Battery Energy Storage System Design and Implementation

David Iskandar

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Demand charge management

NREL study: in 2017, 5 million commercial customers had a demand charge above $15/kW

Do the math:

- $15/kW x 400kW = $6,000 per month savings on electricity bills
- $6,000/month x 12 months = $72,000 saved annually

Most demand charges are based on a 15-minute peak

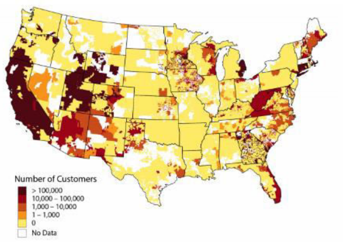
- Small amount of storage = large amount of savings
- Especially true for EV fast charging

Cost of electricity expected to continue increasing

- Renewables replacing fossil fuels
- Grid infrastructure upgrades to support EVs

Energy storage is a reliable, economic solution for managing demand charges

- Reduce peak demand without limiting operations



Demand charges vary throughout a state and often spike in cities.

NREL link

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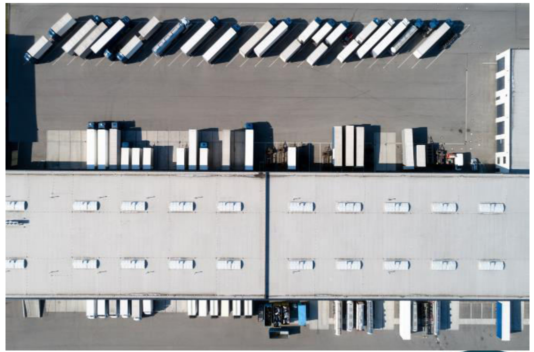
Case study: Impact of truck electrification on the grid

Depot Characteristics:

- 100 Class 6 trucks
- 30 Class 8 trucks
- Site load today ~ **500 KW**

Electrified Depot:

- Class 6 trucks: ~ 100 kWh per day
  - 10,000 KWh in 8 hours = **1250 kW** (@ 100% LF)
- Class 8 trucks: ~ 400 kWh per day
  - Overnight charging
    - 12,000 kWh in 8 hours = **1.5 MW**
  - Slip-seating (multi-shift)
    - 400 kWh in 45 min = ~550 kW per vehicle
    - Assume 4-6 vehicles charging = **2 – 3 MW**



Depot's load on the grid can go from 2.5X to 6 times based on charging deployed

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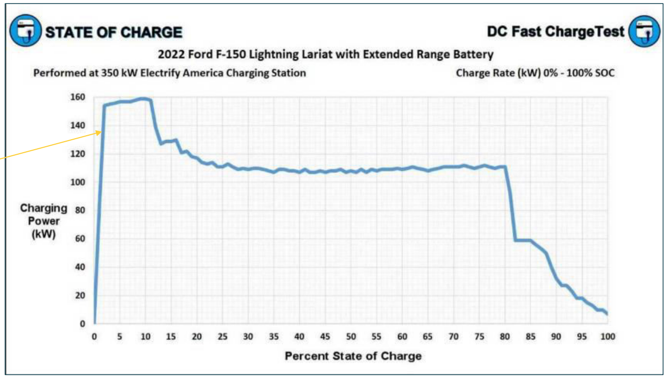
Vehicle charging curve example

Name plate value of most DCFCs are not utilized by the vehicle for long duration (~4-8 minutes in this case)



https://insideevs.com/news/615115/ford-f150-lightning-charging-analysis/

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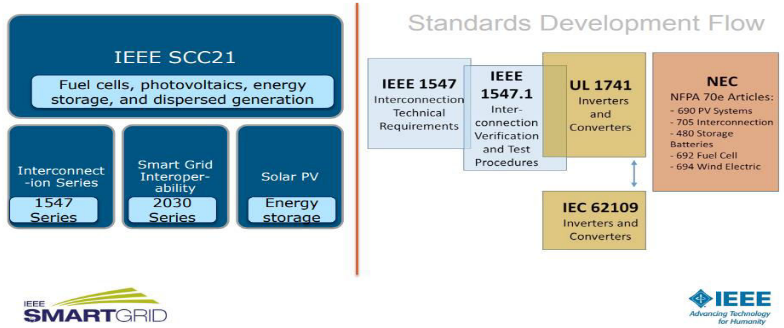
Applicable Standards for DERs



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BESS Codes and Standards

Equipment
- **UL 1741 –** Inverters, converters, and Power Conversion systems (PCS)
- **UL 9540 –** Safety of BESS systems
- **UL9540A –** Fire hazard of BESS systems

System
- **IEEE 1547 -** Standards for Interconnection and Interoperability of DERs
- **IEEE 2800 –** Standards for Interconnection of Inverter Based Resources

Safety
- **NFPA 70 –** Articles 705 & 706
- **NFPA 72 –** National Fire Alarm and Signaling Code.
- **NFPA 855 –** Standard for Installation of Stationary Energy Storage Systems.

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Local regulations

- Each state is adopting various aspects of the IECC, IBC, IRC, and NEC.
  - *Always check the local building code requirements*
- Certain states go beyond the international and national codes and adopt additional policies.
  - California Type Evaluation Program (CTEP)
  - California Air Resource Board (CARB)
  - California Public Utilities Commission – Submetering protocol & EVSE communication protocols
- Other specifications
  - EnergyStar
  - NIST Handbook 44
  - International Organization for Standardization (ISO)

NIST NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY U.S. DEPARTMENT OF COMMERCE

ENERGY STAR

ISO

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UL1741 SA vs SB

UL Solutions

UL 1741-SA

- Published in conjunction with California Rule 21 Phase 1 requirements. These safety tests certify the "smart inverter" grid support functionality needed to modernize the grid through widespread DER integration. The testing requirements for UL 1741-SA are as follows:
  - Anti-islanding
  - Low/high-voltage ride-through (L/HVRT)
  - Low/high-frequency ride-through (L/HFRT)
  - Specified power factor (SPF)
  - Volt/VAR mode
  - Volt/Watt mode
  - Frequency/Watt mode
  - Ramp rate

UL 1741-SB

- Introduced an interoperability conformance test in accordance with IEEE 1547.1-2020. The testing requirements for UL 1741-SB are more stringent and include the following in addition to the requirements defined above for UL 1741-SA certification:
  - Open phase
  - Harmonics
  - DC injection
  - Ground fault overvoltage (GFOV)
  - Load rejection overvoltage (LROV)
  - Prioritization of DER responses
  - Fault current
  - Persistence of DER parameter setting
  - Watt/VAR mode
  - Voltage magnitude and time trip
  - Frequency magnitude and time trip
  - EMI
  - Surge
  - Rate of change of frequency (ROCOF)
  - Dynamic voltage support
  - Enter service
  - Synchronization

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UL 9540

- **UL 9540** is a safety standard for an energy storage system (ESS) and equipment intended for connection to a local utility grid or standalone application. It designates vital issues associated with ESS, including:
  - Safety of the battery system
  - Functional safety
  - Fire detection & suppression
  - Containment
  - Environmental performance

UL Solutions

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IEEE 1547

- **IEEE 1547** refers to "Standard 1547" as developed by the Institute of Electrical and Electronics Engineers (IEEE) to safely and functionally integrate distributed energy resources (DERs) into the electric distribution grid.

IEEE
Advancing Technology for Humanity

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xStorage Overview

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Lithium-ion batteries

Front

Battery

- CATL 280Ah cell
- LFP chemistry
- 1100-1500V DC
- 1C / 0.5C options
- 208V 1P aux power
- DC disconnect included
- 10-year warranty
- Front service access

Features
250kWh or 340kWh usable energy
1+ hour runtime
Field installable
Liquid cooled modules
Compact footprint • 54" x 54" x 92" WxDxH
Outdoor rated • NEMA 3R / IP54 • Pad mounted • Fork or crane • 8000lb
UL 9540A
Fire suppression included

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Liquid Cooling Benefits

Extends battery life 2 years

- Battery cell temperature is a key factor in estimating battery life
- Liquid cooling can maintain cells within 2-3°C of their ideal temperature vs. 5-10°C with air cooling
- Tighter temperature control and more even distribution extends battery life 2 years[1]

Contributes to 58-69% footprint reduction

- See footprint comparison slide

Reduces aux power consumption

- A recent study[2] found that direct to chip cooling like the xStorage cooling system improved cooling efficiency and resulted in a 27% reduction in facility power

Improves reliability

- Air filters are the most serviced component in a BESS, and the frequency varies based on environmental factors like dust and pollen
- Minimizing or eliminating air filters results in fewer failures, less preventative maintenance, and higher uptime

[1] A comparative study between air cooling and liquid cooling thermal management systems for a high-energy lithium-ion battery module

[2] Power Usage Effectiveness Analysis of a High-Density Air-Liquid Hybrid Cooled Data Center

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Bridge Cabinet

Front

Features
Fire Control Panel
Battery Management Unit for monitoring battery cabinets
Temperature controlled
Compact footprint • 54” x ”59 x 69” WxDxH
Communication and Controls • Stored energy controller • CAN to Modbus comm • Inverter islanding functionality • Metering for peak shaving • Network switch

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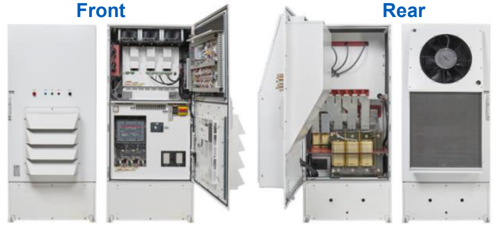
Power Conversion System (PCS)



Electrical

- 3P 3-wire
- 480V AC input/output
- 60hz
- 208V 1P aux power
- >98% efficiency
- 120% overload 3 sec, 116% overload 5 min
- 180kA AC fault current

Features
250kW to 1,000kW • 50kW increments • Field upgradeable
Bi-directional
Air Cooled power electronics
Compact footprint • 67” x 62” x 90” WxDxH
Outdoor rated • NEMA 3R / IP54 • Pad mounted • Fork or crane • 3500lb
UL 1741 SA and SB certified

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xStorage 250-1000 BESS

Product overview

Power: 250 to 350kW
Usable energy: 250 or 340kWh
Installed energy: 279 or 372kWh

Power: 250 to 700kW
Usable energy: 500 or 680kWh
Installed energy: 559 or 744kWh

Power: 250 to 1,000kW
Usable energy: 750 or 1,020kWh
Installed energy: 839 or 1,117kWh

Applications	Energy functions	Environment	Listings
• EV fast charging • Community buildings • Commercial buildings • Industrial facilities • Microgrids	• Peak shaving • Load shifting • Backup power • Solar self-consumption • Demand response	• Enclosures: IP54/NEMA 3R • Temperature: -25°C to 55°C • Humidity: 5% to 100% non-condensing • Elevation: 1000m without derating	• System: UL 9540A • PCS: UL 1741 SA,SB IEEE1547 • Batteries: UL 1973, 9540

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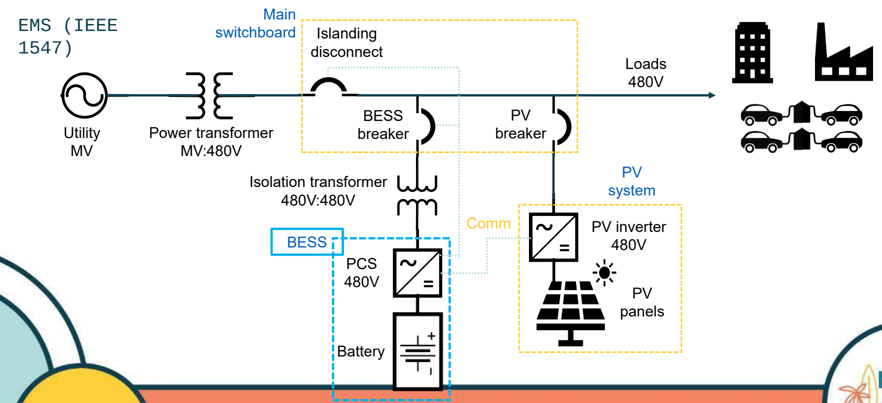
Simple one-line



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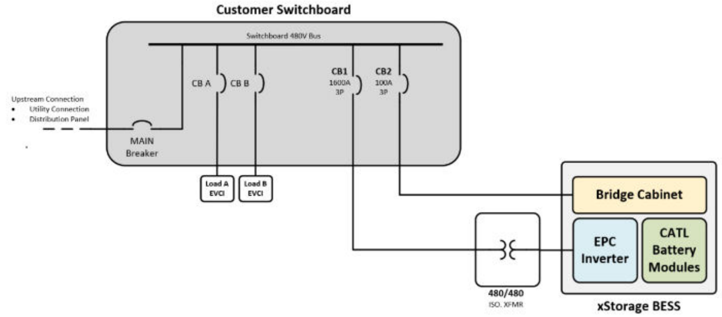
Controller & Use Application

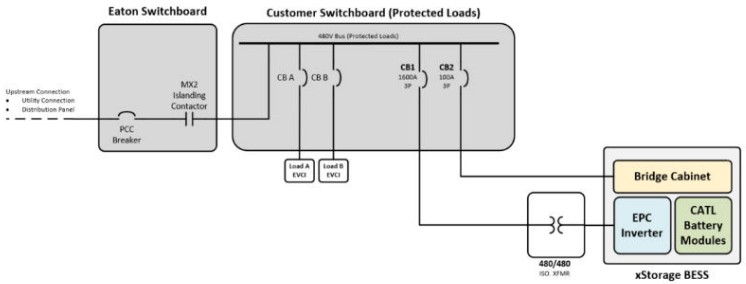
Case 1 – xStorage (No Islanding)

- Install CB1 and CB2 in customer switchboard

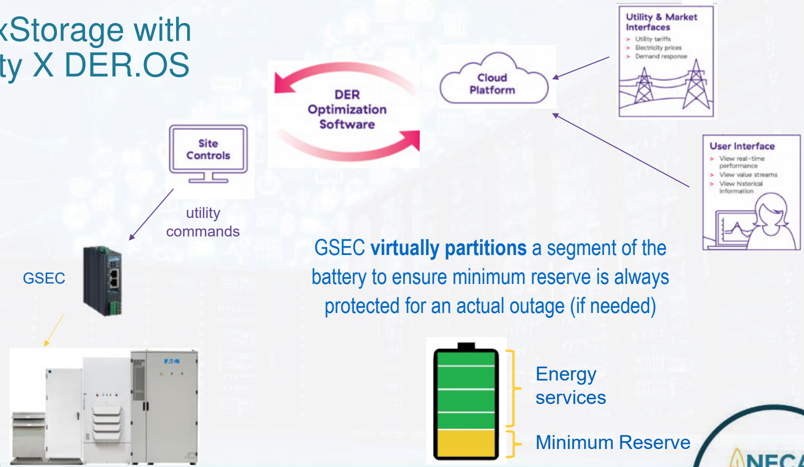


Case 2 – xStorage (With Islanding)

- Install MX2 Islanding Contactor in additional Eaton switchboard
- Install CB1 and CB2 into customer switchboard



Eaton xStorage with 3rd Party X DER.OS




xStorage
Storage / Operation Optimization / Financial Optimization
xStorage features:
• DR
• Peak shaving
• Islanding
• PV integration
Base Storage
xStorage BESS + Power Xpert microgrid controller
xStorage BESS
Inverter
Energy battery
Service contract
Brightlayer Data Centers suite
Monitoring software
GSEC
Higher level controller
xStorage w/ Aggregation features:
• FFR
• Arbitrage
Optimization
xStorage BESS + 3rd Party DER.OS
xStorage BESS
Inverter
Energy battery
Service contract
Brightlayer Data Centers suite
Monitoring software
GSEC
Higher level controller
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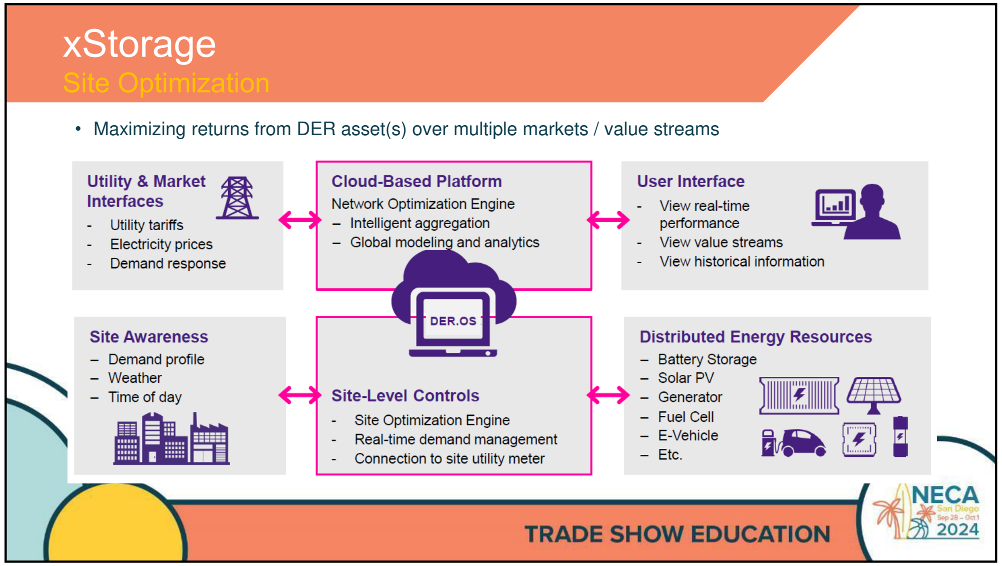
xStorage
Site Optimization
• Maximizing returns from DER asset(s) over multiple markets / value streams
Utility & Market Interfaces
- Utility tariffs
- Electricity prices
- Demand response
Cloud-Based Platform
Network Optimization Engine
– Intelligent aggregation
– Global modeling and analytics
User Interface
- View real-time performance
- View value streams
- View historical information
DER.OS
Site Awareness
– Demand profile
– Weather
– Time of day
Site-Level Controls
- Site Optimization Engine
- Real-time demand management
- Connection to site utility meter
Distributed Energy Resources
– Battery Storage
– Solar PV
– Generator
– Fuel Cell
– E-Vehicle
– Etc.
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Applications and Energy Services
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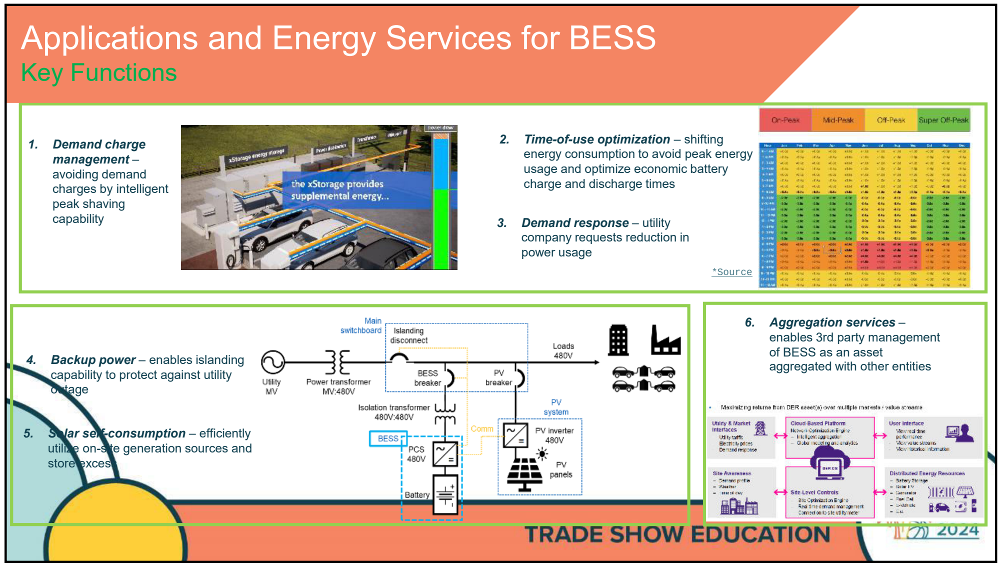
Applications and Energy Services for BESS
Key Functions
1. Demand charge management – avoiding demand charges by intelligent peak shaving capability
the xStorage provides supplemental energy...
2. Time-of-use optimization – shifting energy consumption to avoid peak energy usage and optimize economic battery charge and discharge times
3. Demand response – utility company requests reduction in power usage
On-Peak
Mid-Peak
Off-Peak
Super Off-Peak
*Source
4. Backup power – enables islanding capability to protect against utility outage
5. Solar self-consumption – efficiently utilize on-site generation sources and store excess
Main switchboard
Islanding disconnect
Loads 480V
Utility MV
Power transformer MV:480V
BESS breaker
PV breaker
Isolation transformer 480V:480V
PV system
BESS
PCS 480V
PV inverter 480V
PV panels
Battery
6. Aggregation services – enables 3rd party management of BESS as an asset aggregated with other entities
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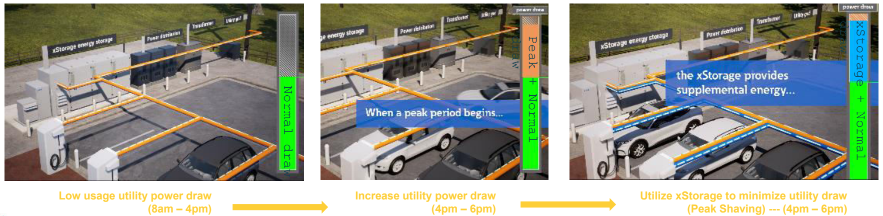
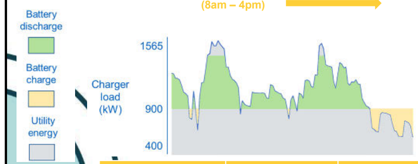
EVCI Demand Charge Management

xStorage reduces demand charges from utility





	No Storage	500kW 1-hr Storage
Demand charge	$20,935	$6,599

Payback:
Investment: 500kW/2hr BESS, $365K
Installation cost: ~$150K
IRA rebate: 30% minimum, ($154.5K)
Total investment after rebate: $360,500
Reduction in demand charges: $158,376/yr.
Payback within 2.3 years

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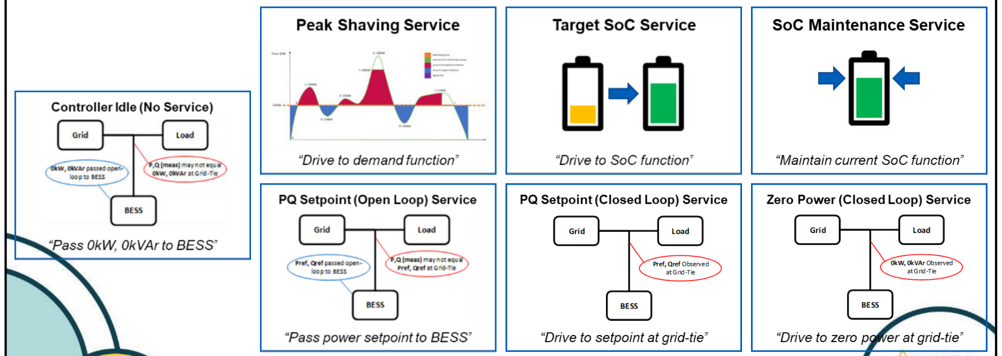
7 Fundamental Building Blocks

Energy Services

GSEC



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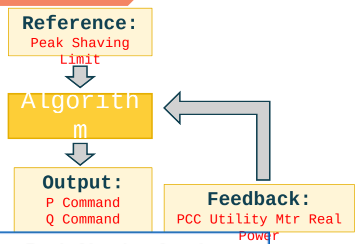
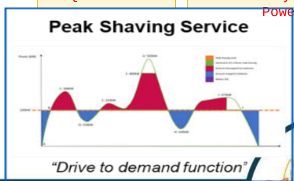
Peak Shaving Service

GSEC

- Definition:
  - The user will select a peak shaving limit (or target utility demand level) at the Point of Common Coupling (PCC). If the load demanded is higher than the peak shaving limit, the batteries will discharge to support the load. If the load demanded is less than the peak shaving limit, the batteries will charge with the available charge power below the peak shaving limit. The ultimate goal of this mode is to ensure that the utility demand never rises above the peak shaving limit.
- Critical Configuration Parameters:
  - Peak Shaving Limit – user defined parameter that is the maximum allowable power draw from the utility at the Point of Common Coupling (PCC)





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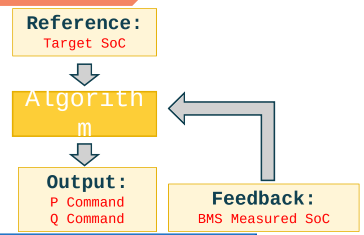
Target SoC Service

GSEC

- Definition:
  - The user will set a target state of charge (SoC) level. If the battery SoC is lower than the target, the batteries will charge. If the battery SoC is higher than the target, the batteries will discharge.
- Note About Practical Use Cases:
  - This mode can often be used as a "preparatory" mode to couple with subsequent modes or features such as peak shaving, which desires a high SoC at the start of the mode, or the PV self-consumption feature, which desires capacity for storing excess PV generation and a lower SoC prior to excess PV generation.
- Critical Configuration Parameters:
  - Target SoC – user defined parameter that is the target State of Charge of the batteries to charge/discharge to while using this service.



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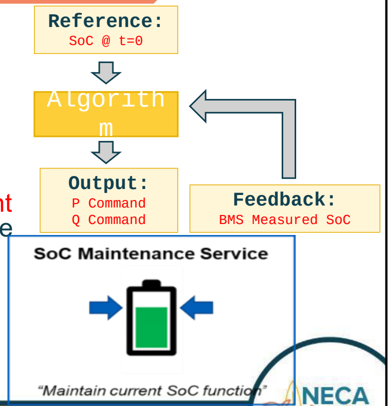
SoC Maintenance Service

- Definition:
  - A service that will maintain the battery state of charge that was observed the moment that the SoC Maintenance service had begun.
- Behavior Note:
  - Note that in order to maintain the current SoC of the battery, the system may have to slightly push or pull power to or from the utility.
- Critical Configuration Parameters:
  - None



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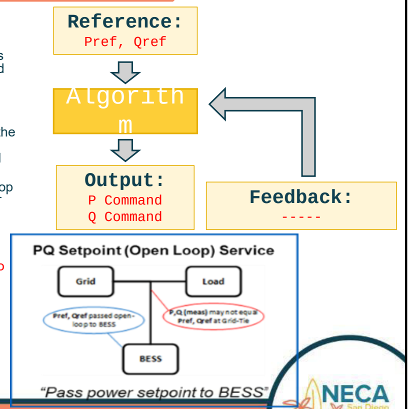
PQ Setpoint (Open Loop) Service

- Definition:
  - In this service the user manually selects an active (real) and reactive power setpoint. The mode serves as a general-purpose mode for the user but also builds the capability for third-party control in which an aggregator or northbound microgrid controller may pass P and Q setpoints to the GSEC.
- Behavior Note:
  - Note that this is an "open-loop" function. The PQ setpoints are passed directly to the inverter without any closed loop control. Due to the metering location and control nature of the inverter, the PQ setpoint command may not be equal to the observed PQ values at the Point of Connection of the BESS to the main bus.
  - Northbound controllers such as Enel X or a Microgrid controller may use closed-loop control through this setpoint to ensure the PQ measured values are correct at their metered locations.
- Critical Configuration Parameters:
  - Real Power Setpoint (P) – user defined real power setpoint to be passed directly to the inverter as a command.
  - Reactive Power Setpoint (Q) – user defined reactive power setpoint to be passed directly to the inverter as a command.



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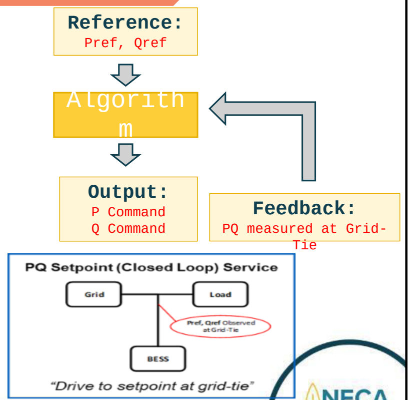
PQ Setpoint (Closed Loop) Service

- Definition:
  - This is a closed loop version of the previous service in which the user manually selects active and reactive power setpoints. In the closed loop variant, a meter placed outside the xStorage system at the main 480V bus is used as a feedback measurement. Here, a 100kW command would result in 100kW being observed at the main 480V bus produced by the xStorage system.
- Behavior Note:
  - Note that this is an "closed-loop" function. The PQ references selected by the user are passed to the controller. The controller uses measured feedback of the PQ values measured at the BESS Meter placed at the point of connection at the Grid-Tie. The controller will determine the correct setpoints to be passed to the inverter such that the references are observed at the BESS Meter.
- Critical Configuration Parameters:
  - Real Power Setpoint (P) – user defined real power setpoint to be observed at the Grid-Tie point of connection.
  - Reactive Power Setpoint (Q) – user defined reactive power setpoint to be observed at the Grid-Tie point of connection



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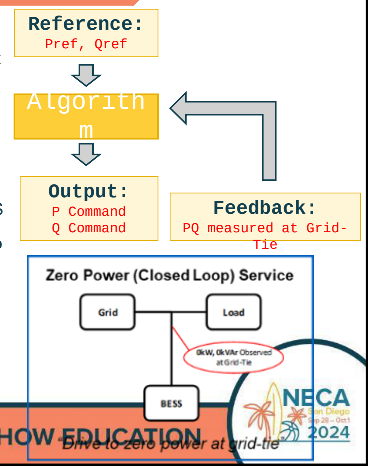
Zero Power (Closed Loop) Service

- Definition:
  - A specific variant of the PQ Setpoint (Closed Loop) service, Zero Power creates a 0kW, 0kVAr setpoint to be observed at the main 480V bus. This ensures that the xStorage system appears to have neutral power flow in the system (no power in, no power out).
- Behavior Note:
  - Note that this is an "closed-loop" function. The 0kW, 0kVAr references are passed to the controller. The controller uses measured feedback of the PQ values measured at the BESS Meter placed at the point of connection at the Grid-Tie. The controller will determine the correct setpoints to be passed to the inverter such that 0kW, 0kVAr are observed at the BESS Meter.
- Critical Configuration Parameters:
  - None



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Services
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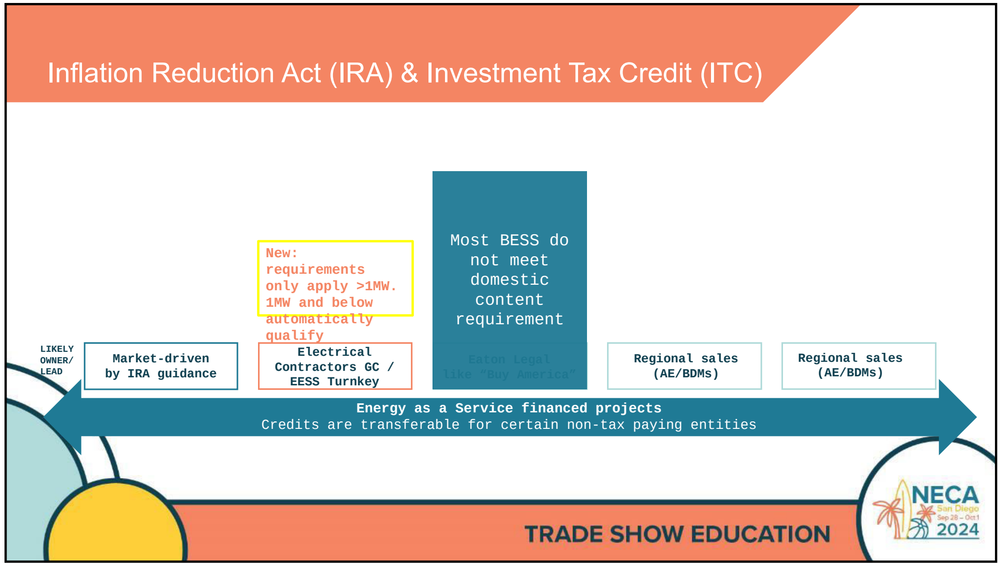
Inflation Reduction Act (IRA) & Investment Tax Credit (ITC)
New: requirements only apply >1MW. 1MW and below automatically qualify
Most BESS do not meet domestic content requirement
LIKELY OWNER/ LEAD
Market-driven by IRA guidance
Electrical Contractors GC / EESS Turnkey
Eaton Legal like "Buy America"
Regional sales (AE/BDMs)
Regional sales (AE/BDMs)
Energy as a Service financed projects
Credits are transferable for certain non-tax paying entities
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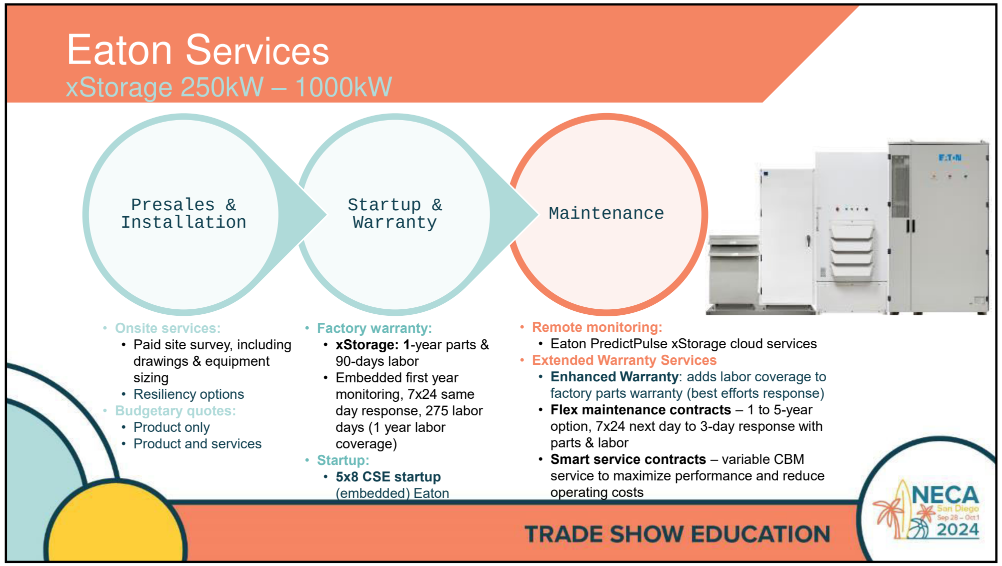
Eaton Services
xStorage 250kW – 1000kW
Presales & Installation
Startup & Warranty
Maintenance
• Onsite services:
• Paid site survey, including drawings & equipment sizing
• Resiliency options
• Budgetary quotes:
• Product only
• Product and services
• Factory warranty:
• xStorage: 1-year parts & 90-days labor
• Embedded first year monitoring, 7x24 same day response, 275 labor days (1 year labor coverage)
• Startup:
• 5x8 CSE startup (embedded) Eaton
• Remote monitoring:
• Eaton PredictPulse xStorage cloud services
• Extended Warranty Services
• Enhanced Warranty: adds labor coverage to factory parts warranty (best efforts response)
• Flex maintenance contracts – 1 to 5-year option, 7x24 next day to 3-day response with parts & labor
• Smart service contracts – variable CBM service to maximize performance and reduce operating costs
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Resources
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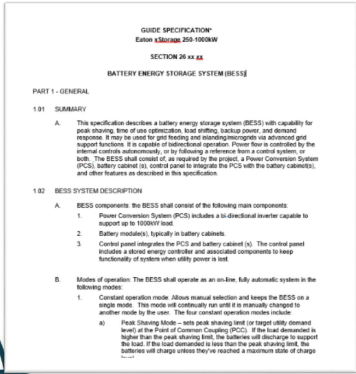
xStorage 250-1000kW
Launch and Resources



GUIDE SPECIFICATION*
Eaton xStorage 250-1000kW

SECTION 26 xx xx

BATTERY ENERGY STORAGE SYSTEM (BESS)

PART 1 - GENERAL

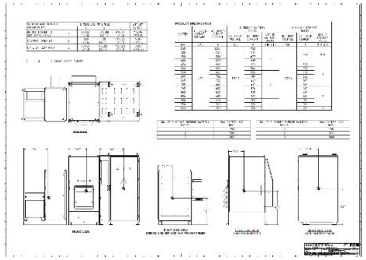
1.01 SUMMARY

A. This specification describes a battery energy storage system (BESS) with capability for peak shaving, time of use optimization, load shifting, backup power, and demand response. It may be used for grid feeding and islanding/microgrids via advanced grid support functions. It is capable of bidirectional operation. Power flow is controlled by the internal controls autonomously, or by following a reference from a control system, or both. The BESS shall consist of; as required by the project, a Power Conversion System (PCS), battery cabinet (s), control panel to integrate the PCS with the battery cabinet(s), and other features as described in this specification.

1.02 BESS SYSTEM DESCRIPTION

A. BESS components: the BESS shall consist of the following main components:
   1. Power Conversion System (PCS) includes a bi-directional inverter capable to support up to 1000kW load.
   2. Battery module(s), typically in battery cabinets.
   3. Control panel integrates the PCS and battery cabinet (s). The control panel includes a stored energy controller and associated components to keep functionality of system when utility power is lost.

B. Modes of operation: The BESS shall operate as an on-line, fully automatic system in the following modes:
   1. Constant operation mode: Allows manual selection and keeps the BESS on a single mode. This mode will continually run until it is manually changed to another mode by the user. The four constant operation modes include:
      a) Peak Shaving Mode – sets peak shaving limit (or target utility demand level) at the Point of Common Coupling (PCC). If the load demanded is higher than the peak shaving limit, the batteries will discharge to support the load. If the load demanded is less than the peak shaving limit, the batteries will charge unless they've reached a maximum state of charge



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