneapolis, MN. He received the B.Tech. degree from the Indian Institute of Technology (BHU), Varanasi, India, in 2013; and the M.S. and Ph.D. degrees in electrical engineering from Virginia Tech, Blacksburg, VA, USA, in 2018 and 2021, respectively. During 2013-2016, he worked as an Engineer in the Smart Grid department of POWERGRID, the national transmission utility of India. His research interests are focused on modeling, optimization, and control for electric power systems and interdependent water and natural gas networks. His doctoral dissertation was awarded the second prize for the 2022 Bill and LaRue Blackwell Graduate Research award at Virginia Tech.