Innovative Control of a Flexible, Adaptive Energy Grid

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Problem
- The current energy infrastructure is in a state of transition where intermittent electricity generation sources (e.g., wind and solar) are being proposed as major elements of the future energy mix.
- Uncertainties as to how these technologies will impact energy infrastructure reliability and efficiency; they are not designed for "easy" integration.
- In addition, the electric grid is being operated closer to instability limits, to maximize resources. Consequently, better approaches are needed to understand, engineer, manage, and control the energy grid.

Kauai, HI Model — Example Wind Gust Comparison Data
- Model: PSCAD Kauai 12 bus system - 60 kV, 70 MW load with diesel & gas generation
- Examined dynamics with addition of 1, 3, and 5 - 2000 PSCAD MOD-2 modeled wind induction generators (WG)
- Examined changes in voltage, frequency and power flows for startup, opening of wind generators, load increase, fault, wind ramp and wind gust conditions

- For example, wind gusts induce similar duration but larger-magnitude frequency changes when more generators are included; but voltage changes are less affected
- Wind Gust Model: wind speed baseline 15 m/s, Gust 30 m/s, duration 5 seconds.

Results (cont.)

Unifying Theory: Nonequilibrium Thermodynamics
- The Hamiltonian is a scalar function used to develop the evolution of dynamical systems. There exist other adiabatic or detailed, irreversible principle assumptions that the system under consideration is characterized by how energy closed-energy functions. Brief, and brief. In addition, further utilizes to perform ordered to perform operational basis. Also, several balancing systems to collective systems by way of information theory.

Nonlinear Power Flow Control Design: Grid Power Applications
- Unifying Theory: Sorting Power Terms and Physical/Information Exergies
- The power grid is treated as an open thermodynamic system where the electricity is pure energy flowing through a self-organizing adaptive network system to provide an important and capable matched-potential energy source that will maximize the irreversible entropy production by maximizing the microvoltage level. Hamiltonian mechanics and connections to describe how the electric power grid is modeled as an open thermodynamic system. The (1) are equivalent to the irreversible entropy, and the generation (1) are equivalent to the work in.

Approach

Project Goals and Approach
- Develop a scalable closed-loop nonlinear analysis and control technique based on energy and irreversible entropy production supporting engineering of a flexible, irreversible energy infrastructure, more resilient to stresses and disruptions.
- The technical approach combined R&D goal: 1) general theory for closed-loop control with information feedback and design of robust critical infrastructure with; 2) numerical simulations using Matlab/Simulink/UnPowerSystems toolboxes; and 3) experimental validation using Opal-RT real-time simulator validation of electric power grids model to test new control and design approaches for specific and analogous applications.

Results

Rapid-Prototyping Environment for Real-Time Exergy/Entropy Control System Validation

Significance

Innovative Control of a Flexible, Adaptive Energy Grid
- Project delivers challenging mix of science-based engineering activities (theory, modeling, experimental)
- Participated in 4 national/international conferences
- Presented one-day workshop at the IFAC-IEMCON Conference on Decision and Control, Cancun, Mexico
- Formally documented results in 5 engineering technical archival journals
- Generated 3 patent pending applications and 2 technical advances
- One book contract signed

Highlights