Unified Knowledge Model for Stability Analysis

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ABSTRACT
Cyber-Physical Systems (CPS) consist of distributed computation interconnected by computer networks that monitor and control switched physical entities interconnected by physical infrastructures. Finding a common semantic among these diverse components that facilitates system synthesis, verification, and monitoring is a significant challenge of a CPS research program. In the emerging smart grid, for example, system state provides input into distributed computer algorithms that manage power and energy via local computation with messaging passing over a computer network collectively resulting in control signals to advanced power electronics. Computational correctness, network timing, and frequency response are all system aspects that conspire to impede design, verification, and monitoring. This paper seeks to unify the knowledge present in these diverse aspects through developing common semantics that span each aspect of a CPS.
Specifically, a smart grid type system is considered. Power commands to various loads and alternative energy sources are stepped in response to cyber controllers that are networked. This paper shows the development of a physical invariant, based on the theory of Lyapunov-like functions, and a cyber invariant, the governs the correctness of a power dispatch algorithm, and couples the two to develop an overall system stability invariant. The invariant approach is tested with two scenarios. In the first case, the system is subjected to two commanded pulses beyond the stable limit, with the second perturbing pulse being of a magnitude greater than the first, which makes the system unstable. In the second case, the system is subjected to two commanded pulses beyond its stable limit but with a comparatively smaller magnitude of the perturbing second pulse, which allowed the system to remain stable. The measure of stability is an energy function which, under certain conditions, serves as a Lyapunov-like invariant that is used to prove stability.