Abstract:
Motivation: Reliable and resilient operation of cyber-physical systems (CPS) of societal importance such as Smart Electric Grids is critical. Efficient models and tools to perform timely fault diagnostics and prognostics are needed for curtailing systemic failures such as power blackouts. Varying system state caused by the fluctuating power consumption, dynamic control actions, physical component degradation, and interactions with possible software anomalies make the failure analysis, prediction, and mitigation difficult.

The Smart Electric Grid is a CPS: it consists of networks of physical components (including generation, transmission, and distribution facilities) that interact with cyber components (e.g. intelligent sensors, communication networks, computational and control software). Today's grid protection systems mostly use a logic-based approach that relies on hard thresholds and local information, often ignoring system-level effects introduced by the localized control algorithms. This leads to scenarios where a local mitigation in a subsystem, especially in case of a malfunction in protection devices may result in a larger cascading effect, leading to a blackout. A 2012 report from NERC identified the importance of preventing wrong local control operations. Clearly, an integrated CPS-based approach is needed.

Our Focus: To develop modeling formalisms, algorithms, and prototype tools that can be used to perform the timely diagnosis and prognosis of failures caused by misoperation of protection systems and automatic controls using available information from the physical and the cyber components of this system. The basis for this work will be a new technique for modeling fault propagations called Temporal Causal Diagram (TCD). The uniqueness of the approach is in that it does not involve complex real-time computations on high-fidelity models, but performs reasoning using efficient graph algorithms based on the observation of various anomalies in the system. TCD is based on our prior work on Timed Failure Propagation Graphs (TFPG). The TFPG based approach relies on using an abstract causal model with simplified dynamics. However, this particular model is not sufficient to represent the dynamics of a large cyber-physical system such as smart grid.

TCD's will be able to include the effect of fault protection mechanisms as well as incorporate lower-level physics based diagnostics into an integrated scheme with a higher-level system-wide reasoner. This approach will enable integration of exogenous reasoners to refine a possible set of failure hypothesis as required. Innovation will be in using newly available data within the smart grid from PMU-s and smart meters for the transmission and distribution system diagnostics and prognostics.