Considerations in Microgrid Control and Communications

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Defining Microgrid

- Collection of controllable loads, distributed energy resources (DER), and storage
  - Within-MG controls for monitoring, demand response (DR), asset dispatch
- Single interconnection to the wider grid
- Ability to operate as an island
- Provides power and possibly other services to the grid
- Scale: Building, neighborhood, campus…
  - 10’s of KW to 10’s of MW?

Motivations for Smart Grids

- Energy reliability (for example, in remote areas subject to frequent outages, or for critical customers such as hospitals)
- Power continuity in case of natural disaster
- Attractive scale for DER integration
- Ability to implement fine-grained control
- Validation environment for advanced SG use cases, technologies, and economic models

Impediments

- Cost per kwh
  - On a declining trend?
- No (or insufficient) spinning inertia
  - Stability and power quality issues?
- Ownership and responsibility
  - Who owns and controls assets
  - System integration
- What's in it for the utility?
  - MG management as a utility service? Regulatory implications?

Control Strategies

- Want to maintain or transition to a goal state, given current state considering multiple decision variables
  - Dispatch heterogeneous energy sources
  - Manage intelligent loads
  - Islanding (IEEE 1547)
  - Provide power and services to the grid
  - State may comprehend electrical state, predicted demand, asset capability, and possibly occupancy, environmental, or other externals
- Numerous centralized and distributed control strategies

Control Strategies

- Centralized (Microgrid EMS)
  - Solves a Mixed-Integer Linear Program (MILP) at each step
    - Consider charge state of battery assets and predicted demand
    - Decision variables: charge or discharge batteries, purchase from or provide power to the grid
    - Ref: Maylsz, Sirouspour, and Emadi, “MILP-based Rolling-Horizon Control for Microgrids with Battery Storage”
- Distributed Generation Control
  - Generators collectively operate according to a pre-determined criterion, while accounting for individual capacity constraints
    - Ref: Cady and Dominguez-Garcia, “Distributed Generation Control of Small-Footprint Power Systems”, NAPS 2012
- Hierarchical (IIT)
  - Upper-level: determine setpoints of generation and load
  - Middle level: Eliminate voltage and frequency deviations
  - Lowest level: Load sharing among fast-response DER (primarily droop control)
    - Ref: Shahidehpour and Khodayar, “Cutting Campus Energy Costs with Hierarchical Control”

Communications

- Monitoring
  - Electrical system state
  - Asset health (e. g., state of charge)
  - Environment, occupancy
- Dispatch directives
- Demand management
- Security:
  - Prevent asset compromise and false data injection,
  - Authentication of measurements and directives
- Verification
  - Dispatch directives acknowledged and properly responded to
  - Integrity of transactions
  - State evolves as per models and control decisions

Microgrid Asset Interoperability

- Goal: Permit "plug and play" for MG assets
- Assets configured according to a "Microgrid Configuration Language" (MCL)
  - Type of asset
  - Asset capabilities (data, services)
  - Instantaneous asset state (health, state of charge)
  - Tools for formal analysis of configuration correctness
- Concept of logical node(s) on physical node
  - Abstract data items and services independent of specific comms protocol
  - Map to underlying protocols that can meet service requirements
  - Leverage high-speed networking technology
- Message types for time-critical events and measurements, configuration, asset status…
- IEEE 1547 defines Microgrid/EPS interoperation
- IEC 61850 adapted for intra-microgrid operations?

New ECE Building at UIUC

- Eventual goal: achieve zero net energy in the long run.
- Approximately 300 kW solar will be on the roof ultimately, and 1200 kW on a nearby parking structure.
- Electrical is net metered and so is chilled water.
- Winter heating via high seasonal energy efficiency ratio (SEER) chillers working with the campus loop as the effective sink.
  - This means the building is heated with heat pumps that interact with the campus system.
- Active energy management for HVAC and lighting, based on occupancy, operating schedules, daylight harvesting.
- We expect to interface with solar generation and with the building systems for monitoring and potential control.
- Islanding not ruled out as a future mode of operation

Micro/Smart Grid Test Center at UIUC

- Currently, 15KW ground-mounted solar and small generator
  - Heterogeneous microinverter technologies
- Plans to add storage, support smart loads
- Possible collaboration with Ameren TAC (located nearby)