Integrating Building Automation Systems with Microgrid Controls

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The Typical Commercial Buildings

• Are aggregates of generation, energy storage, and loads:
  – Emergency backup generation.
  – Solar PV, battery systems.
  – Capable of demand response.
  – HVAC (Heating, ventilation and air conditioning).
  – Extensive motor loads.
  – Plug loads.
Building Automation Systems

- Most buildings are managed by the Building Automation Systems (BAS). A BAS controls the mechanical, electrical and plumbing systems in a building, such as the HVAC, indoor and outdoor lighting, etc. It is a distributed control system with a communication network.
Volttron: A Multi-Agent System Platform

• Developed as an open source software platform by Pacific Northwest National Laboratory (PNNL), Volttron is an agent platform that communicates with sensors and controls to support building automation and smart grid operations.

(Courtesy of DOE EERE: http://energy.gov/eere/buildings/volttron)
Buildings-to-Grid Integration

• The US Department of Energy (DOE) initiative: Buildings consumes over 40% of total energy in US. Vast economic opportunities exist for buildings to integrate with the energy grid and optimize energy use through transaction-based controls.

(Courtesy of DOE EERE: http://energy.gov/eere/buildings/buildings-grid-integration)
The Building Microgrid

Utility Grid
1000 MVA, X/R = 22

PCC
11.2kV

Transformer Parameters:
- $T_{G1}, T_{G2}$: 0.48/11.2kV Δ/Y 2MVA
  - $Z = 5.75\% \ X/R = 6$
- $T_1-T_4$: 11.2/0.48kV Δ/Y 0.5MVA
  - $Z = 5.75\% \ X/R = 6$
- $T_5-T_{10}$: 480/207V Δ/Y 0.25MVA
  - $Z = 5.75\% \ X/R = 3$

Line Parameters:
- $L_1-L_4$: 3-phase 4-wire
  - $(0.049+j0.027) \ \Omega/kft$
- $L_5-L_{10}$: 3-phase 4-wire
  - $(0.06+j0.03) \ \Omega/kft$
Building Energy Management via Volttron
Integration of Microgrid Controls with BAS

Tertiary Control Algorithm: Building generation and load scheduling over the multi-hour planning horizon.

Secondary Control Algorithm: Compute setpoints for DG1 and DG2, solar, wind, BESS and controllable loads.

Primary Controls:
- $P_f/Q-V$ Droop Controls for DG1 & DG2
- Solar/Wind MPPT and $P/Q$ Controls
- BESS $P/Q$ Controls
- Load Controls
The Case Western Reserve University (CWRU) Campus Grid

backup generators
transformers
circuit breakers
lines lumped loads

138KV
11.2KV
2.4KV
480V

Glennan-white-Olin
Tomlinson
North Campus
Euclid Ave
The CWRU Case Study

- The Olin Building

![Diagram showing electrical systems and connections, including emergency genset (200 kW), other renewable sources, and electrical panels.](image-url)
Olin Building Retrofit and Upgrade

• **Phase 1: “Clean Slate”**
  ✓ Resolve current issues to lay groundwork for a more intelligent building and its accurate instrumentation. The tasks will be divided into four categories: Instrumentation, Power Quality, Initial Control, and Improvement (i.e.: retro-commissioning).

• **Phase 2: Closing The Loop**
  ✓ Additional controls and PLC hardware to interface with Direct Digital Control (DDC) system.
  ✓ Additional submeters and sensors to augment controls.
  ✓ Demand response capabilities with HVAC drives, lighting (through lighting contactors)

• **Phase 3: Microgrid Development and Operation**
  ✓ Interconnection switch gear acquisition and operation permission
  ✓ Energy management system development and deployment
PSCAD Simulation Studies

1. On microgrid hierarchical controls
   – Primary control ($P-f/Q-V$ droop controls, MPPT)
   – Secondary control (setpoint calculation)
   – Tertiary control (energy scheduling)

2. On microgrid community
   – Networked microgrids
   – Voltage management
Microgrid Primary and Secondary Controls

- Synchronous generators on P-f/Q-V droop control; PV and wind on MPPT
- Secondary control setpoints are provided by Volttron energy manager

(a) PCC power (P&Q), frequency and voltage during Operation mode transition

(b) DG output power during motor starting; PCC frequency and voltage
Microgrid Energy Scheduling (Tertiary Control)

• A mixed integer programming approach to
  – Minimize offer and bid costs from various device agents
  – Incorporate power-quality constraints to mitigate current total harmonic distortion and phase imbalance, and support sensitive loads

A Community of Networked Microgrids

(a) IEEE 34 Node Distribution System

(b) Microgrid A

(c) Microgrid B

(d) Microgrid C

(A building microgrid)
A Study of Networked Microgrids

- A PSCAD model has been built with detailed switching models for all power electronic devices.
- Energy management systems needs to be present at both the microgrid and microgrid community level.
- Coordination on voltage regulation is required among the secondary controls of microgrids.
- Frequency and voltage are more susceptible to disturbances when microgrid community is in islanded mode, due to the small scale of system.
A “Prepared” Unexpected Islanding Event

(1) Microgrid community PCC frequency

Microgrid has adequate real power from DGs serving the loads before islanding.

When interconnection switch was opened, there was still a certain amount of power interchange at the PCC.

No additional generation was deployed and no significant voltage or frequency transients are observed.

(b) Microgrid community PCC voltage
Battery-Smart Inverter Units
For Frequency and Voltage Regulations

Battery-smart inverter systems can quickly respond to real and reactive power setpoint instructions. It is an excellent control for both frequency and voltage regulation.

On left, a voltage event occurs at around $t = 20$ seconds when battery was quickly deployed to supply reactive power and recover the voltage (which would otherwise drops to insecure levels.)
Conclusions

• Microgrid technology is necessarily required for facilitating Buildings-to-Grid Integration.

• Microgrid controls should be integrated with building automation technologies for power and energy management. A multi-agent based platform such as Volttron provides an ideal deployment environment for the sensing, communication, and control sub-systems involved.

• Due to the small capacity scale of building microgrids, power quality issues and mitigation are among the essential planning and operation objectives.

• Operational issues such as voltage regulation concerning microgrids networked through the distribution system are to identified and further studied.
Thank you!