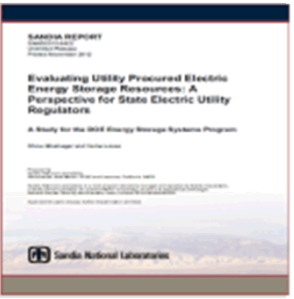

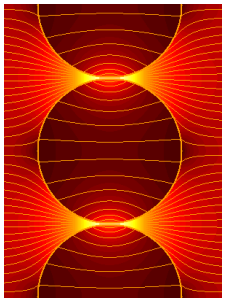

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Exceptional service in the national interest

Improving the Economics of UPS Systems by Adding Additional Storage Applications - Possibilities and Challenges

SAND2015-5561C

Daniel Borneo, P.E. - Sandia National Laboratories

Ben Schenkman - Sandia National Laboratories

Jeff Hires, P.E. / Sol Haroon - Pursuit Engineering, Inc.

John Bryan– EPC Power Corporation

Intersolar North America
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U.S. DEPARTMENT OF ENERGY NNSA

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Agenda

- Traditional UPS and Energy Storage Systems
  - Differences and Applications
- Using ES in a UPS application
  - Benefits and utilization
  - Characteristics for UPS+
- Energy Storage Systems
  - Batteries/Capacitors/Flywheels
- Project Considerations
  - 1-line
  - Cost consideration
  - Typical systems
- Summary

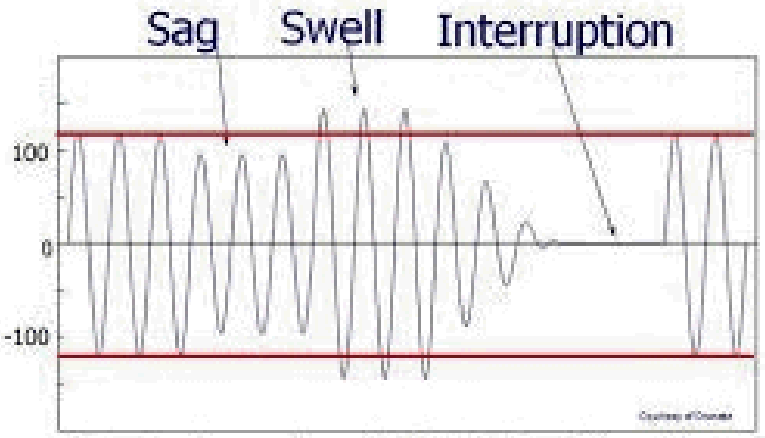
Traditional UPS and Grid Tied Energy Storage: what's the difference?

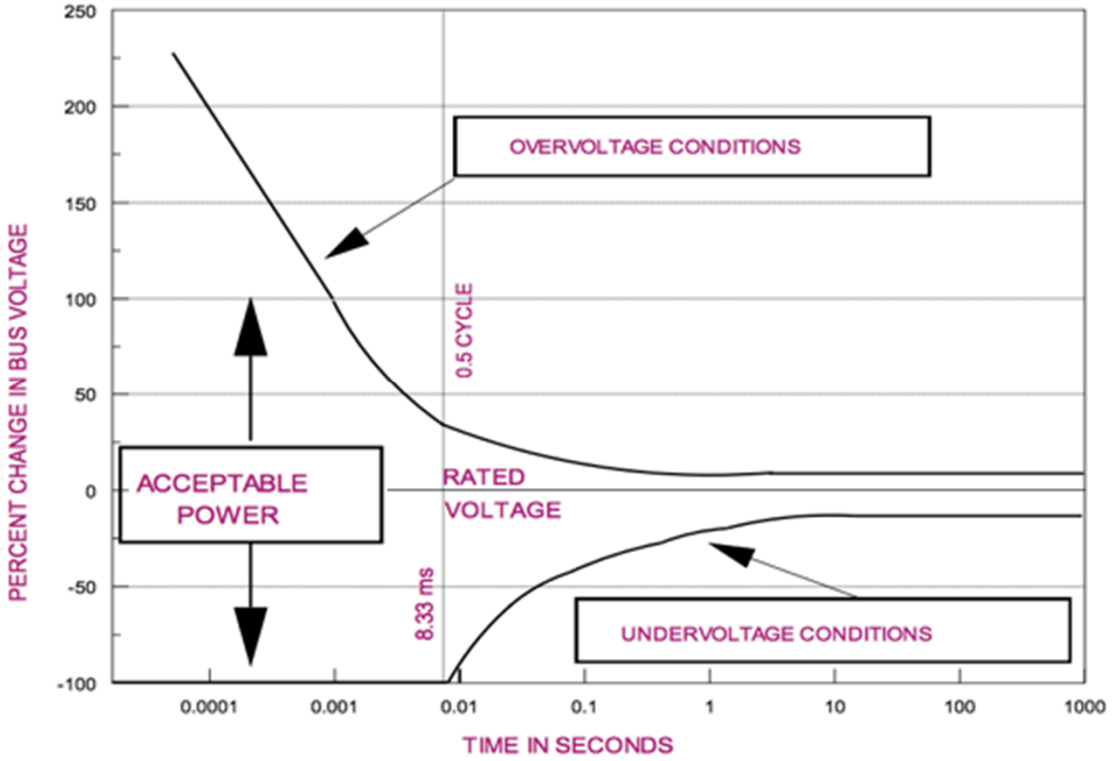
- Traditional UPS
  - Two stage conversion AC/DC – DC/AC
  - Inverter only needs Grid Forming capability (no grid following)
  - Standby mode of operation - Battery always on trickle charge but not supplying energy to the load
  - Maintenance Bypass to allow system to be off-line without impacting load

- Energy Storage
  - One stage conversion – AC/DC
  - Inverter needs to have Grid following as well as Grid Forming Capability
  - Multiple applications potential
  - Enhanced control function needed.

Application of Traditional UPS

- UPS
  - Power Quality/ Reliability: Can provide instantaneous ride through during power glitches or momentary interruptions.



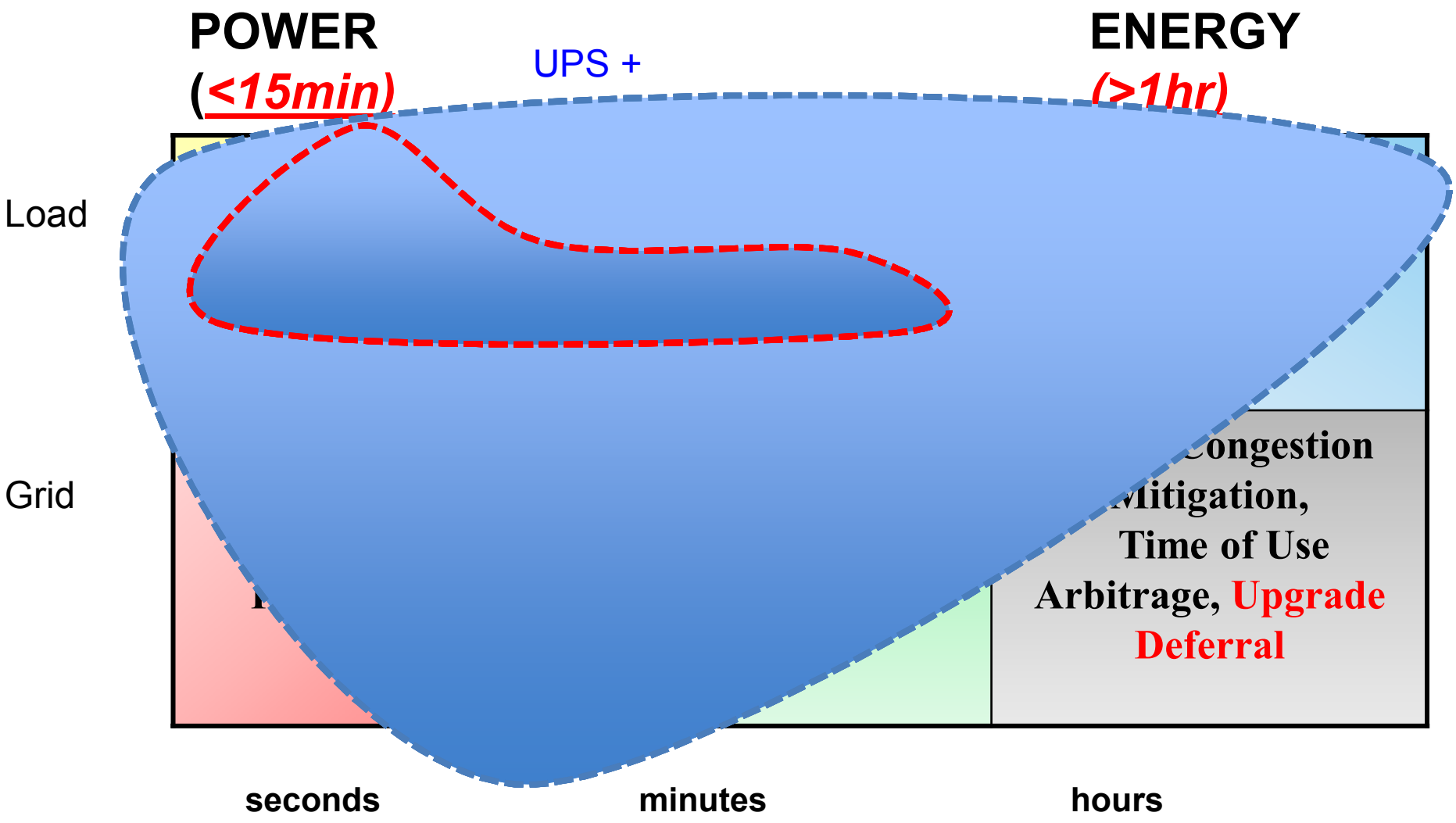


Applications of Grid Tied ES

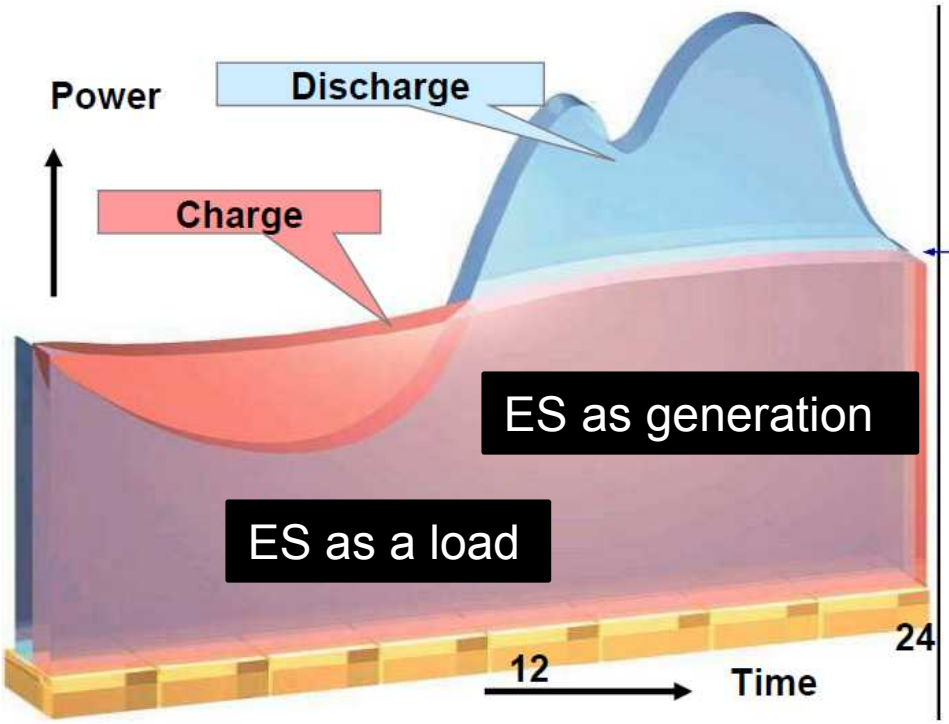
- In Addition to Traditional UPS Functions, Grid Tied Energy Storage Can Provide:
  - Demand Reduction: Decrease peaking load on the grid, which may eliminate need for upgrade to distribution equipment.
  - Renewable Energy and Distributed Energy support: Steady source of energy during any variability caused by Renewables or other Distributed Energy Resources (DER).
  - Generator Support: Load on Generator to increase generator efficiency and if matched to load, ES can be used to reduce generator run time.

ES SERVING MULTIPLE APPLICATIONS IS THE MOST COST EFFECTIVE

Energy Storage Applications

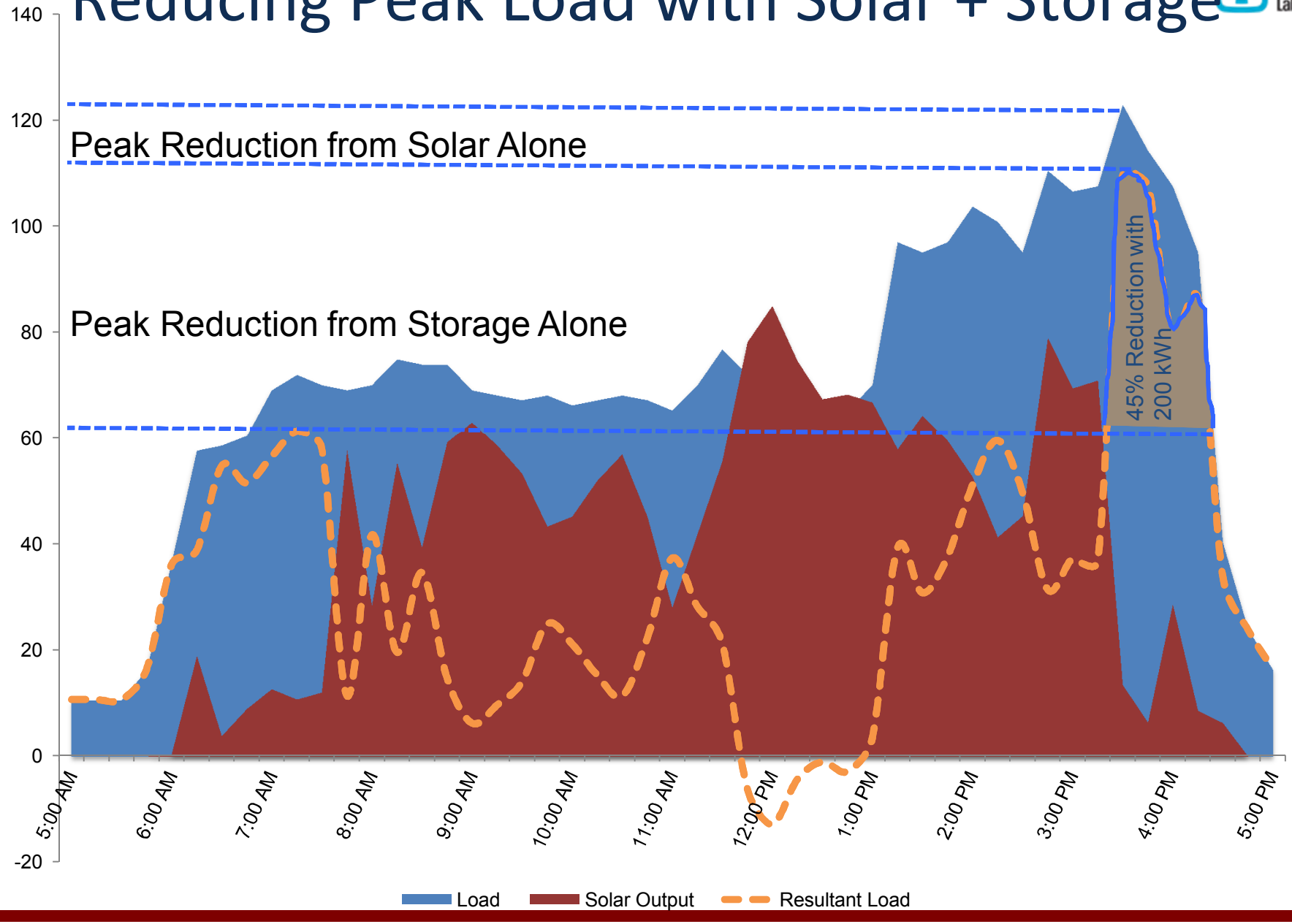


Storage Applications – Demand Reduction

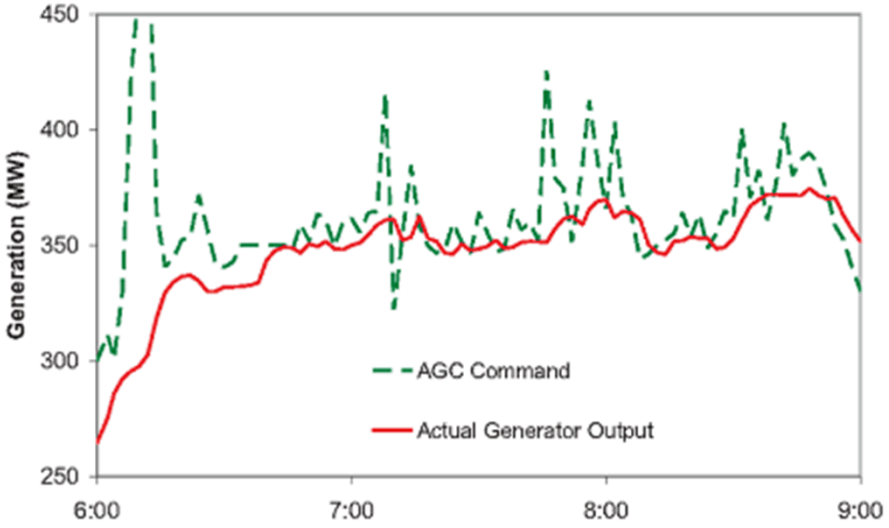


- Energy Shifting
  - Gen run-time reduction
  - DER Support
  - Arbitrage

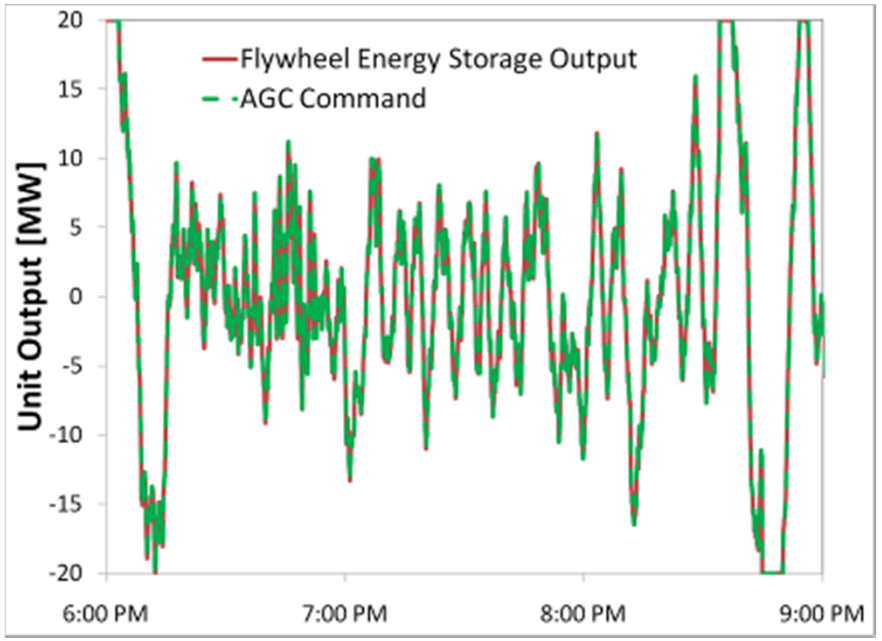
Reducing Peak Load with Solar + Storage



Fast Response: Speed Matters



Significance of ES Contribution



ES Attributes

- Storage has a near instantaneous response
- Provides Power Quality and ride through
- Helps firm variable generation like wind & solar

Storage for Load/Power balancing is new state of the art

Real World Grid Control is Dynamic

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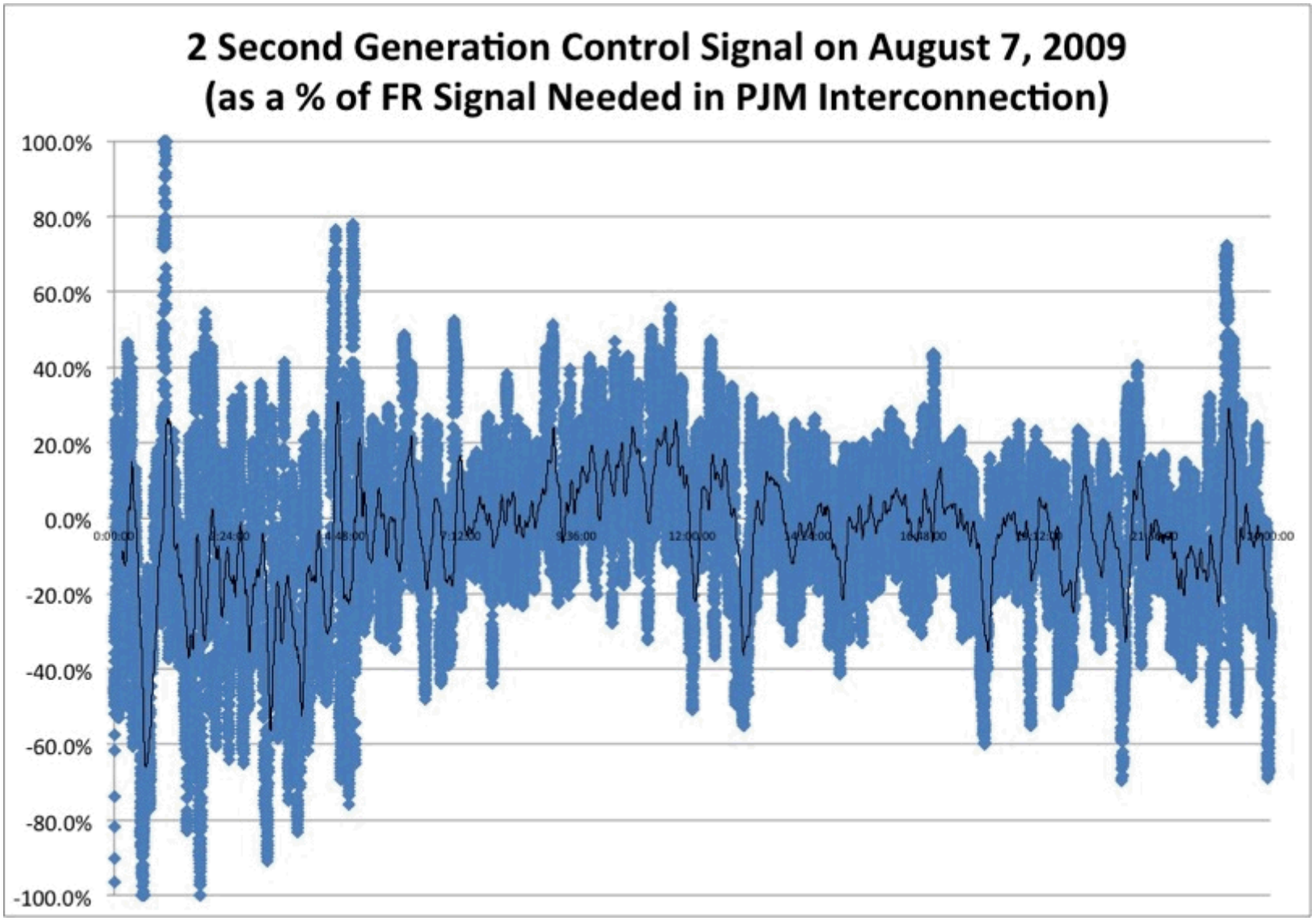

Power Stability is Continuous Process and Must Be Stable at ALL Points of Use

Benefits of using ES in a UPS+ Design

- Traditional UPS used only when there is a power disturbance or outage.
- ES can be used daily for other applications.
- Seamless transition of grid tied to islanded operation allowing higher renewable penetration, load leveling and power stability.

Where UPS+ can be utilized

- Situations where a 24/7 UPS is always critical.
  - Sporting venues/events – UPS only needed during event
  - Cultural venues/events – UPS only needed during event
  - Batch Processing – UPS only needed during certain process steps
  - Evacuation facilities
  - Microgrids

Characteristics of ES for UPS+

- Power Electronics need to be able to switch from Grid following to grid forming in typically less than 1 cycle
- Control Flexibility to allow different Applications

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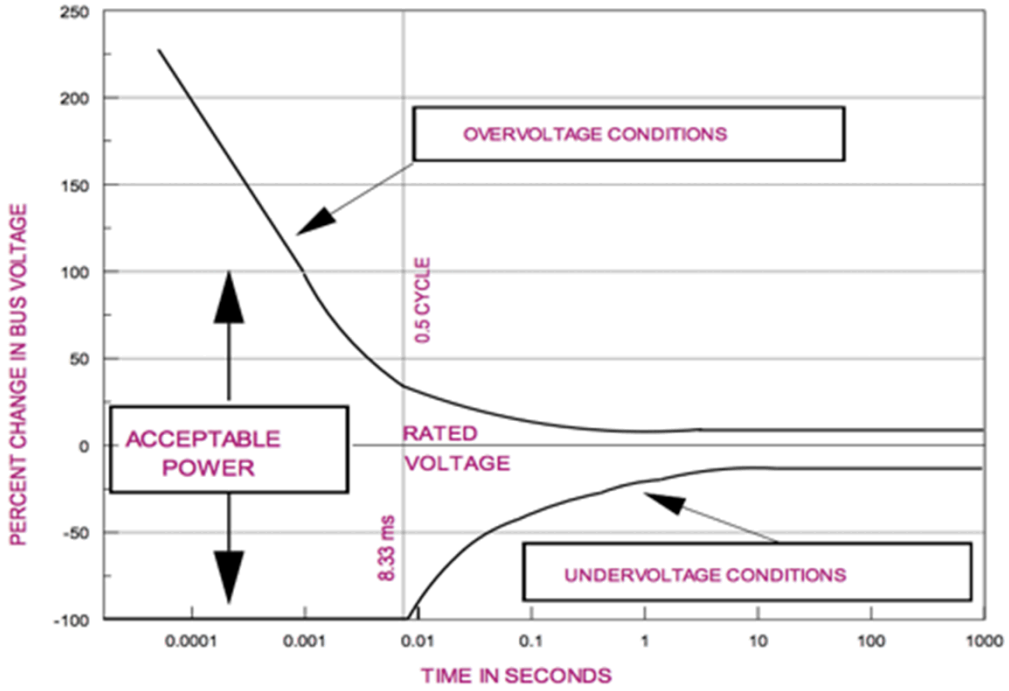


Storage Types

Type	Storage Mechanism	Common Duration	Cycles
Capacitor	Electrical charge	Seconds (minutes)	100,000's
Flywheel	Kinetic energy	Seconds / Minutes	1000's - 100,000's
Battery	Electro-chemical	Minutes (hours)	100's-1000's

Battery Options

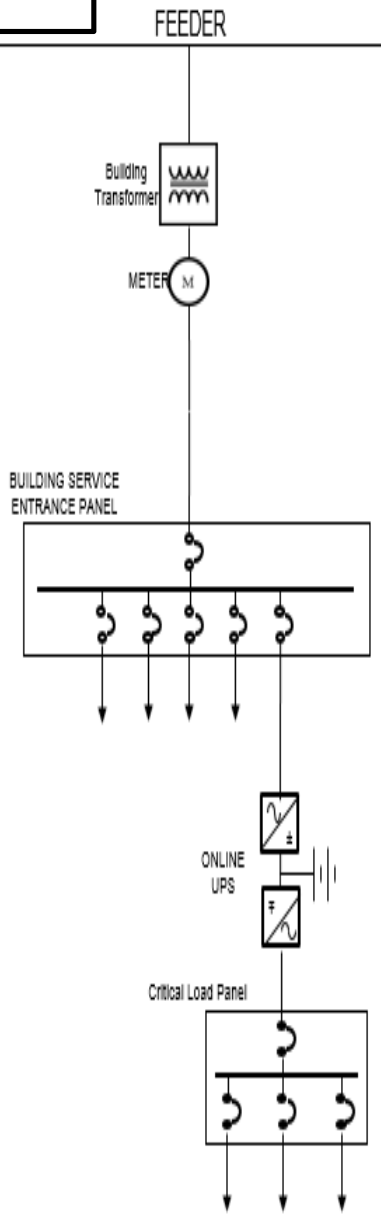
Type	Storage Mechanism	Common Duration	Cycles
Lead Acid and Advanced Lead Acid	Electro-chemical	Seconds to Hours	100's – 1000's
Li-ion	Electro-chemical	Seconds to hours	1000's plus
Vanadium Flow	Ion Exchange	Hours	1000's plus

An Old Farmer Takes Up Fishing

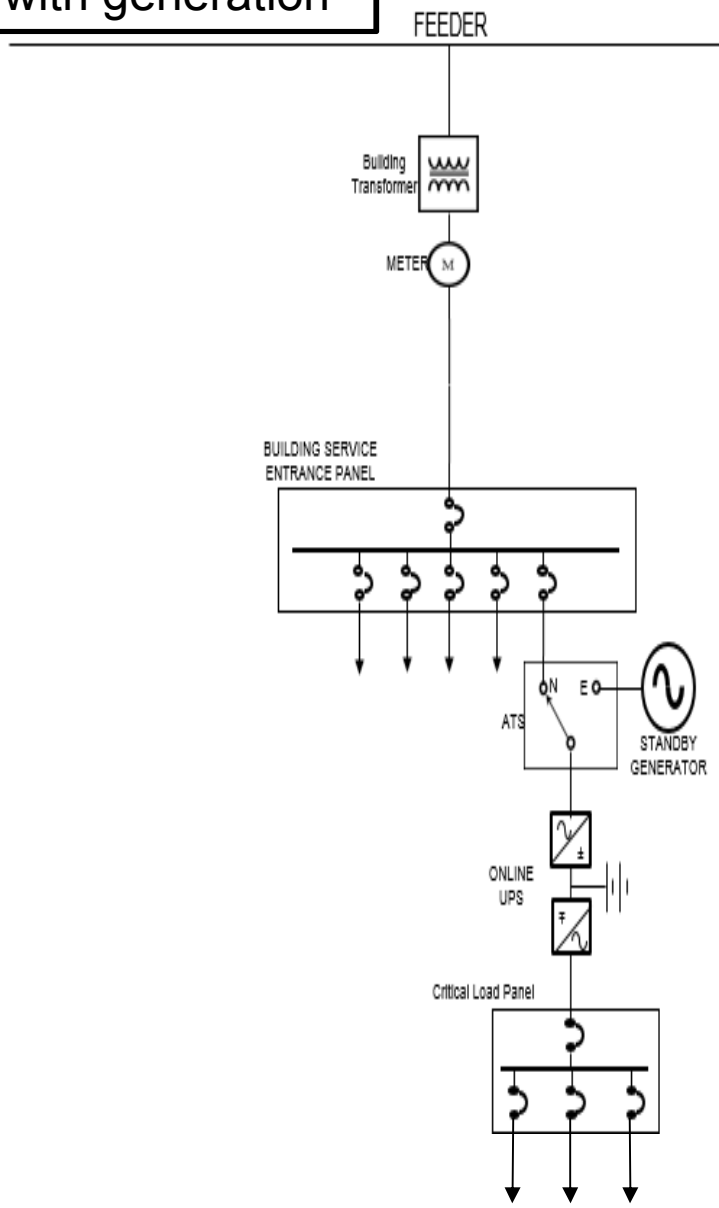
Project considerations - Energy Storage Design

- Understand the applications and design ES Appropriately
  - Optimize the kW and kWh
  - Some technologies better suited for long durations rather than short
  - Environmental concerns (extreme heat vs. cold)
- Design the control to perform the various applications and integrate with DER
  - Centralized vs. Decentralized controller
  - Utilize ES to offset demand charges, capacity constraints, and fuel charges
- Does system have necessary certifications
  - UL listed - If not, need to get buy-in from AHJ
- What codes and standards are required to install ES
  - Local and National

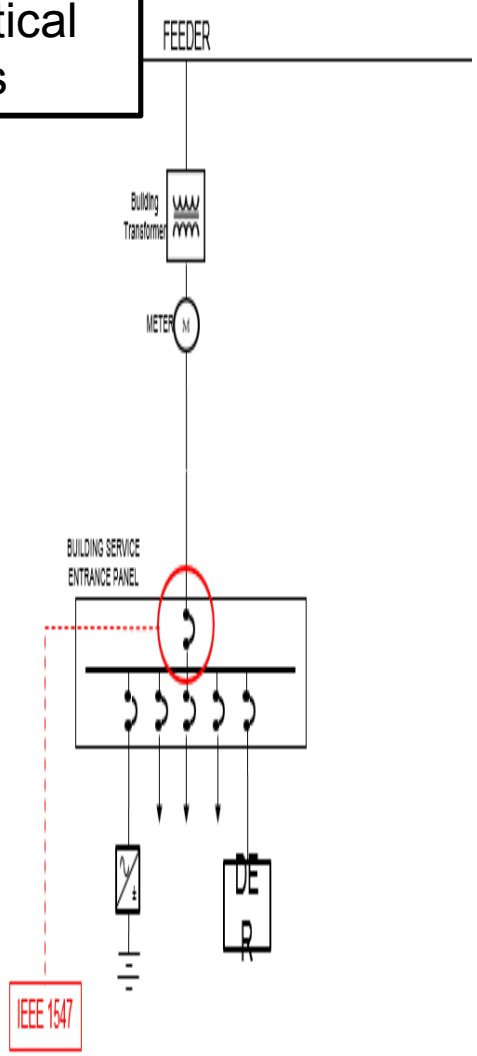
Traditional UPS



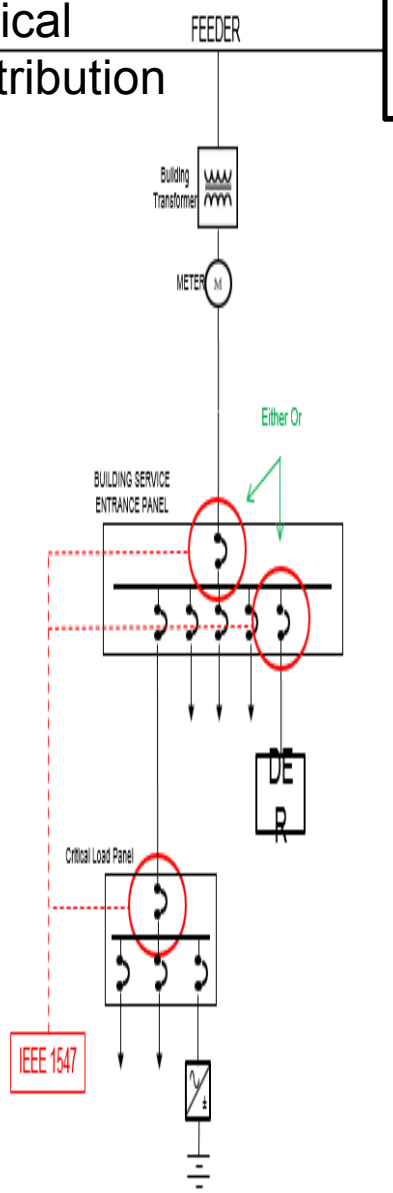
Traditional UPS with generation



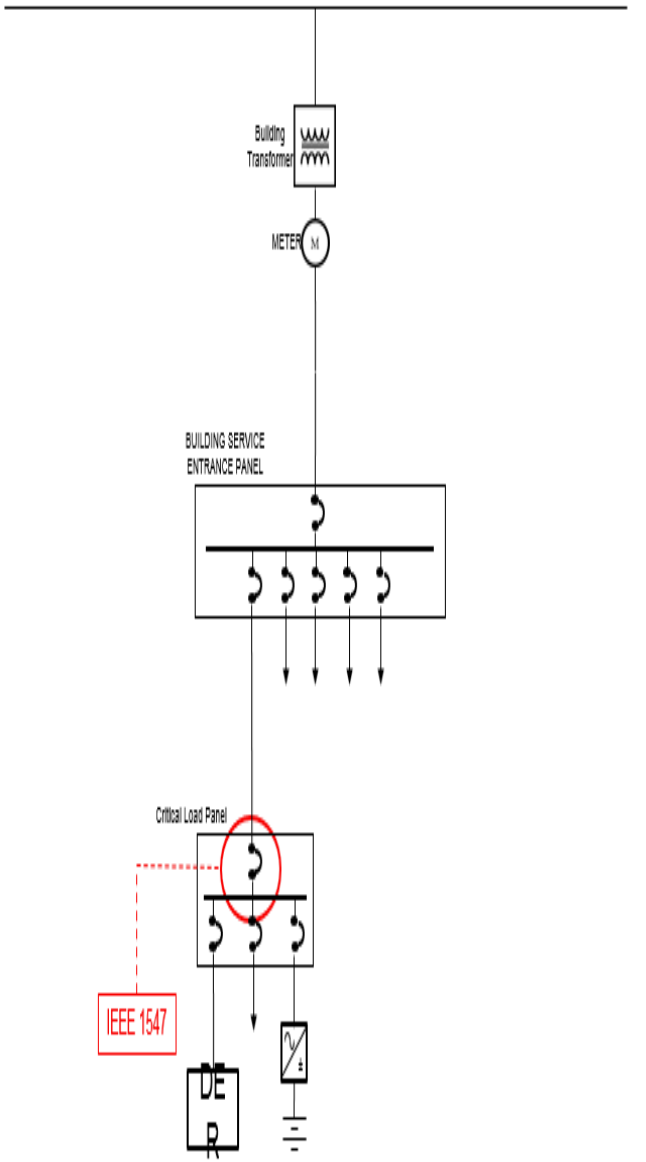
Critical bus



Critical Distribution



Critical panel



IEEE1547 = UL1741

ES Cost Considerations

Capital Costs

- Design/permitting/Studies
- Site and infrastructure prep
- ES System - $/kW and/or $/kWh
- Balance of Plant
- Installation

Operating Costs

- Efficiency factors
- Cycle life/replacement
- Operations
- Maintenance/Warranty
- Debt Service
- Disposal Cost

Cost metric must include a variety of important elements.

GS Battery Energy Storage
(An Example for Microgrids)

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HES RESCU
HYBRID ENERGY SYSTEM RUGGED ENERGY STORAGE CONTAINMENT UNIT

Compact ESS with Solar PV

Storage: 108kWh VRLA storage (@20hr)
- 432Vdc nominal bus voltage (36 batteries, series connected) with custom BMS

PV: 4.5kW (DC @ STC)
- Custom scalable and adjustable racking system

Inverters: Battery and PV Inverter
- 60kW (battery inverter)
- 9kW (PV inverter)

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GS

epcpower
excellence in power conversion

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1MW/4MWh Uni.System™

UniEnergy Technologies

UET is well positioned to serve a large portion of multiple accelerating and massive markets for instantaneous and seamless electricity storage

Gen3 advanced chemistry for extreme thermal stability and

- ✓20-60MW/acre @ 4h duration
- ✓20 year service life with no capacity fade
- ✓Unlimited cycles from 0-100% SOC

EaglePicher A/GES Technologies

Energy Storage Simulator

Software simulates a grid-tied energy storage system to calculate business case analysis/estimated ROI

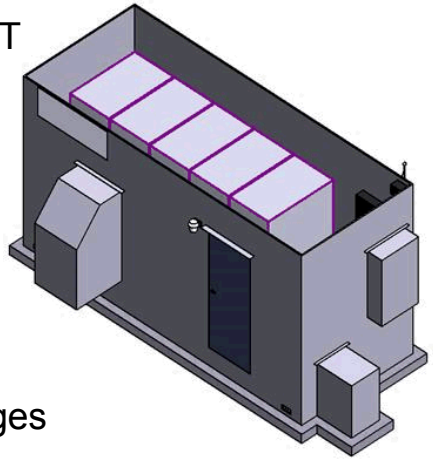
Load Profile

Tariff Definition → Operation Strategy = Modified Utility Costs

Storage Definition

Na-Beta Battery Project

- U.S. DOE ARPAe & EPT funded effort
- Planar Sodium Nickel Chloride
- + 30% Energy Density
- 10X Cost Reduction
- 30% Temp Reduction
- Transformational Changes



PowerPyramid™

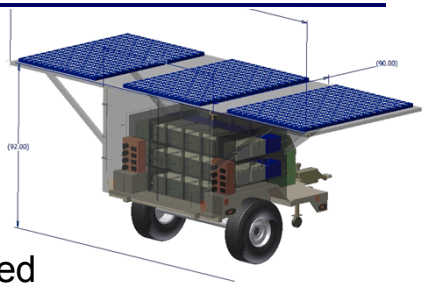
Energy Storage Options

Electrochemical Solutions
- Lithium-ion
- Lead Acid
- Sodium Sulfur
- Sodium Nickel Chloride
- Redox Flow Batteries
- Nickel Cadmium
- Electrochemical Capacitors

Mechanical Solutions
- Flywheels
- Compressed Air Energy Storage (CAES)
- Superconducting Magnetic Energy Storage

Benefits of Hybrid Approach
- Optimize Cost
- Leverages Existing Technologies
- Adaptable to Technology Improvement
- Balances Variability with Variable Power Sources
- Smoothes/Levels Supply to Grid
- Represents "Spinning" Capacity

RAPIDS



- Mobile energy generation and storage station
- Provide regulated prioritized load shedding power to balance energy supply and demand
- Accepts power from multiple sources
  - Solar
  - Wind
  - Generator set
- Designed using EPT Patented Power Pyramid ™ Technology

Summary

- ES can be used for stack applications that include UPS
- Need to optimize the kW and kWh rating of ES
  - PNNL Evaluation Tool
    patrick.balducci@pnnl.gov
- ES installation may require additional oversight:
  - Insurance, codes and standards
  - Utility Interconnection, AHJ, First Responders

Thank You

a special mention of our SNL Sponsor – DOE/OE - Grid Energy Storage program managed by Dr. Imre Gyuk

Contact Information

- **Dan Borneo - drborne@sandia.gov**
- **Ben Schenkman - blschen@sandia.gov**
- **Jeff Hires – jeff@pursuitengineering.com**
- **Ryan Smith – ryan.smith@epcpower.com**
- **John Bryan - john.bryan@epcpower.com**

Questions?

Resources

- www.cleanenergystates.org/projects/energy-storage-technology-advancement-partnership/

- www.eelectricitystorage.org
- DOE/EPRI 2013 Electricity Storage Handbook…
  - http://www.sandia.gov/ess/publications/SAND2013-5131.pdf