Dynamic Control of Power Systems with Distributed Energy Resources

Aranya Chakrabortty

Significant infrastructural changes are currently being implemented on power system networks around the world by maximizing the penetration of renewable energy, by installing new transmission lines, by adding flexible loads, by promoting independence in power production by disintegrating the grid into micro-grids, and so on. The shift of energy supply from large central generating stations to smaller producers such as wind farms, solar photovoltaic (PV) farms, roof-top PVs, and energy storage systems, collectively known as distributed energy resources (DERs) or inverter-based resources (IBRs), is accelerating at a very rapid pace. Hundreds of power electronic devices are being added, creating hundreds of new control points in the grid. This addition is complimented by an equal progress in sensing technology, whereby high-precision, GPS-synchronized dynamic measurements of voltages and currents are now available from sensors such as Phasor Measurement Units (PMUs). With all these transformational changes happening in the grid, operators are inclining to explore new control methods that go far beyond how transmission systems are controlled today.

In this talk I will describe a suite of such new control methods, starting from modular plug-and-play decentralized control of DERs to distributed wide-area control of synchronous generators using sparsity-promoting techniques. For brevity, the presentation will be limited to one specific application - namely, power oscillation damping (POD). Applicability of the controllers to other broader classes of grid control problems such as frequency control, voltage control, and congestion relief will also be illustrated via case studies. Various practical issues on the implementation of these controllers starting from observability constraints on PMU data for reliable state estimation to challenges in data management, model uncertainties, and scalability will be touched upon. Special attention will be paid to the issue of scalable design where ideas from singular perturbation and clustering will be shown to be useful tools for designing aggregate controllers that exploit specific structural properties of the grid models. Experimental case studies of these control algorithms in face of various cyber-physical failures will be demonstrated using IEEE prototype models.

The overall goal of the talk will be to pinpoint some of the most challenging control, optimization, and CPS problems for tomorrow’s renewable-centric energy infrastructure where power engineers can largely benefit from collaborations with control theorists, communication engineers, computer scientists, and numerical analysts.