Energy Storage Inverter

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Systems Driven Approach
To Inverter R&D

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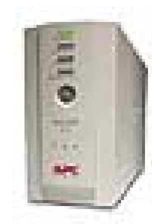
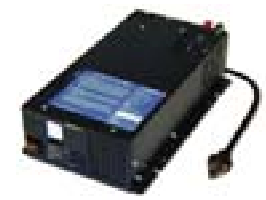
Energy Storage Inverter - Status





- Broad subject
  - Uninterruptible Power Supplies
  - Mobile power
  - Utility scale systems
- There are a variety of applications (loads) with different characteristics that drive inverter requirements
- A variety of storage devices exist with different characteristics that drive inverter requirements
- Electronics for charging the storage device required - may be incorporated into inverter

Energy Storage Inverter - Applications

- Power control (short time)
  - Uninterruptible Power Supplies
  - Power quality improvement
- Energy control (longer time)
  - Energy management
  - Peak shaving
- Mobile power
- Renewable generation support

Source: ESA

Energy Storage Inverter - Applications

- Inverter must be compatible with energy storage device
- Inverter often tightly integrated with energy storage device
- Application Topologies
  - On-line systems
  - Switching systems
- “Mature” Systems
  - Small Systems <2kW – high volume production
    - Modified sine wave output
    - Sine wave output
  - Large Systems - up to MW – significant volume
- “Emerging” Systems
  - Use of new storage technologies
  - Implemented for new application types

Energy Storage Inverter – Storage Technologies

- "Mature" Technologies
  - Capacitors
  - Lead Acid Batteries
  - Lithium Ion Batteries
  - Nickel Cadmium Batteries
- "Emerging" Technologies
  - Flow batteries (ZnBr, VRB, PSB)
  - Other advanced batteries
  - Electro-chemical capacitors ("Ultra" or "Super")
  - Flywheels
  - Superconducting Magnets
  - Hydrogen (Fuel Cells)
  - Other mechanical storage (compressed air, pumped hydro)
- Each technology presents some different inverter/charger requirements

Energy Storage Inverter - Market

- Electricity storage device sales - $15B (source ESA)
- "Mature" products are a multi billion $ market
- "Emerging" market segment is small but growing
- Strong demand for improved power quality as dependence on electrical equipment increases
  - computers
  - internet
  - communications
  - security
- Increasing opportunities for energy management systems as electricity market becomes more competitive

Energy Storage Inverter - Future

- Lower cost per kW
- Higher reliability
- Higher efficiency
- Smaller size per kW
- Higher unit volumes
  - Increasing demand
  - Greater use of common modules
- Higher level of integration
  - Semiconductor devices
  - Control
  - Passive components
- Support for new and emerging storage technologies
- Transition from modified sinewave to sinewave for smaller systems
- Expanded communication features – standard protocols
- Failure prediction features
- Factory configured systems with generation and storage combined

Common Electrical/Mechanical Characteristics

- Sensitivity to Perturbation
  - Very low sensitivity
  - Job is to protect loads against perturbations
- Utility-interactive/Stand-alone
  - Either or both depending upon application
- Capacity (Continuous, Surge, Overload)
  - Varies with application (from Watts to Megawatts)
  - Typical surge and overload requirement of 2x+ of nominal
- Dimensions – Size and Weight
  - Varies with application
  - Smaller and lighter is better
  - Inverter typically small compared with energy storage device

Common Electrical/Mechanical Characteristics

- Communications (Local/Remote)
  - Limited requirements for smaller systems
  - Elaborate expectations for larger systems
  - Not yet standardized
- How Much Reliability
  - Must support system warranties (1-2+ years typical)
- How to Measure It
  - Lots of real world historic data for smaller systems
  - Calculations for new systems
- Is Degradation Acceptable?
  - Not for most applications
  - Install and forget about until needed
  - Some energy storage device degradation is typical

Common Electrical/Mechanical Characteristics

- MTBF
  - Must support warranty and application
  - Off-line systems operate rarely
  - On-line systems operate continuously
  - Xantrex products range from 20,000-80,000+ hours
  - Storage device is typically the issue
- Overall Lifetime
  - Consistent with application and energy storage device
  - Longer than lifetime of energy storage device
- Can Reliability Trade Off with Cost
  - Yes – but high reliability is a requirement
  - Market exists for "Premium" systems
- Key electrical design consideration is storage device voltage and voltage range – strongly impacts inverter

What is Missing from Today's Inverters?

- Lower cost
- Higher reliability
  - Methods for predicting reliability
- Higher Efficiency
- Enhanced communications
  - Standardized protocols
  - Greater connectivity – internet, wireless, …
- Support for emerging storage technologies
- Support for specialized applications
- Development of tools for optimizing applications
  - Capture value for power quality
  - Sizing of larger energy storage systems

Issues

- Performance
  - Inverter developments to support new storage technologies
  - Higher efficiency
  - Higher reliability
- Cost
  - Cost curve always going down
  - Some systems are commodity items (smaller “mature” systems)
  - Inverter is often a small part of the cost of an energy storage system
- Market
  - Market growing
  - Electricity reliability expectations growing

Conclusion

- There is a model from the energy storage industry for the inverter requirements:
  - Inexpensive
  - Works
  - Reliable