Microgrid Resiliency at Yale University

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February 13, 2020
A modern campus microgrid is incredibly complex, with many integrated components – generation, switchgear, protection and control, automation and SCADA, power distribution and building substations.

This complex physical infrastructure must be operated reliably and efficiently against a complex backdrop of campus operations, unpredictable weather, aging electrical grids, shifting academic priorities and constrained operating budgets.
Microgrid Resiliency Strategies

• Develop an operating philosophy for your system
• On new projects, build in reliability from the start
• Make your system as flexible as possible
• Take extra time and money to fully commission everything
• Use automation so “when the bad thing happens” stable operation is maintained
Yale University Microgrids

- 2 Sites – Main Campus (Central Power Plant) and Medical School/Hospital (Sterling Power Plant)
- Each 15 MW with heat recovery and grid interconnection
- Primary Select Campus Distribution Circuits fed at 15 kV
- Sterling Plant converted to cogeneration in 2010
- Central Plant original cogeneration in 1997, repowered in 2016
Yale Central Power Plant Microgrid

Central Campus Chiller Plant
CCCP

Supplemental Diesel Generators

Utility Feeder #1
Utility Feeder #2
Utility Feeder #3
Utility Feeder #4

Central Power Plant (CPP)

Gas Turbines
Emergency Diesel Generators

Normal Campus Building Feeder Set 1 (C/B/S)

Normal Campus Building Feeder Set 2 (C/B/S)

Examples:
• 25 Science Park
• 344 Winchester
• GML

Emergency Power: Local to building

Campus buildings directly connected to Utility

Utility Feed (UI)

Campus Buildings (typ)

Normal
Normal loads

Normal Feeder 1
Normal Feeder 2

CE (1)
SE (1)

C = Central Campus / Dorms (2)
B = Engineering / Dorms (1)
S = Science Hill (2)

Alt
Alternate Feeder

ATS
Alternate loads

Alternate
Normal

Feed between buildings

Campus Buildings
Like JE, Trumbull & Saybrook, fed from Branford

CE (1)
SE (1)

C = Central Campus / Dorms (2)
B = Engineering / Dorms (1)
S = Science Hill (2)
Stay on grid as long as possible, but ultimately generation is our most reliable source.
Fast Bus Transfer – Stay on Grid

- Implemented via contact logic
- Enabled and supervised by Synch Panel PLC and local Synch Check
- Sequence:
  - 2 UI feeders trip (not Arc, Bus Diff, Bus O/C)
  - UI Breakers proven open
  - Main Tie breaker closes
  - GT Tie breaker stays open
Uses electromechanical frequency-based load shed relays
First installed with original cogen – hardwired scheme:
  • Residential/Academic buildings shed first
  • Low Density Science/Academic next
  • High Performance Science last
Made sense until October 29, 2012 – Hurricane Sandy:
  • Load too high to Island
  • State of Connecticut travel ban
  • Yale University closed to non-essential personnel
  • Students told to shelter in their dormitories
  • One Problem: In the event of a loss of utility, these buildings would be the first to lose power!
Selectable Load Shed – Flexible Solution

- Load shed relay outputs rewired to local PLC-based controller
- Load shed lockout relays installed for each campus breaker
- Controller outputs to each LOR
- DCS Supervision of controller allows outputs to be reconfigured to different load shed levels as needed
- PLC refresh adds small amount of time; however, experience has been that the system works very well
Operating Philosophy

Supplemental Diesel Generators

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Reliable building service is a key priority

Campus Buildings (typ)

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Normal Feeder 2

Normal loads
Alt: Alternate Feeder

ATS: Alternative loads

Feed between buildings

Campus Buildings Like IE, Trumbull & Saybrook, fed from Branford

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CE (1)
SE (1)

Reliable building service is a key priority
Double-Ended Substation with Auto-Throwover:

- Automatic system supervised by PLC
- Bus Undervoltage trips main and closes tie
- Inhibited on overcurrent, ground fault or arc detection
- Automatic retransfer after 10 seconds
“Commissioning is a process that begins in design, continues through construction, and concludes with functional testing.”
Cx Best Practices: Design

• Make sure you (as the owner) understand:
  • What your electrical system is and is not capable of – especially the Protection and Control
  • What is required to enable this capability?
  • How will we test it to make sure?

• Design Considerations:
  • Have we included break points in the system, such at test switches?
  • Where will the load come from to test? How will it be connected to our system?
  • Do the project documents describe the full control philosophy? Do they include enough documentation to troubleshoot?
Construction QA is vital to functional testing going well:

- Validation of key inputs that are not “settings” per se – such as PT and CT ratios
- CT polarity
- Documentation of control wiring between pieces of equipment (e.g., generator differential CT wiring to generator breaker relays)
- Relay I/O Mapping
- Interface to plant control system
Example: Show complete wiring path on Schematic
**Cx Best Practice: Integrated Functional Testing**

- Challenge as much of the protection circuit as possible
- Validate external outputs – e.g. control system annunciation/SOE
- Be prepared to add to your test script on the fly
Questions?
Thank You!

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