26 October 2018

Black & Veatch Innovation Pavilion Microgrid - A Living Laboratory

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BUILDING A WORLD OF DIFFERENCE®

BLACK & VEATCH

Agenda

- Innovation Pavilion Microgrid Goals
- Microgrid Overview & Usage
- Individual Technology Overview
  - LAB (Living Laboratory, Proactive)
  - LESSON (Lesson Learned, Reactive)
- Summary

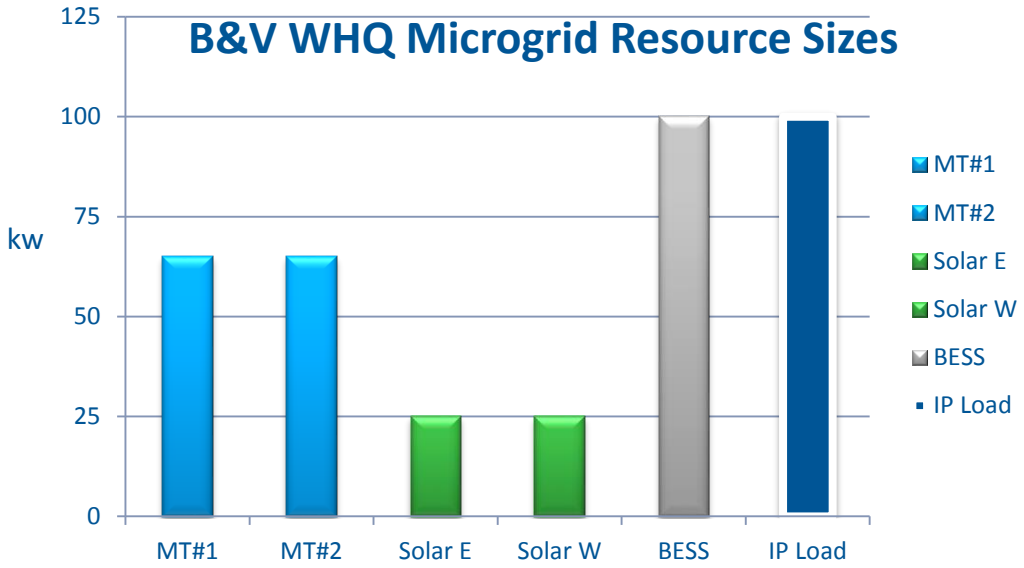
Innovation Pavilion Microgrid Goals

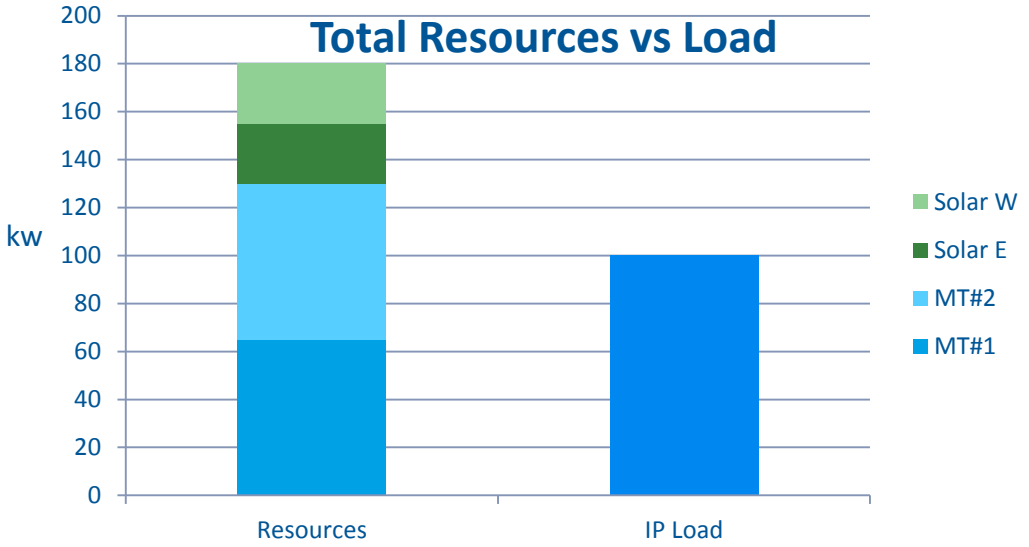
- Investment in the Future
  - Develop Experience (Design, Procurement, O&M, Troubleshooting)
  - Drive Learning & Analysis
- Utilize and Learn from Diverse Technologies
- Promote Public Awareness
- Payback was not a Primary Driver

Initial Operation in 2015

Microgrid Overview

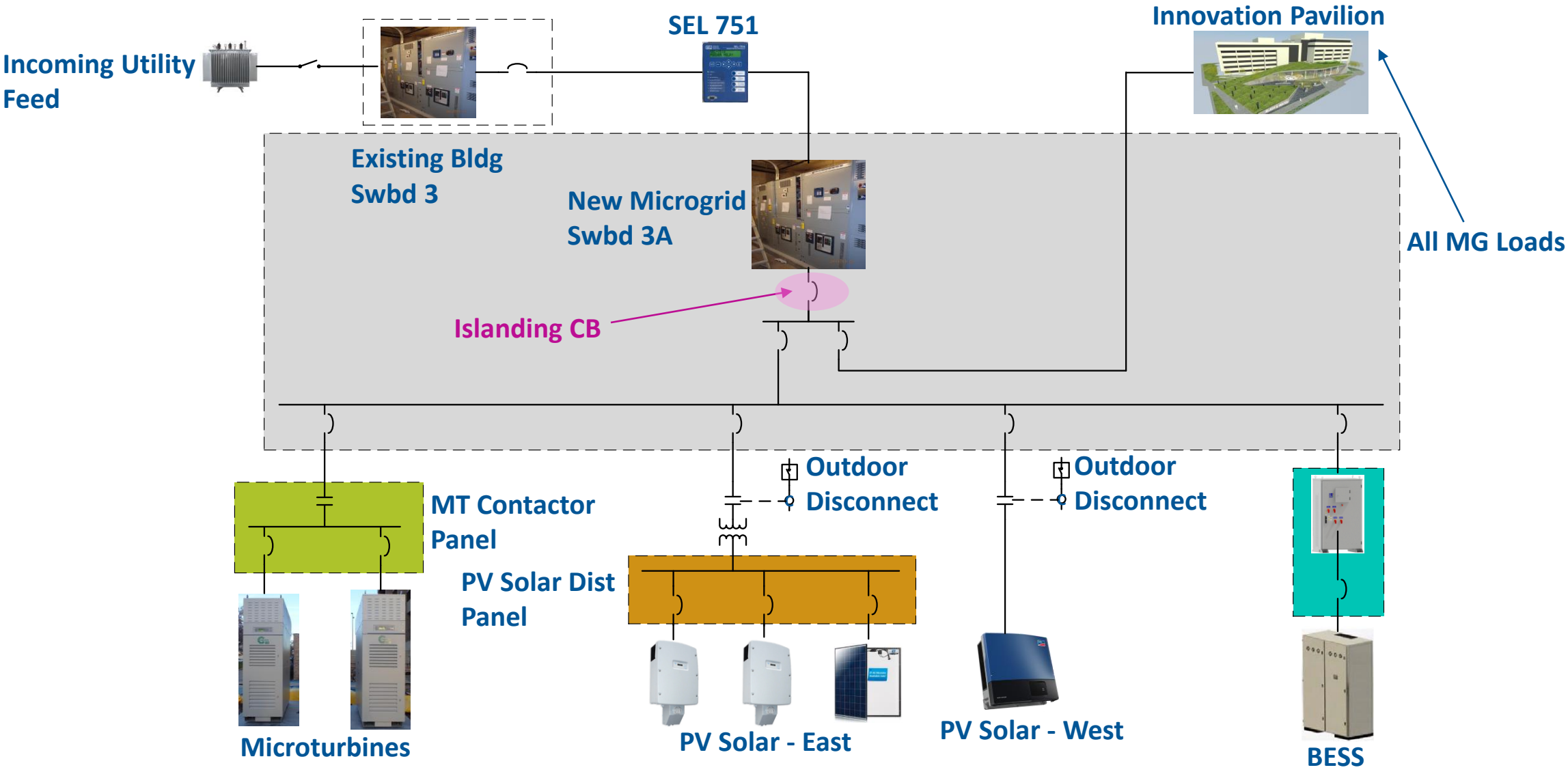
Scale of Resources and Load



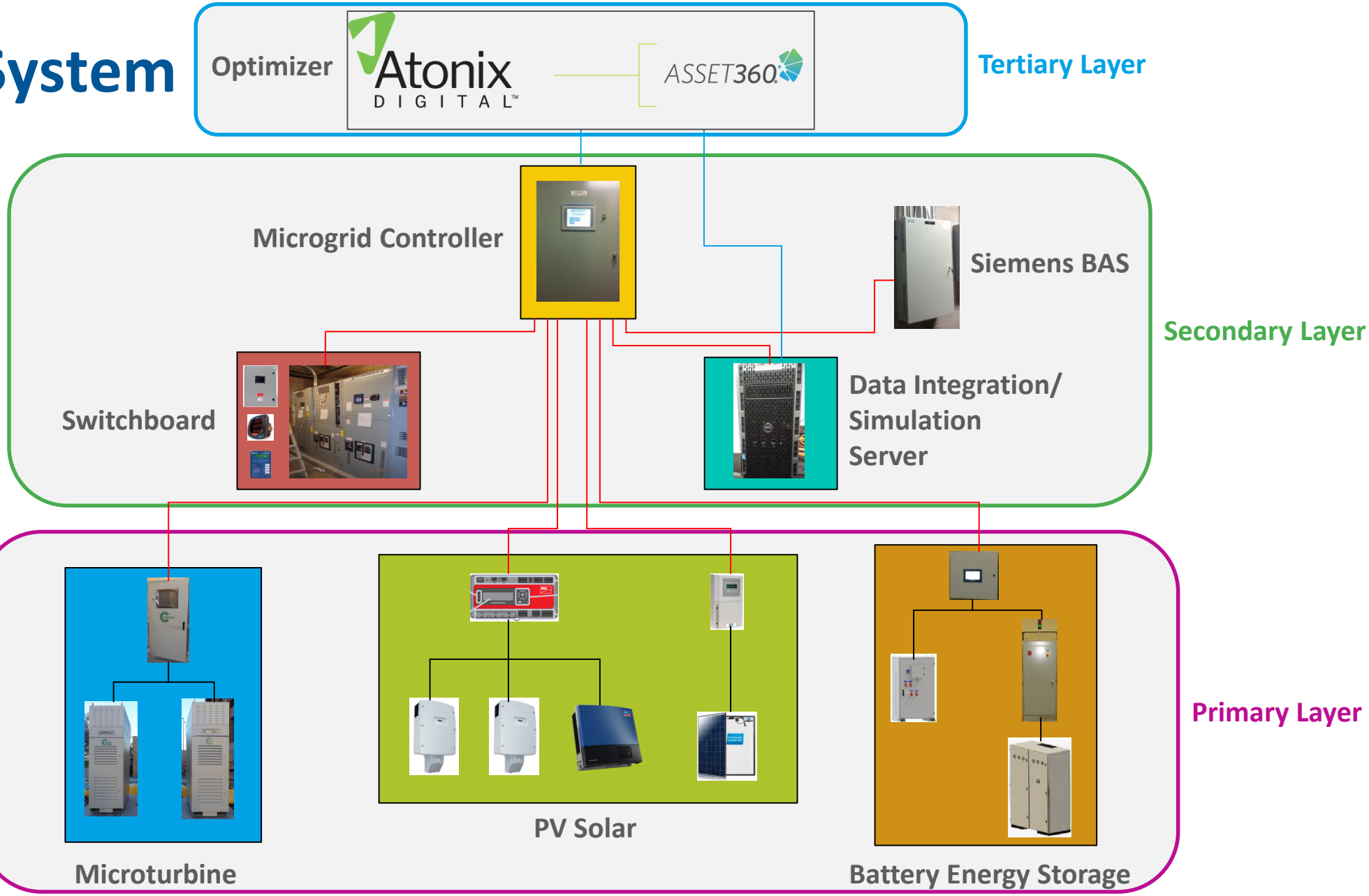


IP Load = Innovation Pavilion Load Served by the Microgrid DERs

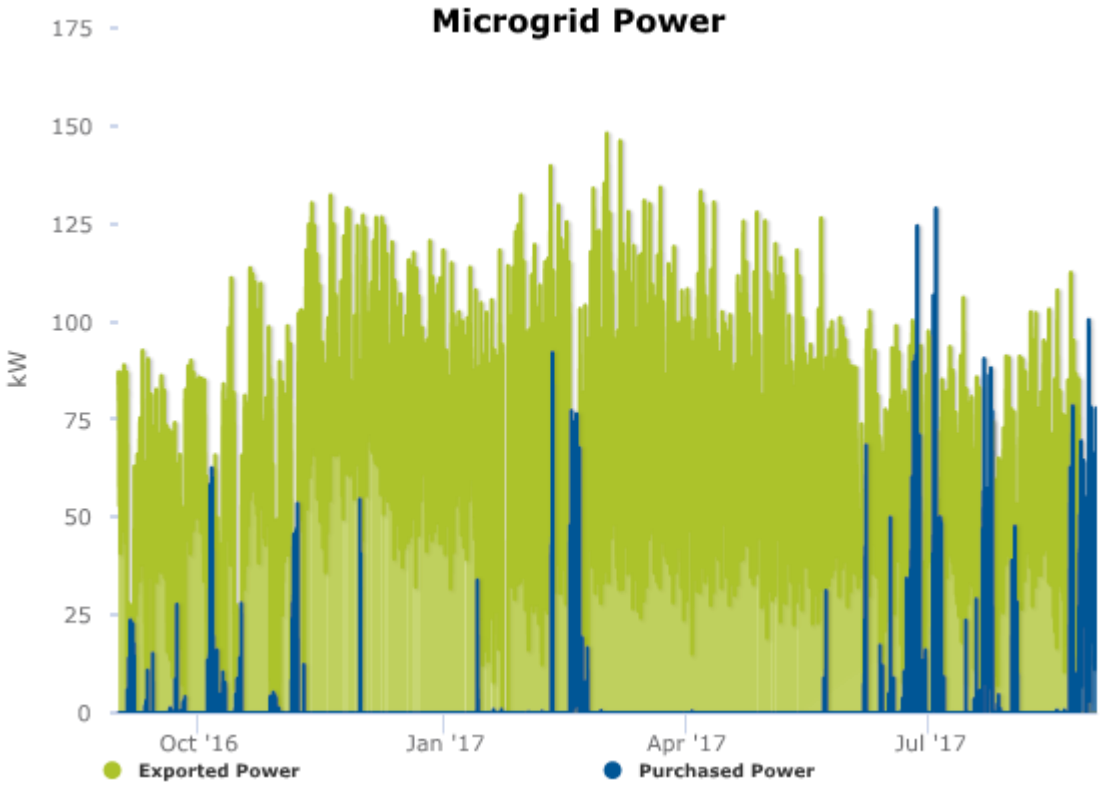
Microgrid Power Distribution

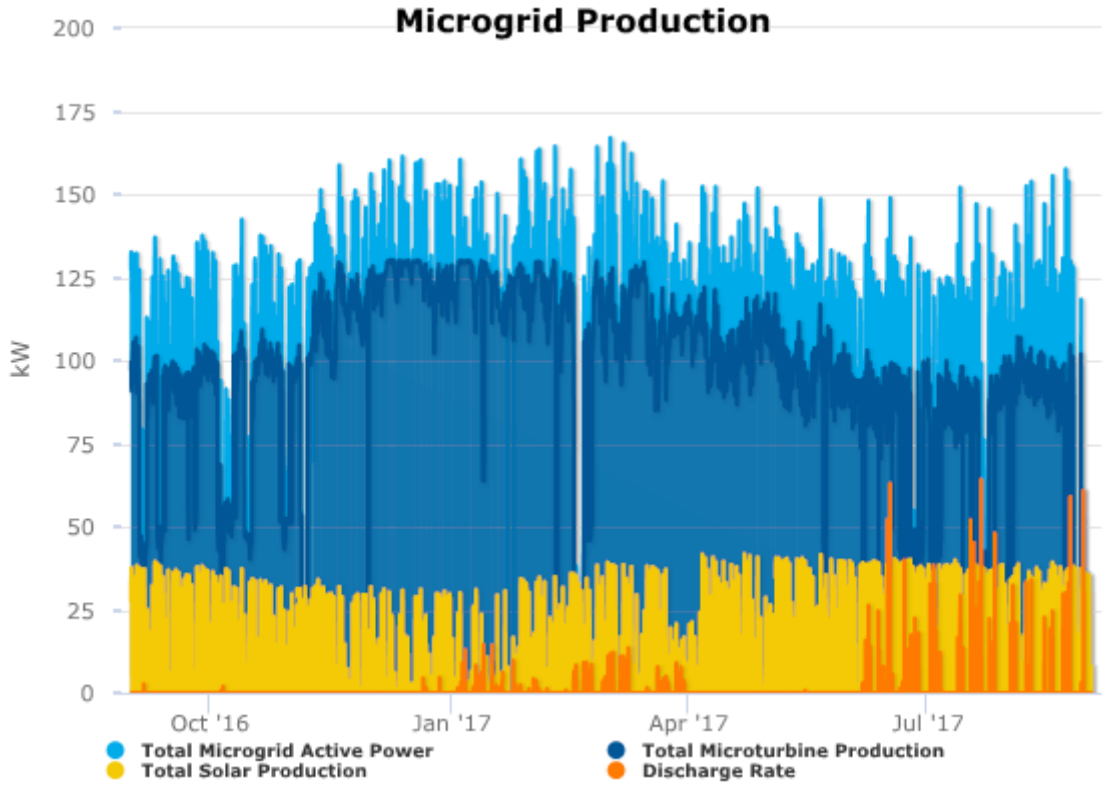


Control System



Usage

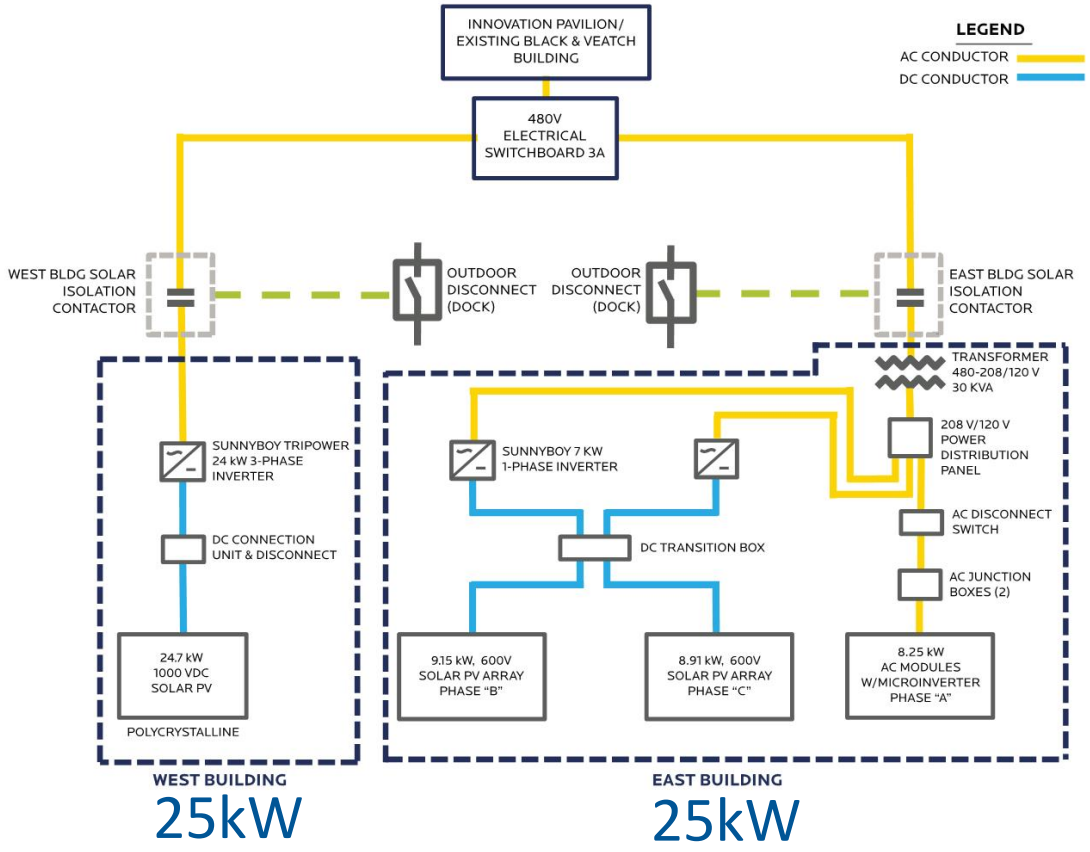

Microgrid Power
175
150
125
100
75
50
25
0
kW
Oct '16
Jan '17
Apr '17
Jul '17
Exported Power
Purchased Power

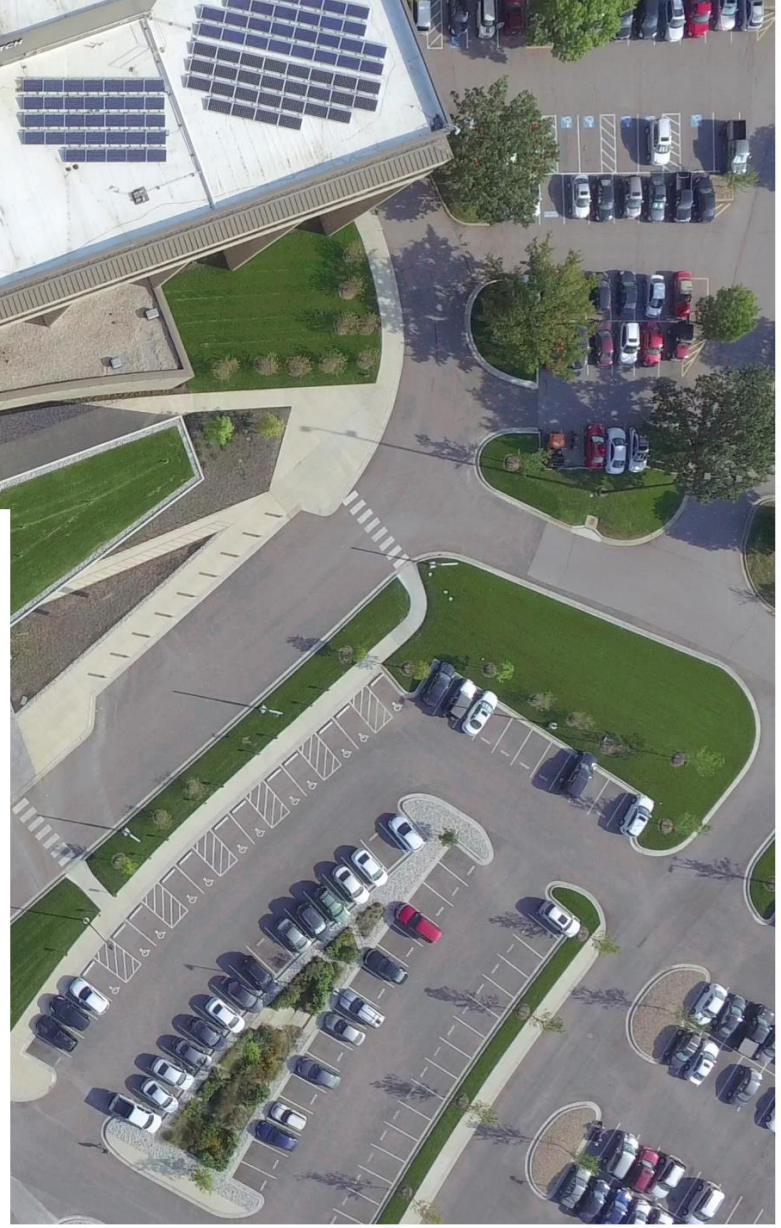

Microgrid Production
200
175
150
125
100
75
50
25
0
kW
Oct '16
Jan '17
Apr '17
Jul '17
Total Microgrid Active Power
Total Solar Production
Total Microturbine Production
Discharge Rate

Individual Technologies

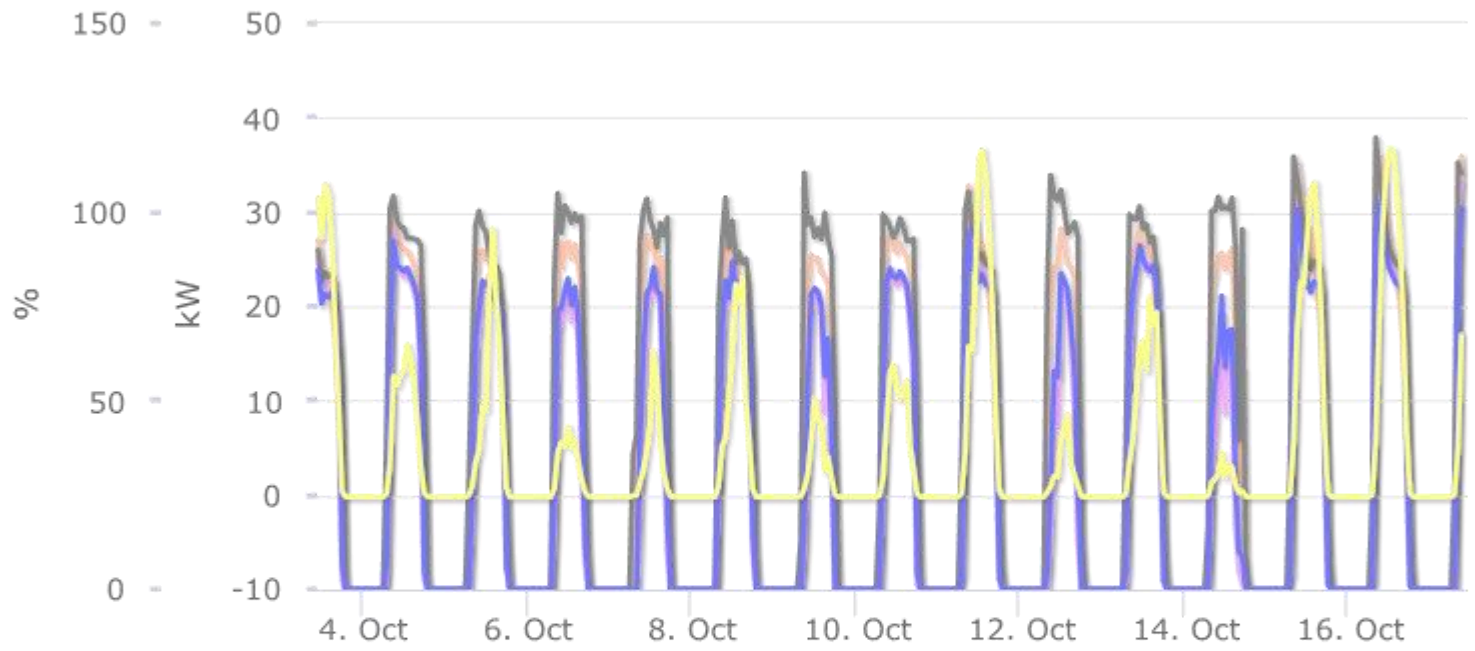
Primary Control Layer

Solar PV


INNOVATION PAVILION/ EXISTING BLACK & VEATCH BUILDING
480V ELECTRICAL SWITCHBOARD 3A
LEGEND
AC CONDUCTOR
DC CONDUCTOR
WEST BLDG SOLAR ISOLATION CONTACTOR
OUTDOOR DISCONNECT (DOCK)
OUTDOOR DISCONNECT (DOCK)
EAST BLDG SOLAR ISOLATION CONTACTOR
TRANSFORMER 480-208/120 V 30 KVA
SUNNYBOY TRIPOWER 24 kW 3-PHASE INVERTER
SUNNYBOY 7 KW 1-PHASE INVERTER
208 V/120 V POWER DISTRIBUTION PANEL
DC CONNECTION UNIT & DISCONNECT
DC TRANSITION BOX
AC DISCONNECT SWITCH
AC JUNCTION BOXES (2)
24.7 kW 1000 VDC SOLAR PV
POLYCRYSTALLINE
9.15 kW, 600V SOLAR PV ARRAY PHASE "B"
8.91 kW, 600V SOLAR PV ARRAY PHASE "C"
8.25 kW AC MODULES W/MICROINVERTER PHASE "A"
WEST BUILDING
25kW
EAST BUILDING
25kW



PV Performance Ratio (P/Pmx)/(1000*Irr [W/m2])



Solar PV

- **Multiple Technologies** LAB
  - Monocrystalline (1ø, 600V)
  - Polycrystalline (3ø String, 1000V)
  - Polycrystalline (1ø String, 600V)
  - Polycrystalline (1ø Micro Inv)

Microturbines

- Shared Natural Gas Compressor
- CHP Providing Boiler Preheating
- Mechanical System (Most Complex)
- Islanding control

Microturbines

- Mechanical System
  - Turbine Exhaust Heat Recovery (Cold Season)
  - Glycol Loop into Building
  - Building Boiler Water Preheat
- Efficiency
  - Summer: 29% (nameplate electrical efficiency)
    - Warm season is electric only
  - Winter: 68% (electrical + recovered thermal energy)
    - Heat recovered increase glycol loop temp 160 F – 180 F
    - Heat rejected via heat exchanger to boiler feed

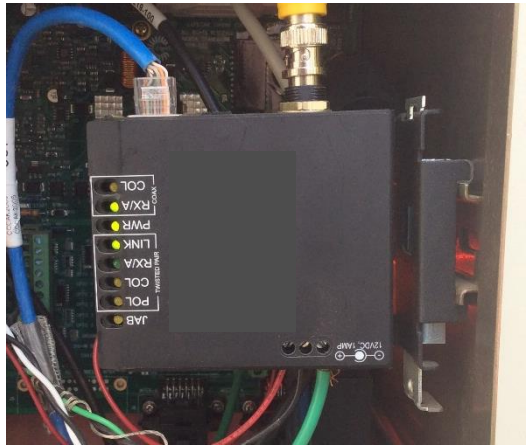
Microturbines

- Filter Clogging – Filter Collapse
  - Consider Seasonal Siting LESSON
  - More Frequent Visual Inspections LESSON
  - Consider Additional Spare Parts – Lead Time, No LTSA LESSON
  - Consider Additional Instrumentation LESSON

Microturbines

- Compressor Failure
  - Consider Redundancy LESSON
  - Additional Troubleshooting Time – Consider LTSA LESSON
- Blower Failure
  - Consider additional spare parts – Lead Time LESSON
  - Consider Redundancy (swapped blower from MT2) LESSON
  - Additional Troubleshooting Time – Consider LTSA LESSON

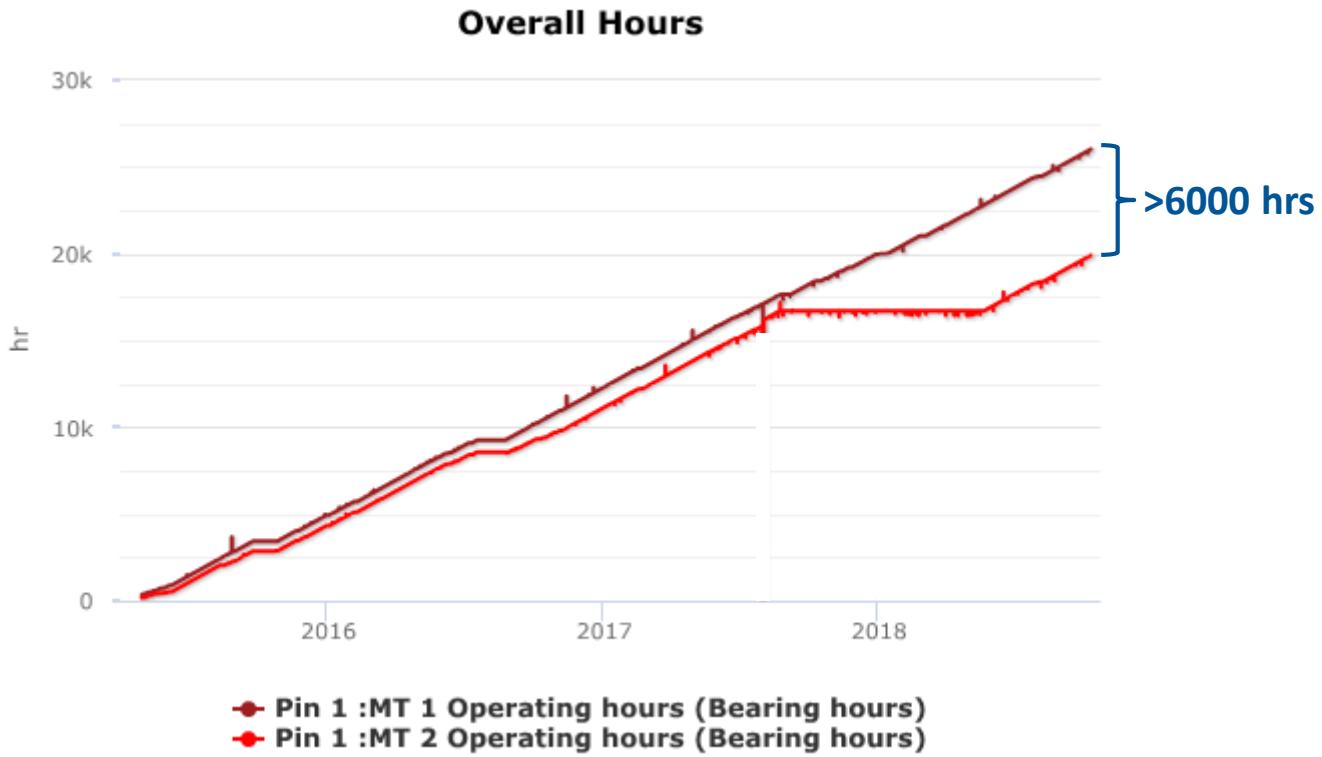
Microturbines



- Data Converter Failure / Coms Faults
  - Limited Diagnostic Capability via HMI
  - Consider Redundancy LESSON
  - Additional Troubleshooting Time – Consider LTSA LESSON
- OEM Islanding Program Modifications
  - Modified Program to Reduce Trips during Islanding
  - Consequently Complicated HMI Islanding Routine
  - No OEM Source Code – Consider LTSA LESSON
  - Additional Troubleshooting Time – Consider LTSA LESSON

Microturbines

- Growing Disparity of Running Hours Between Units
  - Maintenance Intervals No Longer Lining Up
  - Consider Redundancy LESSON



Battery Energy Storage System (BESS)

- Lithium Ion Storage (100kW / 100kWh)
- BMS + PCS + MSC
- Islanding Capable*

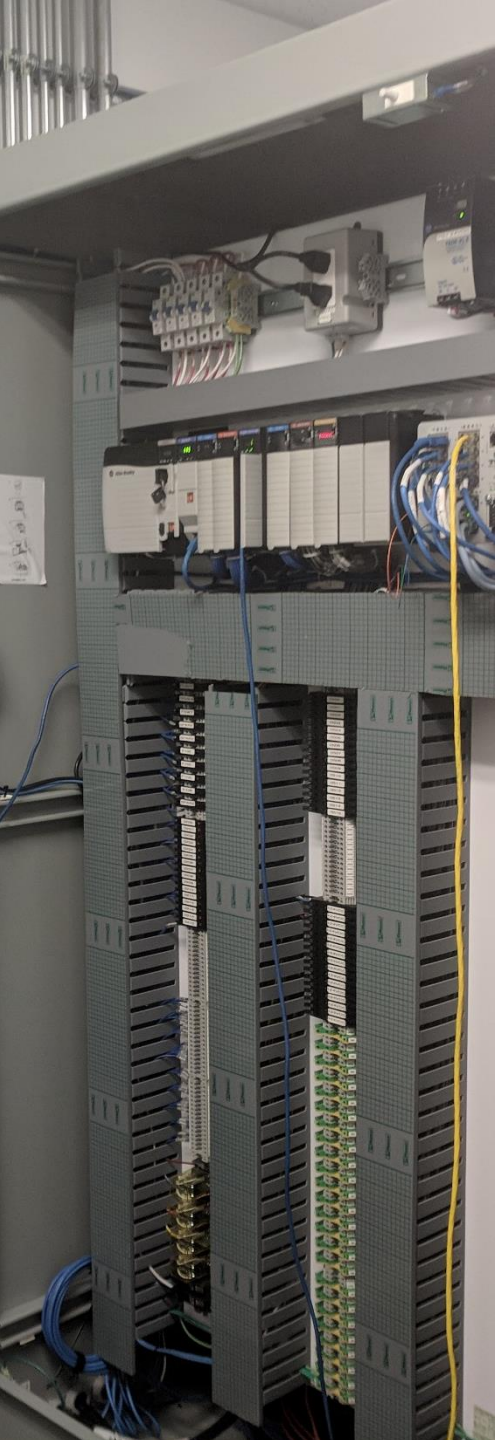
Battery Energy Storage System (BESS)

- PCS: “UPS” Style Architecture
  - Separate Line and Load Contactors
  - Islanding-capable, but not in our configuration
  - Consider All Future Desired Use Cases during Design LESSON
- Communications Fault (Unspecified)
  - Limited diagnostic capability via HMI
  - No OEM Source Code – Consider LTSA LESSON
- Plans for Future BESS Islanding Configuration LAB

Microgrid Controller

- Supervisory Control
- Control Strategy – Programming Originally Outsourced
  - Limitations of Control Program were Realized During Operation
- Secured In-house Resources for Programming
  - In-house Modifications for: Manual BESS Control, Watchdog Timer Adjustment, Scheduling Routine, Enhanced PV Monitoring, Supervisory Islanding LAB
  - Now have In-house Programming Capability LAB
  - Anticipate Modifications After Commissioning LESSON
  - In-house Resources? (Consider LTSA) LESSON

Secondary Control Layer

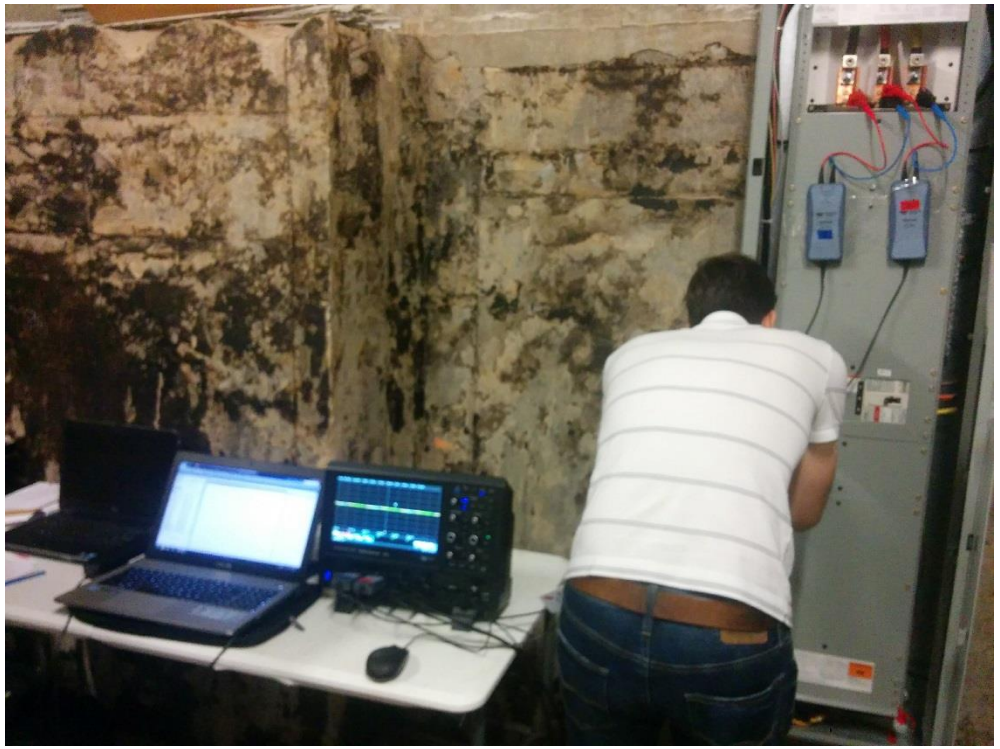


Microgrid Controller - Testing

- Developed Client's Control System on Same Platform
- Simulated Client's Control System Prior to Implementation
  - Allowed On-site FAT LAB
  - Collaborated Testing Campaigns Between sites LAB

Microgrid Response Modeling

- University Graduate Program Collaboration
- Transient Modeling & Real-World Verification LAB



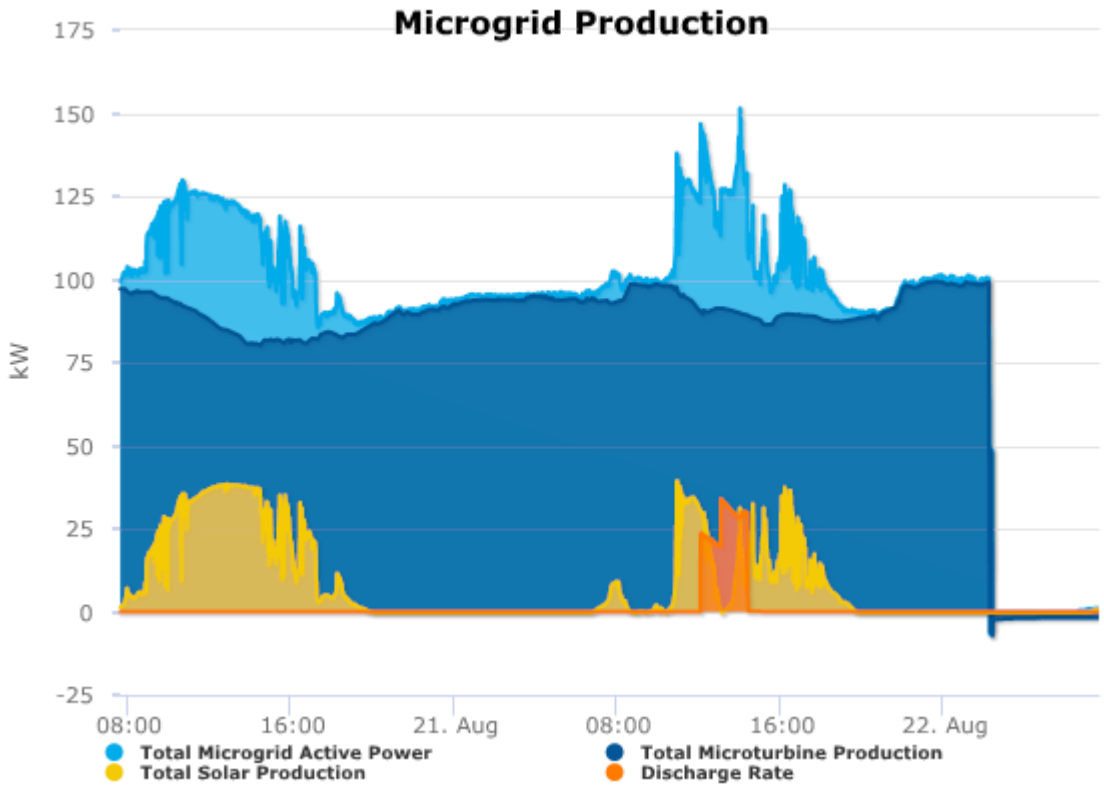
Dispatch Optimizer

- Tertiary Control: Developed In-House, After Microgrid LAB
- Outputs: Rolling Hourly DER Setpoints
- Inputs: Rates, Weather, Efficiency, BESS SOC, Load Forecasts, Fuel Costs
- Evolving: Three Major Revisions, Additional Applications LAB

Tertiary Control Layer

Dispatch Optimizer

- Basis for “Smart” Wellfield Ground Water Extraction LAB
- Performance during Solar Eclipse 2017 LAB



Tours

- **Over 200 Tours**
- **Students: Over 600 Pre-graduate Level Student Guests across 30 Groups** LAB

Summary of Lessons Learned

- Develop In-house Expertise LAB
- Collaborate with Clients and Universities LAB
- Consider Future Use Cases LESSON
- Anticipate Desire for Controls Changes LESSON
- Consider LTSA for More Complex Systems LESSON
- Consider Redundancy LESSON

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