Microgrid Applications: Case Studies of Energy Cost Optimization

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Overview

- Defining a Microgrid via Sequence of Operations
- Identifying Cost Effective Microgrid Solutions
- Identifying Opportunities
- Solutions Utilizing Microgrid Applications
- First Microgrid – Middle Tennessee State University
  - System Overview
  - Lessons Learned
  - Cost Optimization Highlights

Overview (Continued…)

- Future of Microgrids – Dominion Power Kitty Hawk
  - System Overview
  - Batteries
  - Cost Optimization Highlights
- Current Microgrids – Santa Clara University
  - System Overview
  - Cost Optimization Highlights

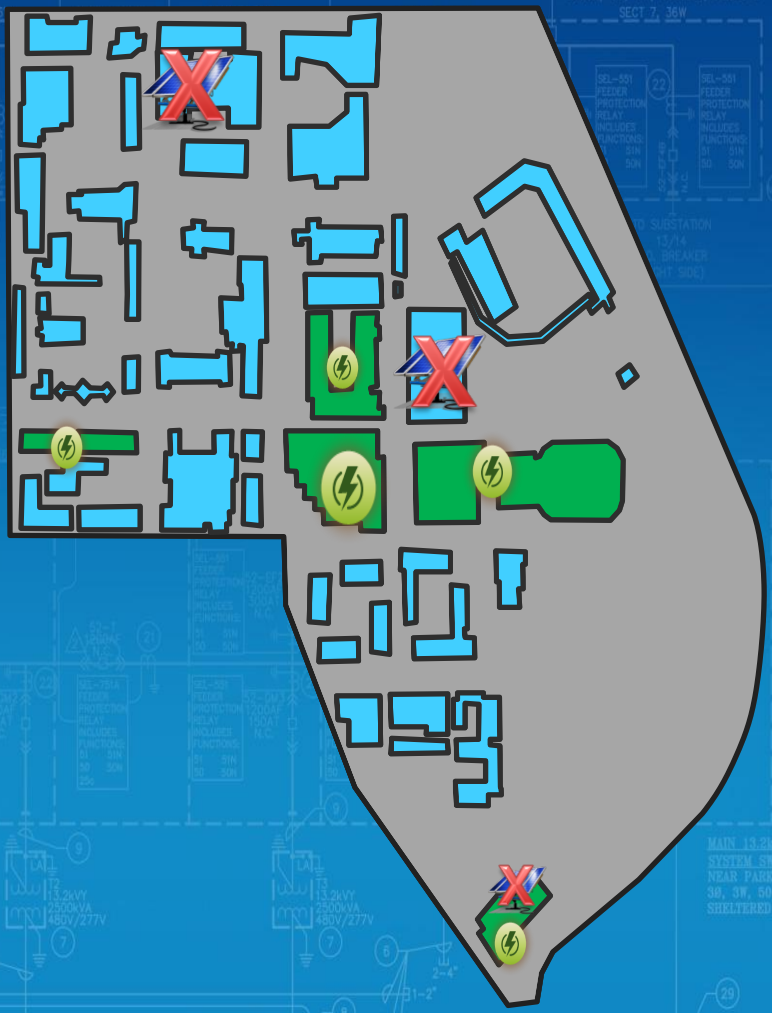
Normal Campus Operation

- Utility feeds Circuit A and Circuit B

Utility Outage Without Microgrid

(Short term outage without microgrid)

- Buildings disconnect from utility
- Buildings with Generators get power (Run Time Varies)
- Solar shuts off for safety (UL1547 Requirement)
- Rest of campus is dark.
- **Campus operations cease.**



Extended Utility Outage With Microgrid

- Campus disconnects from Utility
- New Gen at Pump House Energizes Circuit A
- New Gen at Facilities Energizes Circuit B
- Solar Provides Power During Outage
- Smaller Gens shut down
- Fuel on site for minimum of 72 hrs of run time
- Mid sized gens can parallel for added surety and efficiency
- Damaged circuits can be identified, isolated, and shut down from operator station
- Loads can be reduced by microgrid operator (whole buildings or loads within buildings)
- A and B Circuits can be tied together for further backup and efficiency
- When utility returns, campus synchronizes, reconnects, and shuts down gens
- Momentary or no outage when utility drops and none when campus reconnects
- **Campus operations continue throughout**

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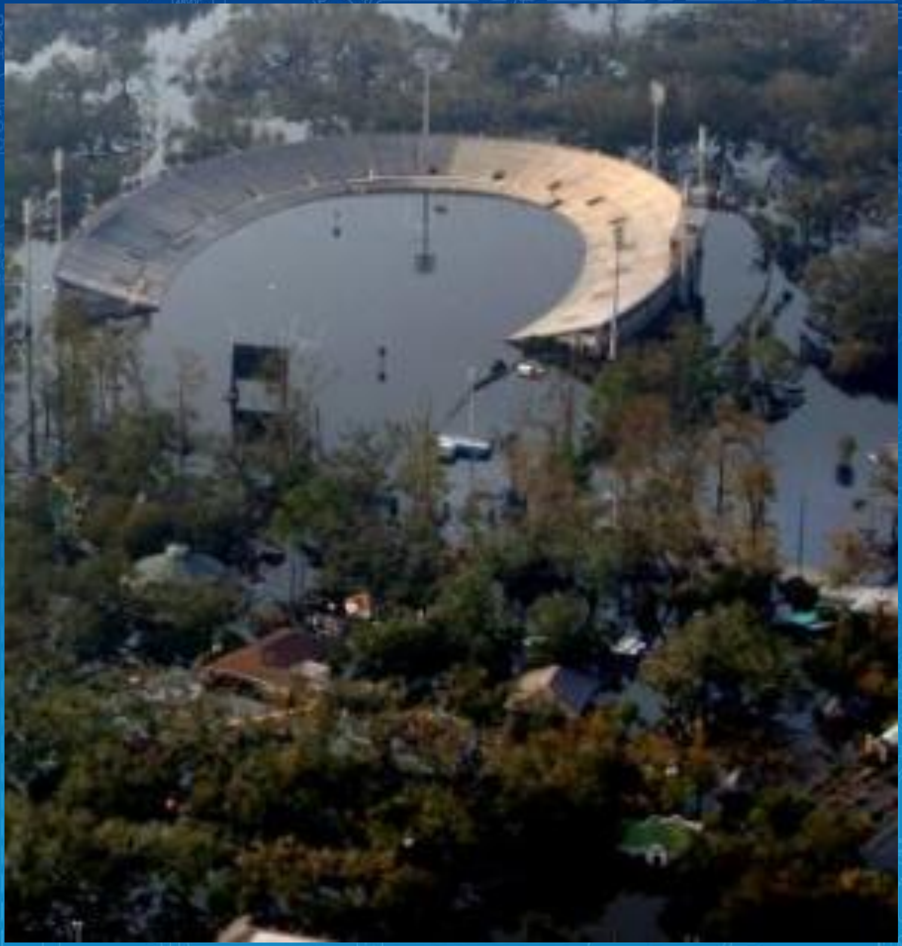
Identifying Cost Effective Microgrid Solutions



Tulane University Stadium Post-Katrina

- **May pay for itself through a single event** (ie. Tornado, Flood, Snowstorm, extended Power Outage)
- Reviewing existing infrastructure → Utilizing existing infrastructure as much as possible will minimize project costs
- Realistically monetize the value of uninterrupted campus power given likelihood of specific events
- Lessons Learned: Nothing is as effective as an onsite visit to verify and understand the existing infrastructure

Opportunities to Lower Microgrid Costs

- Potential for Utility & Government Grants
- Potential for Tax Credits
- Savings from decreased energy costs
- Value from providing ancillary services

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Identifying Opportunities

- Overcome Risks from Unreliable Utility Power
- Enable Stranded Assets (ie. Gas-Turbines)
- Solve Power Quality Issues (ie. Voltage)
- Enable Campus-Wide Black Start
- Team with experts to overcome stringent Interconnection Requirements
- Stringent Renewables Interconnection Requirements

Identifying Opportunities (Continued…)

- Identify and work within Import/Export Limitations
- Firm Intermittent Renewable Energy
- Overcome Infrastructure Limitations
- Prevent costly loss of power or poor power quality events, even if it is momentary or a voltage sag
- Reduce Energy Costs
- Improve Electrical Operations Safety
- **Become a disaster relief center, not a disaster site**

Solutions Utilizing Microgrid Applications

- Infrastructure Retrofits (ie. SWGR, Gas Turbines)
- Additional Equipment (ie. Back Up Generators, Batteries)
- Additional Control Infrastructure (ie. Fiber)
- Additional Controls (ie. Voltage/Frequency Regulation, Ramp Rate Control)
- Enable Islanding with switchgear automation
- Seamless Transition from Grid-Connected to Islanded and Islanded to Grid-Connected

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Solutions Utilizing Microgrid Applications (Continued…)

- Import / Export Control
- PF Control
- Renewable Firming
- Utilizing Storage for energy optimization: demand charges, time of use, equipment efficiency
- Load & Generation Management (as Needed)
- Automated Safe Electrical Operations & Controls
- Kiosk to share with public
- Data that can be shared with students for educational and research purposes

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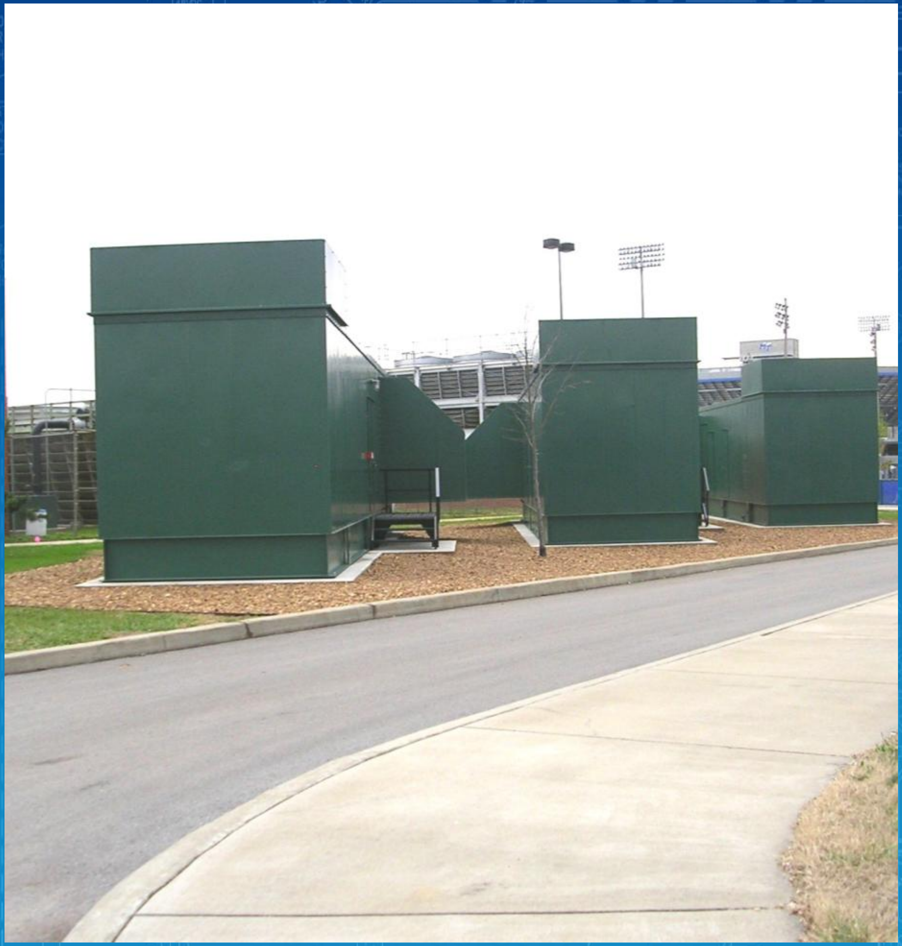
First Microgrid – Middle Tennessee State University

- 10 MW system
- Utility Feed
- Installed 5x2MW generators, TX, SWGR and other infrastructure
- Custom software
- Variable Price Interruptible (VPI)
- Islanding Mode
- Remote monitoring

Middle Tennessee State University: Cost Optimization



- Diesel Generators were added to minimize demand charges. MTSU signed up for TVA's Variable Price Interruptible rate and this would finance the project alone. Inherently, additional value was gained as they also acted as backup / standby generators.
- Load Sharing Lines and generation/load balancing controls allow increased fuel efficiency, decreased emissions, and reduces operating expenses

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Middle Tennessee State University: Lessons Learned

- Involve Customer, Sales, and Technical teams from very beginning to prevent unforeseen cost
- Use or install dedicated fiber and/or set up cyber secure virtual private network. Saving costs by operating unprotected on existing network exposes system to nefarious student activity.
- Ensure that project financing is guaranteed for the life of the project. In this case, the utility VPI program which financed the project was not contractually guaranteed for a set duration and the utility cancelled the program after 2 years.

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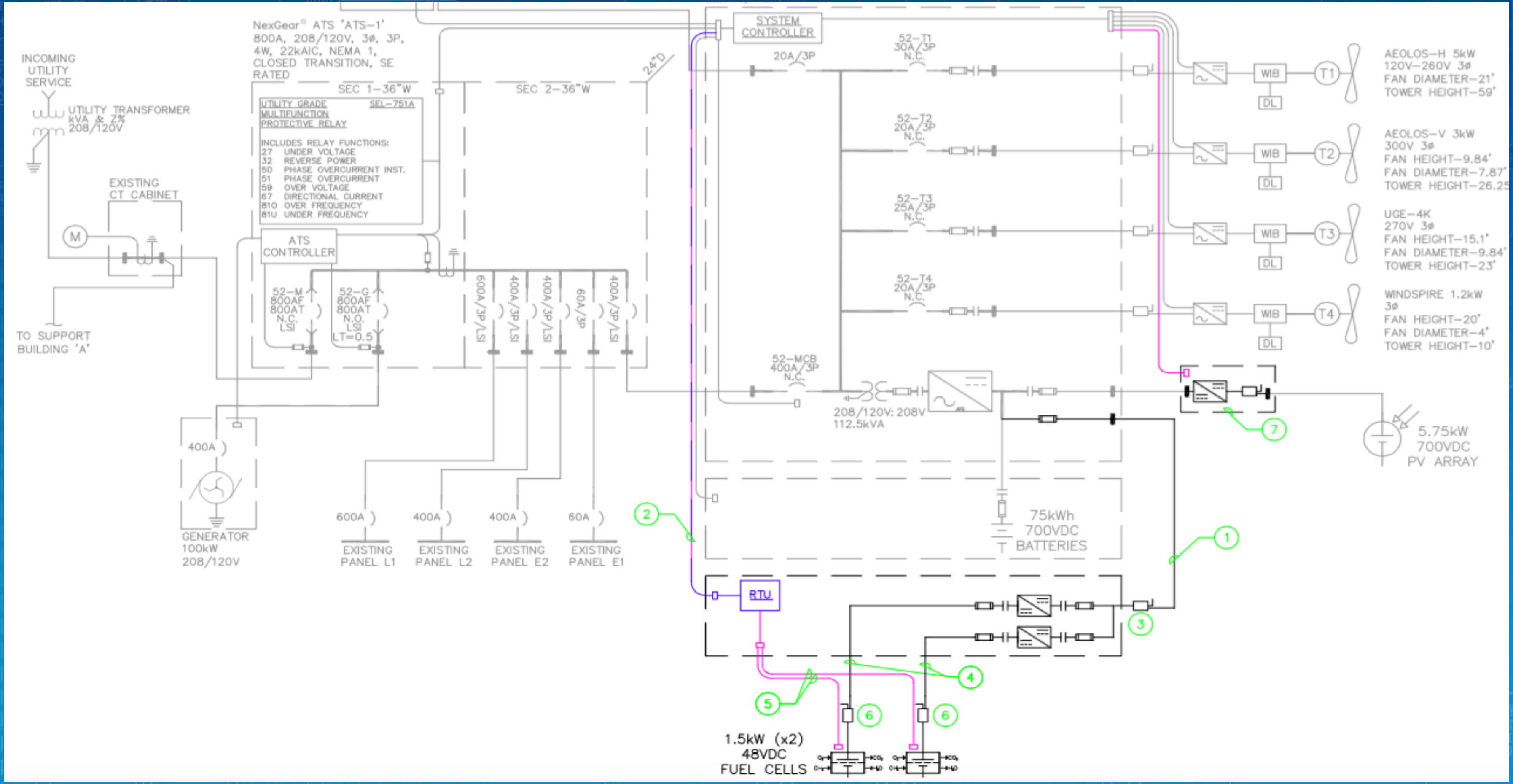
Future of Microgrids – Dominion Power (Kitty Hawk)



Dominion Power (Kitty Hawk): Cost Optimization

- Optimized costs of integrating multiple systems: Batteries, Fuel Cells, and PV via a common DC Bus. The common DC bus outputs to the system via a bulk central inverter. This topology optimizes total project costs via engineering, equipment, and maintenance. This is due to lower count equipment, lower points of failure, and lower integration requirements.

- Maximized battery system value by peak shaving / load shifting

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Energy Storage System - Batteries

- Grid-Forming Capabilities
- Opens avenue for increased system versatility and robustness (value generation during nominal, backup when critical, increased renewable penetration and effectiveness)
- Pros: Inherently beneficial for most microgrid applications
- Cons: Batteries are expensive
- Near Future Outlook: Batteries costs are dropping and they are becoming more cost effective. Similar to solar's cost trend.

Example Battery System

Battery Management System Overview

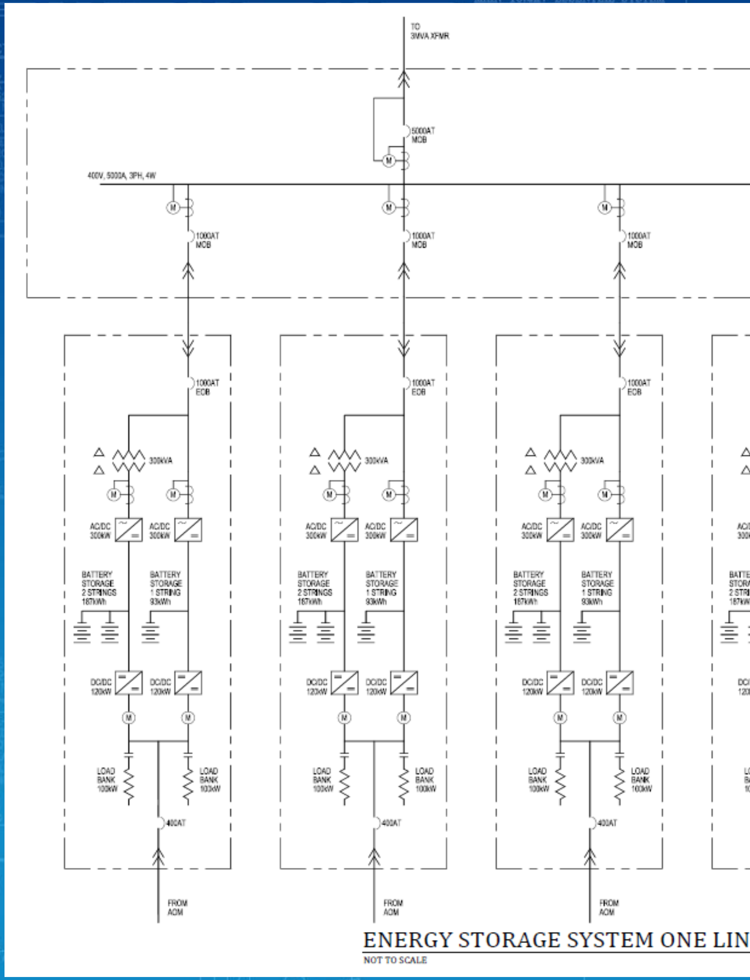
- Battery Modules: 16
- Batteries Per String: 53
- Total Strings: 48
- Total Batteries: 2,544
- Storage Capacity: 4.494 MWh

Battery Specifications

- Nominal Battery Module Voltage: 12.8 Vdc
- Nominal Battery Capacity: 138 Ah

DC Bus

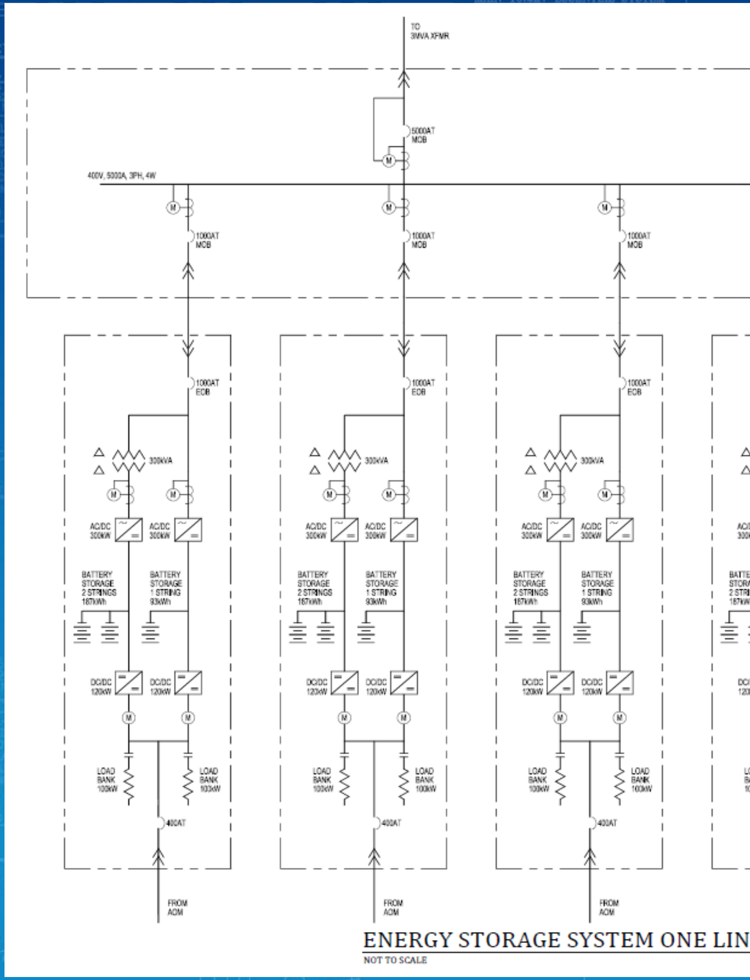
- Nominal Bus Voltage 700Vdc
- Minimum Bus Voltage 600Vdc
- Maximum Bus Voltage 800Vdc



Example Battery System (Continued…)

DC Bus (continued…)

- Nominal DC Current (1 String): 300Adc
- Peak DC Current (1 String): 535Adc
- Nominal DC Current (2 String): 450Adc
- Peak DC Current (2 String): 735Adc



INPUT DC

- Minimum DC Operating Voltage: 30Vdc
- Maximum DC Operating Voltage: 800Vdc
- Rated Power: 120 kW or 200A

OUTPUT AC

- Nominal AC Power, Continuous: 8.0 MW*
- Sustained Peak AC Power, Continuous: 10.8 MW*
- Maximum Peak AC Power, Continuous: 14.0 MW*

*Ratings Based on 3.2 MW Total Fuel Cell Contribution

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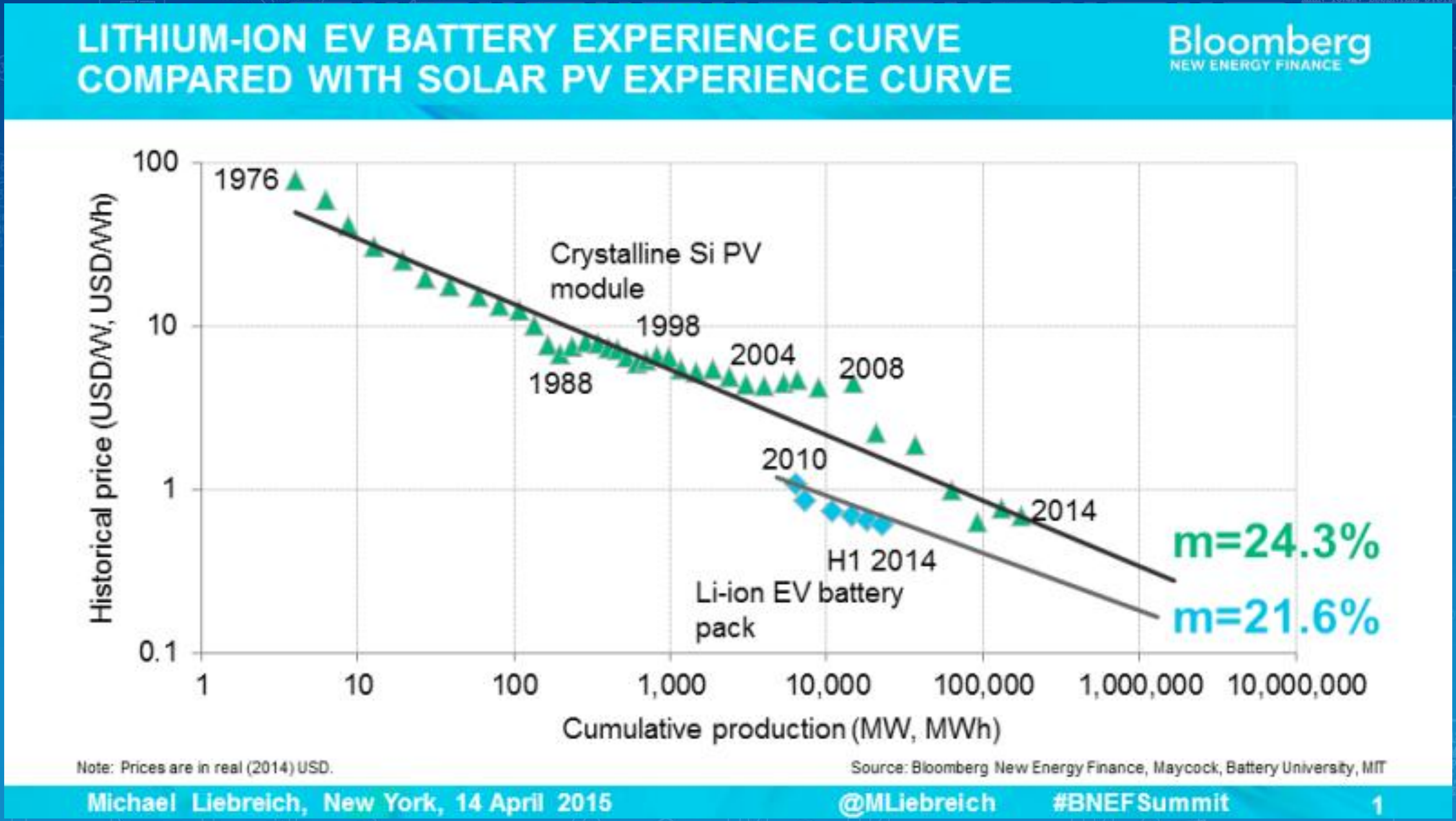
Battery System Costs



Current Microgrids – Santa Clara University

Currently under design and construction in partnership with Honeywell

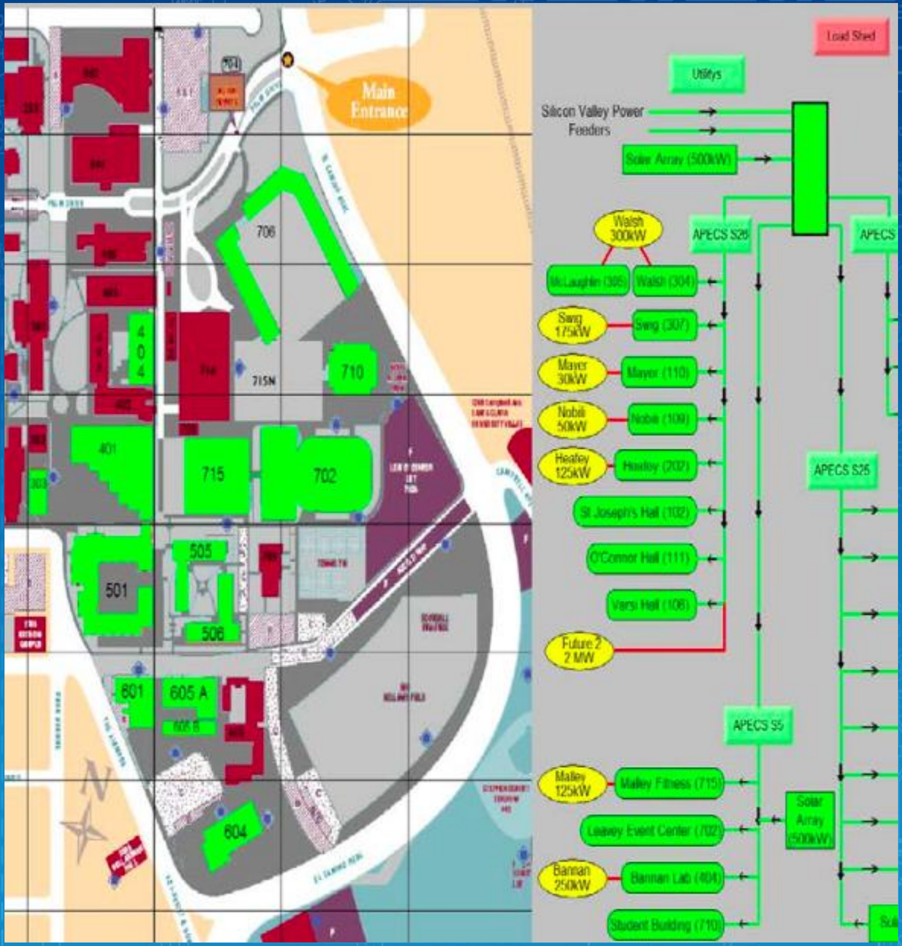
- Connecting existing stranded generation capacity
- Allows solar production during standby events
- Storage added for peak shifting of solar production
- Storage for firming solar and DG during standby events.
- Demand controls for campus to lower load during standby events with the ability to prioritize loads during standby events to allow flexibility of load profiles.

ie. San Jose Earthquakes (MLS team) play on campus resulting in peak demand charges

Santa Clara University: Cost Optimization

- Integrating larger existing (8) generators to Microgrid controller. Smaller existing generation (75 kW or below) would not be integrated into Microgrid system due to costs not worth the value. Small generators would continue to work as previously intended so their value is maintained.

Santa Clara University: Cost Optimization (Continued…)



- Installation and financing in stages
- Retrofits only as needed to modernize distribution system
- Reusing existing generators and distribution
- Understood Existing System, built a microgrid around it instead of reconfiguring the system
- Minimized trenching and other new infrastructure and equipment. Creative use of existing infrastructure can reduce project cost by a factor of 4

Questions???