EXPANDING THE USE OF BATTERIES TO SUPPORT BUILDING LOADS

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STATIONARY BATTERIES AND THEIR APPLICATIONS

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Learning Goals:

- Stationary Standby Power
- Major Battery Types
- Battery Systems
- Batteries for Energy Storage

INTRO TO STANDBY POWER

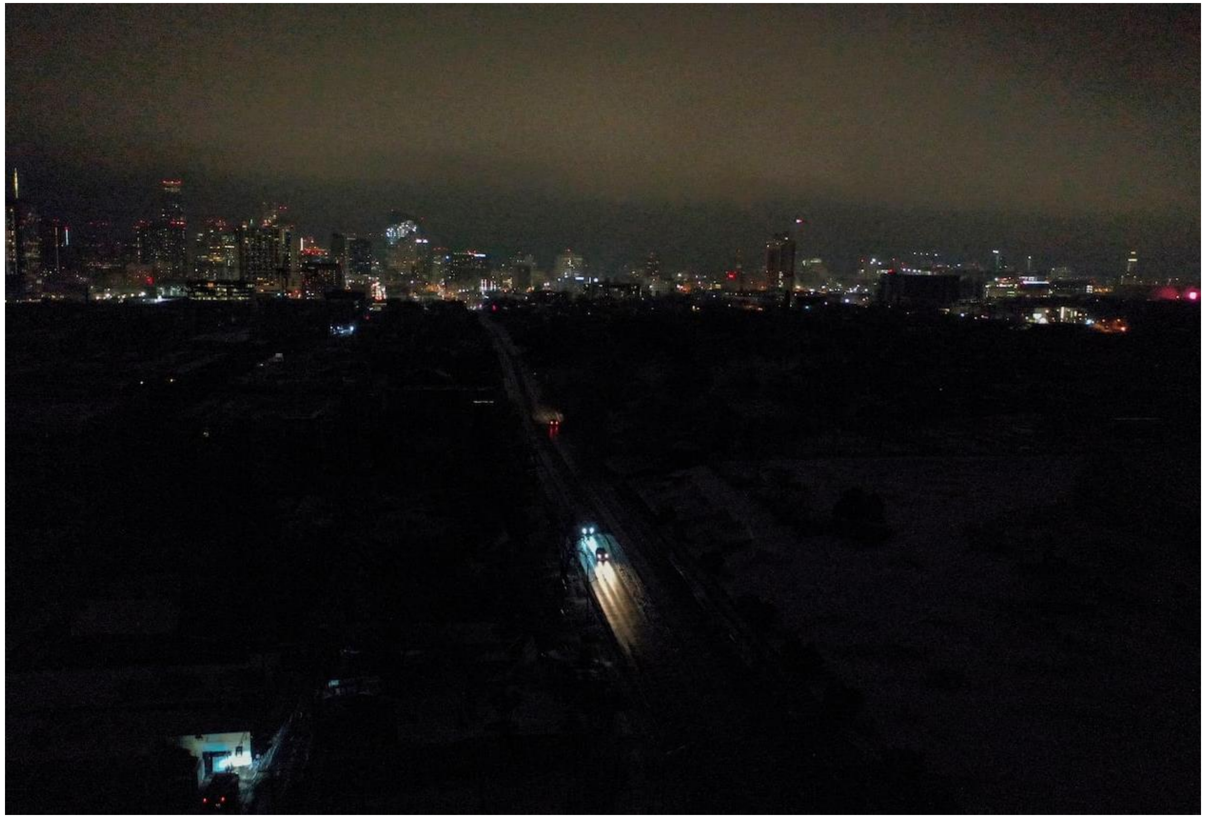
STATIONARY POWER MARKET

Providing Reliability

Power disruptions are common, lasting from less than a second to weeks. Areas affected can range from a single circuit to continents

Some systems cannot tolerate even a momentary power disruption without significant impact

- Data Centers
- Telecommunications
- Industrial plants and generating facilities
- Safety and Health facilities



COMMON BATTERY INSTALLATIONS

Modern buildings already use batteries in a variety of applications

- Emergency lighting
- Data integrity
- Generator starting
- Telecommunication systems

Batteries as energy storage offers new options for cost savings and environmental benefits

STANDBY POWER SYSTEM DESIGNS

Critical power applications use defense in depth to assure continued power supply

- Independent grid connections
- On-site electrical generation
- Stored energy - batteries

The robustness of the system depends on the application

- Tolerance for power loss
- Protection time needed
- Reliability of supply
- Cost

Batteries are uniquely qualified for emergency power applications

- Instantaneous availability – no starting or spin-up delay times
- Modular – systems can be designed to run for minutes to days if needed
- Reliable – batteries have grown with the electrical industry and have a proven track record

BATTERY DESIGNS AND CHARACTERISTICS

WHAT’S A BATTERY?

A battery is a device that produces electrical energy from chemical reactions between dissimilar materials

Voltage can be generated between many different types of materials immersed in a conductive solution.

Only a few combinations can make a practical battery

The voltage generated depends on the type of materials chosen

- Zinc – Carbon ~ 1.5 V
- Nickel Based
  - Nickel – Cadmium ~ 1.2 V
  - Nickel – Metal Hydride ~1.4 V
  - Nickel – Zinc ~ 1.8 V
- Lithium Ion
  - Cobalt – Carbon ~ 3.7 V
  - Iron – Phosphate ~ 3.2 V
- Lead Dioxide – Lead ~ 2.1 V

The amount of power available depends on the voltage and the amount of material available in the battery

WHAT'S A BATTERY

A battery is a device that produces electrical energy from chemical reactions between dissimilar materials

Electrodes – Energy Storage

- Positives – accept electrons on discharge, emit electrons on charge
- Negatives – emit electrons on discharge, accept electrons on charge

Electrolyte – Ion Transport

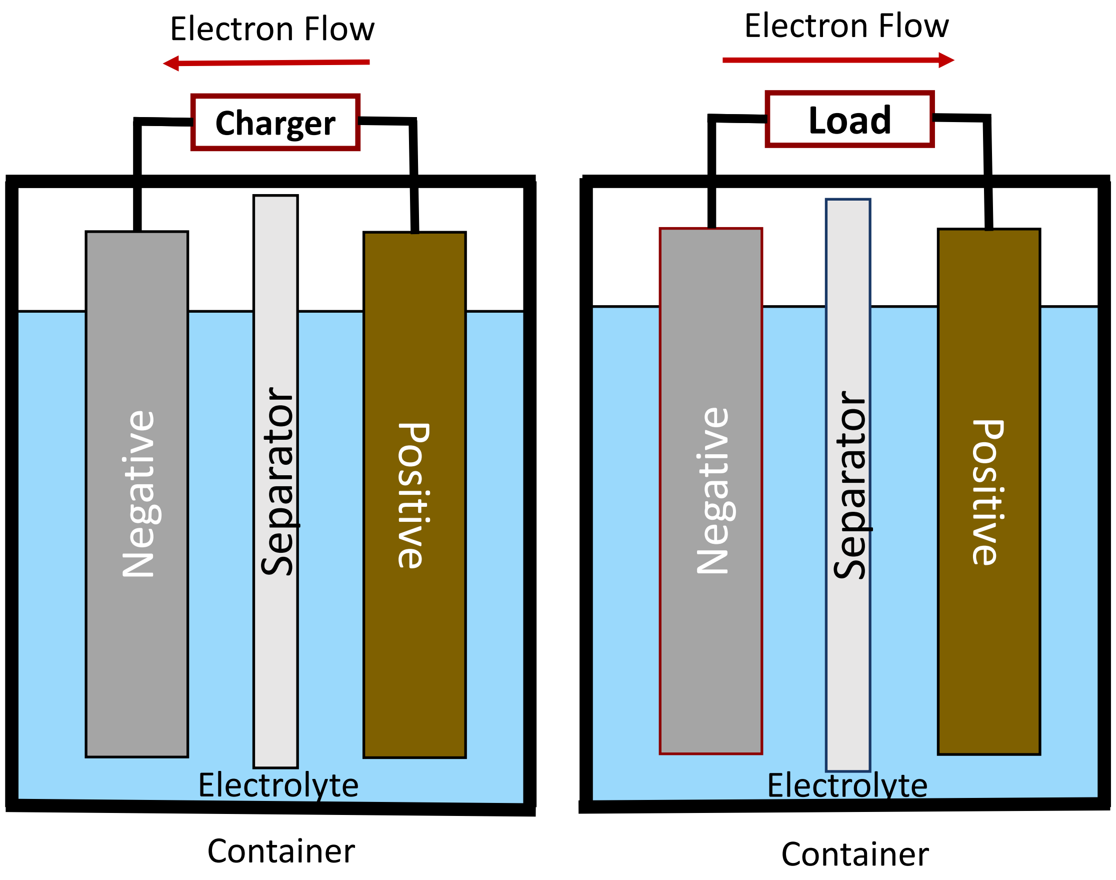
- Ions travel through the electrolyte balancing the electron flow. Some types (lead-acid) participate in the power generating reactions

Separators – Insulation

- Separators electrically insulate the electrodes – allowing ions to pass but preventing electrical contact.

Containers-Covers-Terminals

- Packaging that contains the active materials and allows electricity to flow to and from the battery.



STANDBY BATTERY TYPES

Choosing a Battery Chemistry

There are hundreds of standby secondary battery types, but only a few dominate the market – lead-acid, lithium-ion, nickel based

Choosing a chemistry requires balancing product features and drawbacks. Total cost of ownership should be considered – including replacement cycles and risk of unexpected failures

- Initial cost-both the battery and all required accessories and infrastructure
- Energy Density – Power storage/unit volume or unit floor area. Must include safety spacing
- Product life and replacement interval
- Reliability during life
- Maintenance requirements – testing and actual preventive maintenance
- Disposal and replacement costs

STANDBY BATTERY CHEMISTRIES

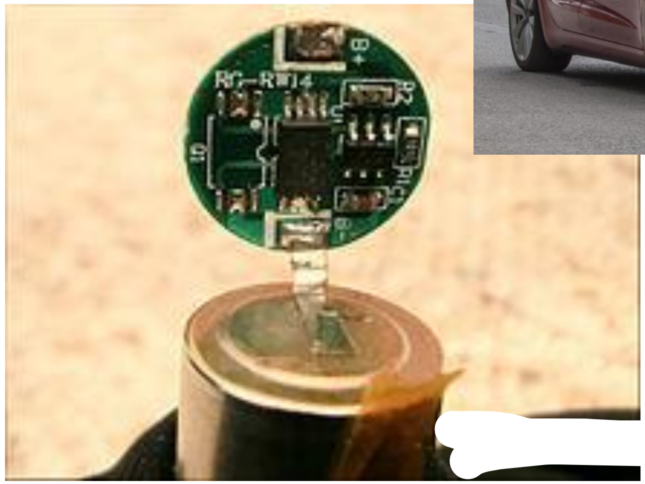
Nickel Based Designs

- **Uses** nickel oxide-hydroxide as the positive material. Negatives include cadmium (Ni-Cd), metal hydrides (Ni-MH), and zinc (NI-Zn). All use a caustic (potassium hydroxide-water) electrolyte. Available in sealed and vented types to very high capacities.
- **Advantages:** Extreme temperature tolerance, ability to handle deep discharges, ability to handle high-rate discharges with little loss in capacity. Excellent cycling capability. Reliable technology – over 100 years old for Ni-Cd
- **Disadvantages:** High initial cost, high disposal cost for some types. Ni-Cd May be banned in certain markets due to cadmium content. Memory effect (capacity declines with multiple shallow discharges). Low voltage – 1.3 V-1.7 V per cell. Requires more cells in series to match other technologies. Some technologies cannot be trickle charged.
- **Costs:** Highest of common types

STANDBY BATTERY TYPES

Lithium Ion

- **Uses** lithium compound as a positive, graphite (typically) as a negative in an organic electrolyte. Available in small cell, sealed pouch and large assemblies. Technology is still evolving – options for positives include Lithium Cobalt Oxide, Lithium Iron Phosphate, Lithium Manganese Oxide, as well as variations in negatives and electrolyte. Market share growing as technology advances and costs are reduced.
- **Advantages**: High voltage – up to 3.5-4.0/cell. Excellent cycling capability. Highest energy/volume for common battery types. Developing infrastructure due to use in electric vehicle (EV) applications
- **Disadvantages**: Newer technology, actual service life in large stationary applications undetermined. Requires separate battery controller/monitor for every cell, adding costs and reliability issues. Limited fast discharge capability. Limited high temperature capability. Flammable electrolyte, banned in some locations due to fire risk, other standards limit quantity per unit area. Immature recycling market – disposal in landfill still dominate.
- **Costs**:   High but dropping as infrastructure develops. Limitations to deployment must be considered in costs.

STANDBY BATTERY TYPES

Lead-Acid

- **Uses** lead dioxide as a positive, metallic lead as negative, in a sulfuric acid electrolyte. Available in absorbed electrolyte and vented configurations, in wide variety of sizes and configurations. Dominates standby power market, with migration towards AGM designs
- **Advantages**: Relatively high voltage – 2.1 V per cell. Excellent fast discharge capability. Fully developed technology (>100 years old), known reliability in most types and applications. Excellent cycling for some designs. Wide variety of configurations. Excellent lifecycle infrastructure – all components 100% recyclable. No memory effect, no separate monitoring/control necessary.
- **Disadvantages**: Low power/unit weight, medium power/unit volume may limit applications in space limited circumstances. Practical limit on temperature environment -40C to +40C. Vented installations require special room, regular watering and ventilation.
- **Costs**: Lowest initial cost of common types. Overall costs depend on choice of vented/absorbed electrolyte, and replacement cycle.

STANDBY BATTERY SYSTEMS

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BATTERY SYSTEMS

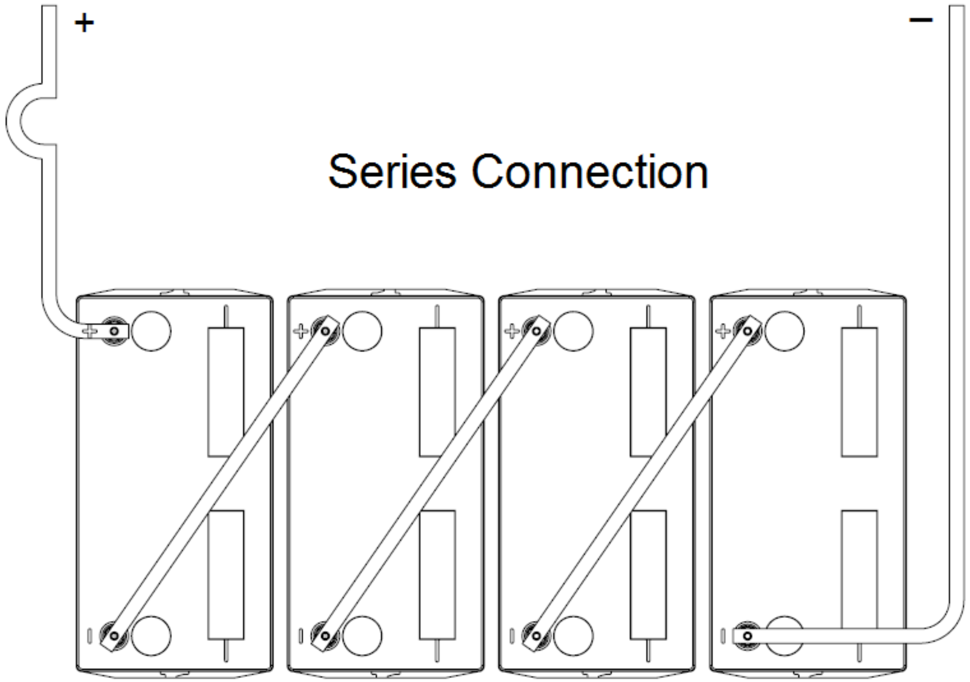
Standby battery systems need to be built up from individual cells to provide practical power solutions.

- Electrical connections to match application voltage and power demands
- Physical supports to meet installation dimensions and seismic requirements



BATTERY BASICS

Series Connection



Series Connections – building voltage

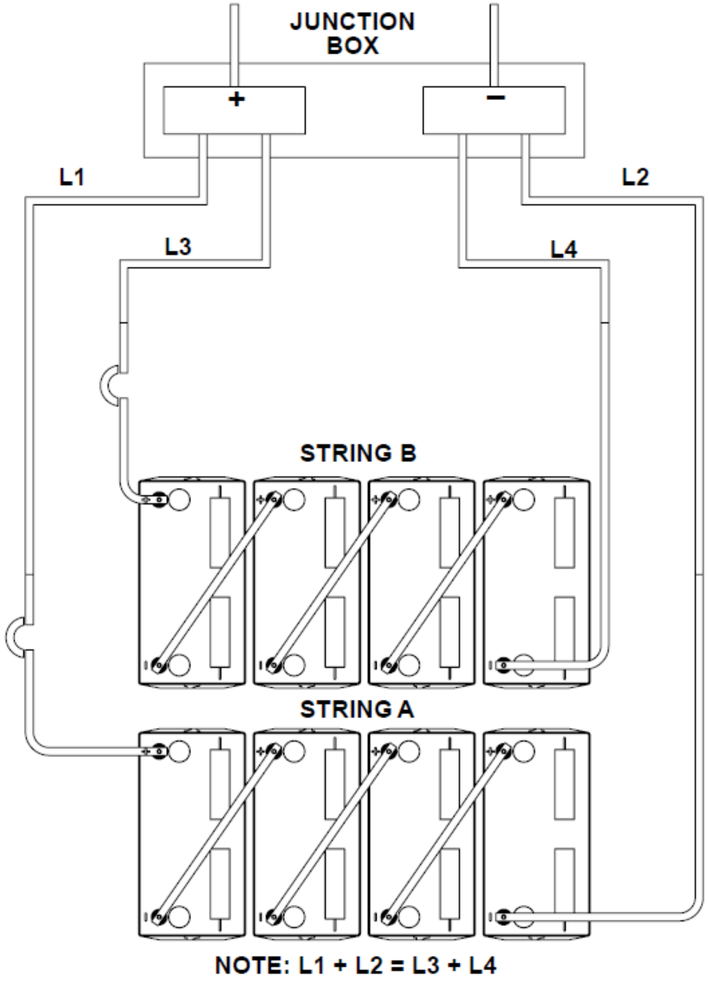
- Most standby systems range from 48V to 480V
- Series connections add battery voltages together to match system requirements

Examples:

- Four 12V-25Ah units connected in series = 48V-25Ah
- 40 12V-1000 W/Cell in series – 480VDC, 480kW

BATTERY BASICS

Parallel Connection



Parallel Connection

- Parallel connections increase system capacity while maintaining voltage
  - Increases runtime
  - Increases available power
- Examples:
  - Two 48V 25 Ah strings create a 48V 50 Ah system
  - Two 480V 1000W/Cell strings – 960 kW

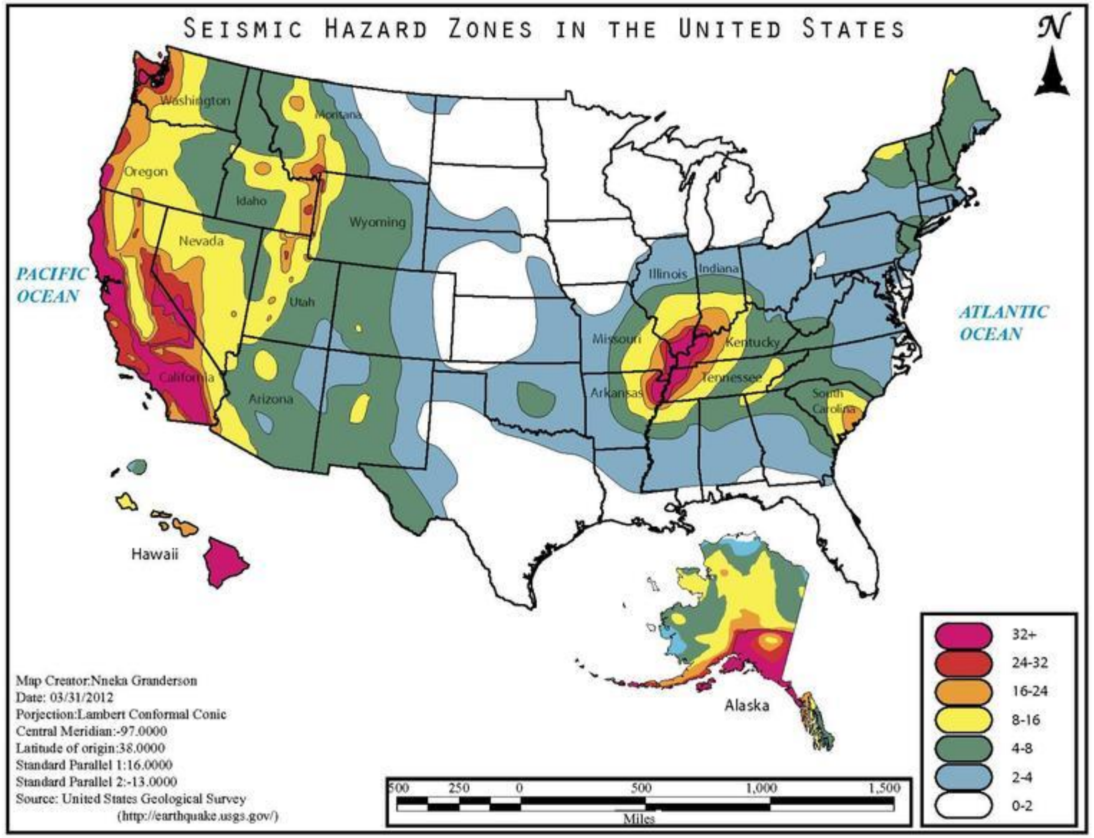
BATTERY RACKS AND CABINETS

Battery systems require support for proper operation and protection from shock

The nature of the support will vary by installation location – especially the seismic rating.

Considerations:

- Check with local engineering and zoning officials to see what seismic requirements exist for the site
- Contact battery manufacturer to match the battery system to the seismic zone
- Use care when replacing one battery type on another rack – some areas may require new qualifications.
- Verify that the room and floor are also sized properly for the seismic zone.



FACTORS FOR CHOOSING AND OPERATING STANDBY BATTERIES

WHAT IS THE BEST BATTERY FOR ANY APPLICATION

Input factors

Choosing a battery type for any application depends on good inputs and accurate cost/benefit calculations. Inputs include:

- Duty Cycle – How many cycles are expected over a product's life
- Discharge Rate – How much power/current is required and for how long
- Environment – Is the temperature controlled or uncontrolled, what is the seismic zone
- Life expectancy – What is the application's expected life, how does that compare to the battery
- Cost – Initial costs vs total cost of ownership
- Accessibility for routine maintenance

BATTERY SELECTION

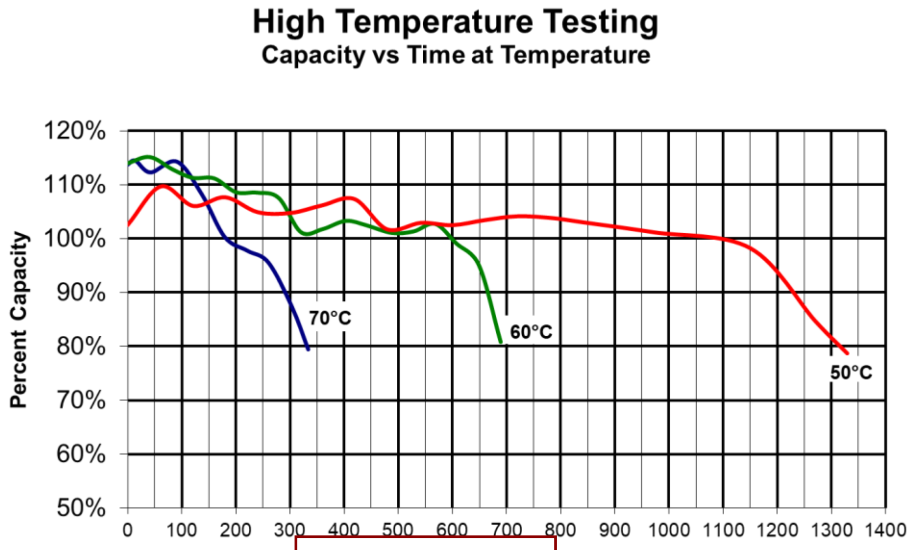
Life Expectancy

Life expectancy for battery systems has primary importance for total cost of ownership and reliability.

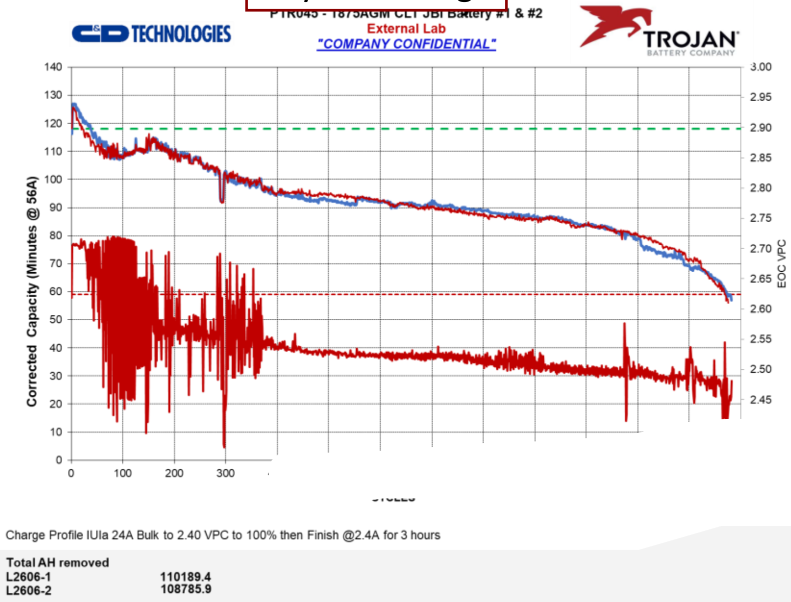
- Standby systems generally measured as calendar life
- Cycling systems (including renewables) measured as cycle life

Owners need to consider multiple inputs to get a true measure of system life and overall reliability

- Cycle life can be meaningless for standby applications – systems can age and wear out before meeting overall cycle life.
- Terms such as “design life” can overstate calendar life.
- Field experience is the best indicator of replacement cycles.



Cycle Testing



BATTERY ENVIRONMENT

Temperature Impact

Batteries are chemical devices – and are affected by environmental conditions

- Temperature is the most important factor in determining battery life and performance

High temperatures increase battery capacity, but can significantly decrease product life

- General rule - 10°C increase in temperature over nominal results in 50% reduction in battery calendar life

Temperature variances can also affect battery performance – recommend keeping maximum differential within 2-3°C

BATTERIES AS ENERGY STORAGE

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STANDBY VS ENERGY STORAGE OPERATION

Traditional stationary battery systems operate as standby equipment – only used when the power goes out

- Depending on local conditions – may be 0.05% risk

Advances in battery technology and alternative energy sources offer opportunities to reduce energy costs and improve infrastructure sustainability

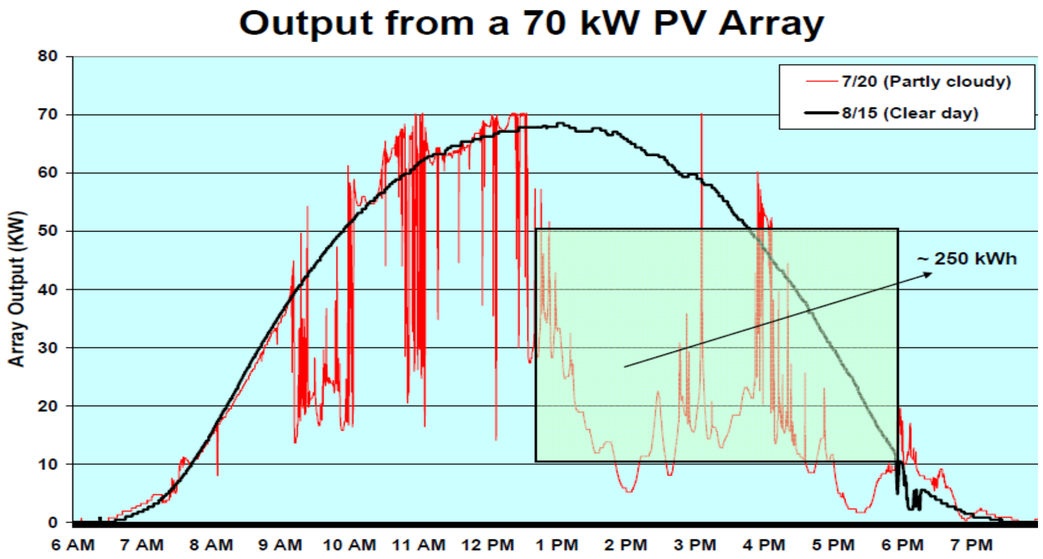
RENEWABLE ENERGY STORAGE

Steady power to the load is the goal of all energy delivery systems

Renewables do not have the stable output that fossil fuel or nuclear plants feature

A renewable energy source plus battery storage provides steady power to critical and non-critical loads – reducing dependance on fossil fuel-based energy sources

Demonstration systems have been deployed on various scales – from individual buildings to entire towns – 20 kWh to 2 MWh



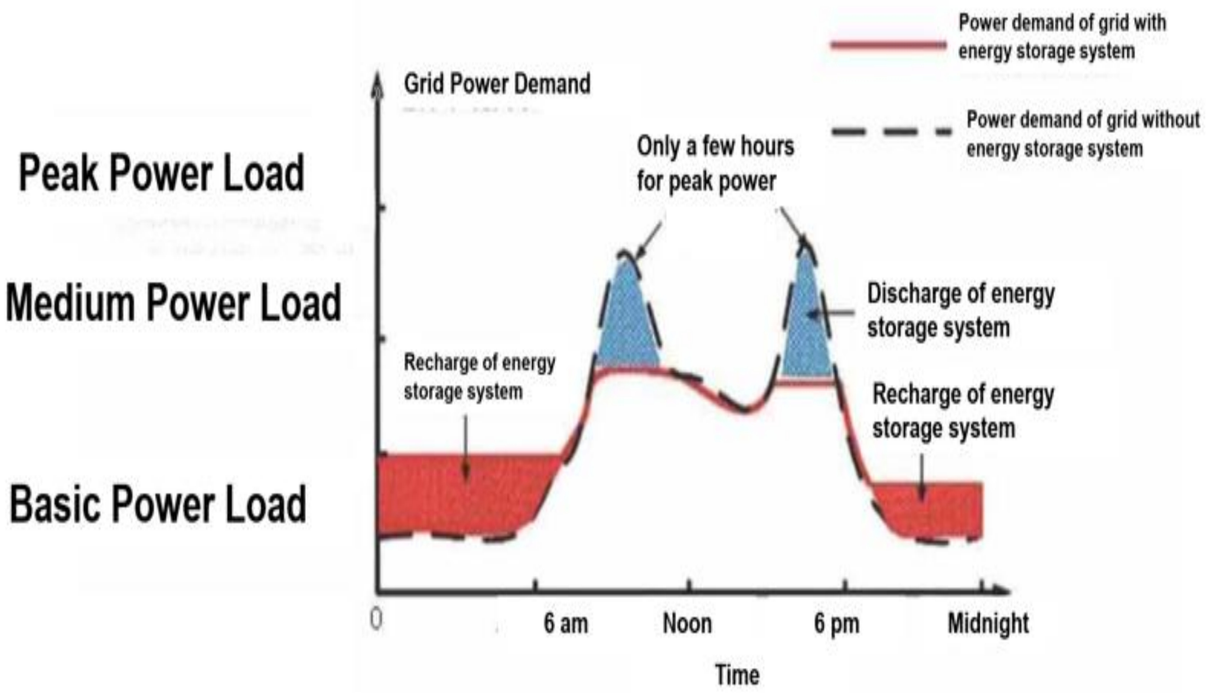
UTILITY COST MANAGEMENT

Peak Shaving

Battery systems offer the opportunity to optimize power cost by offsetting peak power charges

- Peak demand charges may range up to 250% of base power charges
- Utilities may negotiate deals with users capable of providing power at peak demand

Sophisticated controls may be necessary if the battery system is intended to provide blackout protection and peak demand performance



BATTERY APPLICATIONS

Cycling – Renewable Energy

Grid Tied Peak Shaving

Off Grid / Portable Power

Increasing in Popularity

Varied Applications – Heavy Cycling

- Peak Shaving & Investment Deferral
- Renewable Energy Storage
- Maintain power in unreliable areas
- Supply power in remote areas

Typically paired with an inverter/power conditioning system to supply power to the load, battery is only a small part of the system

Widely varied applications

- 24-1000+ VDC Systems
- Backup time ranges from 15 minutes to 100 hours

TYPICAL ENERGY STORAGE APPLICATIONS

Goldwind Headquarter

- Microgrid power generation combined with energy storage
- 120kWh and 600 kWh Carbon Battery System

Charging Station at Shanghai Qingpu

- First new type of energy storage of super charging station in China
- 1MWh Carbon Battery System

BATTERIES FOR ENERGY STORAGE

Optimizing Cycling Performance

Batteries intended for storage service need to be optimized for cycling performance

- Standby batteries are typically optimized for long calendar life and strong high discharge performance for UPS service
- Cycling batteries are optimized for daily performance and long cycle life – may have slightly lower energy density and higher cost per unit power

Modular systems can simplify system growth and minimize replacement time and cost

Control systems are vital to maximizing performance and economic benefit.

THANK YOU

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