Battery Energy Storage Applications
Micro-grids
&
SWER lines

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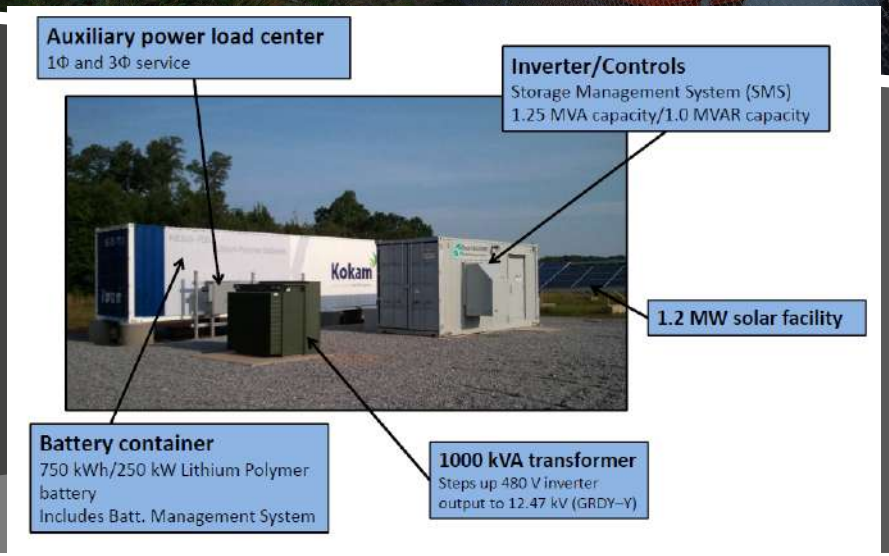
Who is S&C?

- Specialists in electric power since 1911
- True R&D focused innovators of electrical T&D technologies
- Headquartered in Chicago, USA
- 100% Employee owned
- Financially-stable
- 2300 employees globally

S&C and Energy Storage

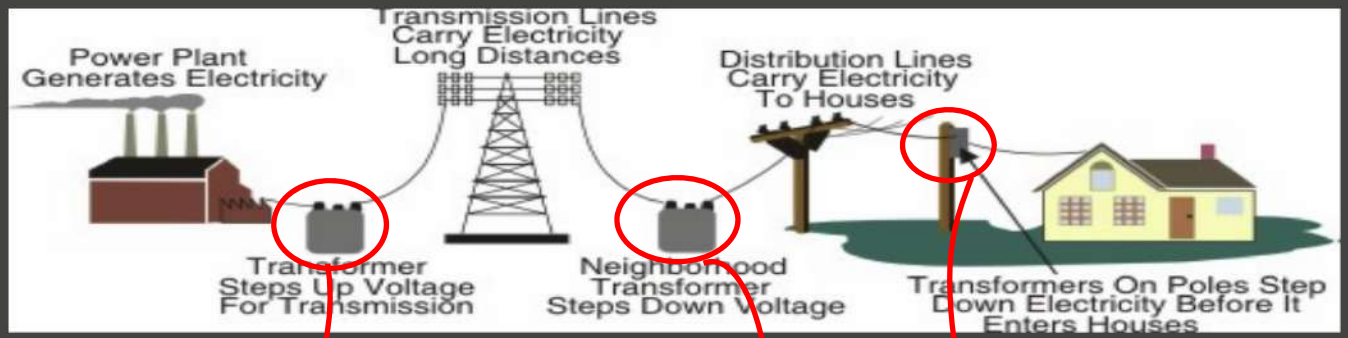
- Globally recognised technological innovators of Battery Energy Storage
- MW Sized projects in service since 2006
- 300+MW of grid connected large scale inverters in service
- Integrated with more batteries than any other PCS manufacturer



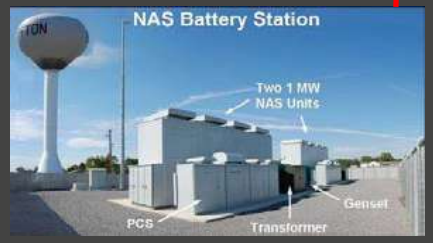
Industry leaders since it's inception

- Past chairman of IEEE Emerging Technologies committee
- Executive Director of the Electricity Storage Association and past chairman of the board
- Member of the US Department of Energy Electricity Advisory Committee and Chairman of the Energy Storage Sub-committee.

Hierarchy of Grid-Connected Energy Storage



Large Central Units
100s of MW



Substation Batteries
10s of MW

Storage at Grid Edge
10s of kW

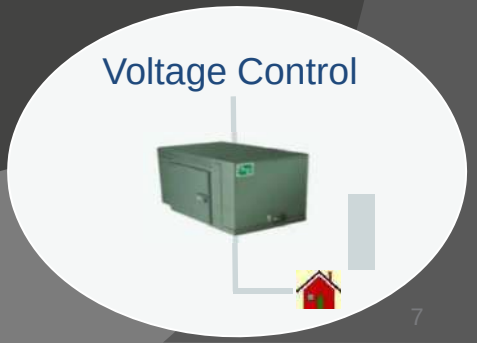
Graphics adapted from an EPRI Presentation by Joe Hughes

Centralised Energy Storage Applications

- Infrastructure upgrade deferment
- Peak Shaving
- Network support
  - Voltage regulation
  - Frequency Regulation
  - Power Factor control
- Increasing penetration of highly variable generation such wind and solar
- Large Scale UPS
- Dynamic Islanding
- Micro-grid support

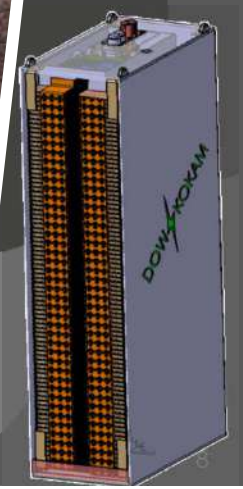
Distributed Energy Storage applications

- SWER line support
- Peak Shaving
- Network support
  - Voltage regulation
  - Power Factor control
- PV integration
- UPS/Dynamic Islanding
- Dynamic Islanding
- Micro-grid support



Battery Experience

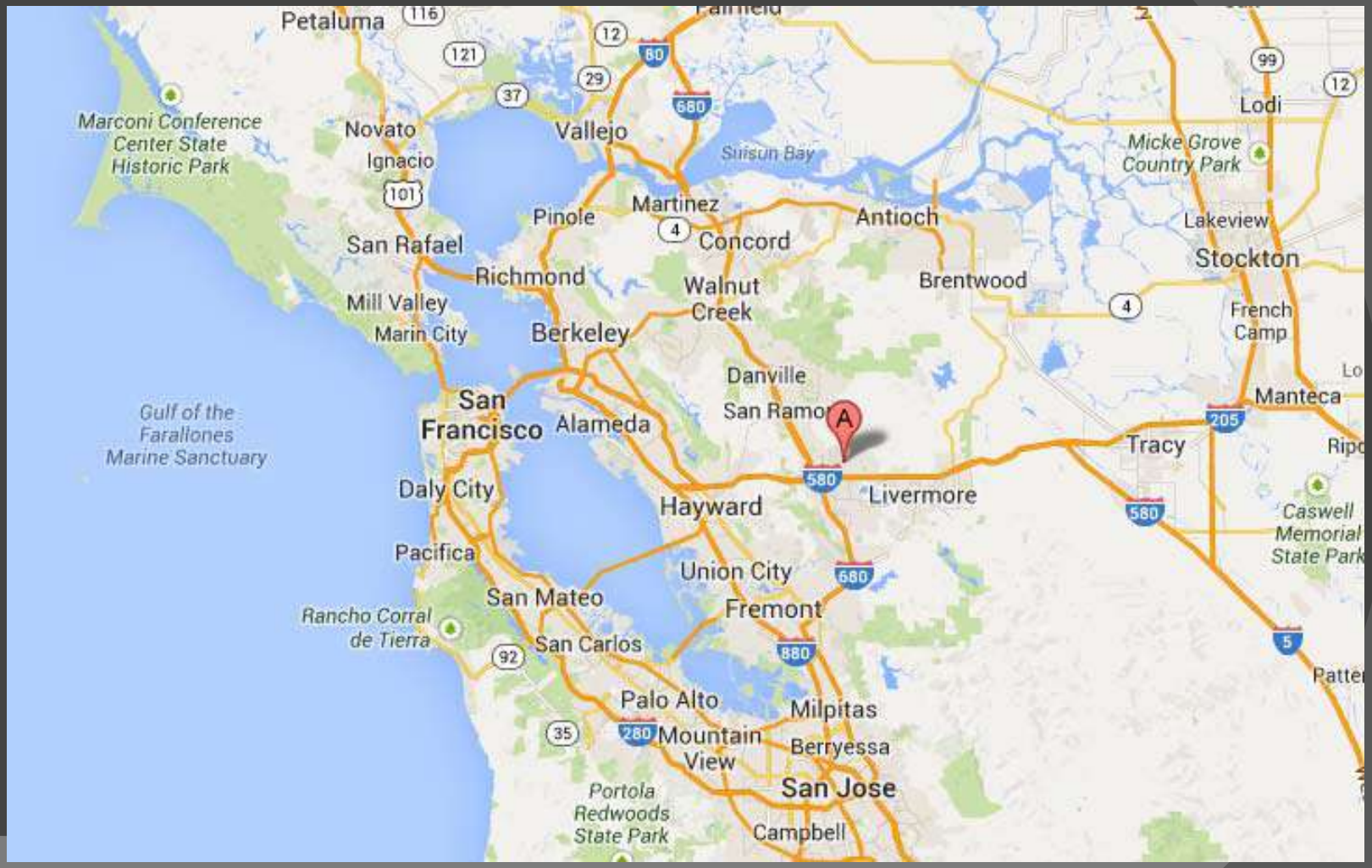
- NaS (Sodium Sulphur)
- Lithium Ion (5 different manufacturers)
- NaNiCl (Sodium Nickel Chloride)
- Ultrabattery (Lead acid/super capacitor combination)
- Flow Batteries



Santa Rita Jail

- Location –Dublin California USA
- 4000 inmates
- 3rd largest Jail in California, 5th largest in USA
- Highly automated facility
- 100% of electrical load is critical
- Peak Loads
  - Summer 2.8MW
  - Winter 1.8MW


Vancouver
Washington
Montana
North Dakota
Minnesota
New Brunswick
Nova Scotia
Montreal
Maine
Wisconsin
Toronto
Michigan
Oregon
Idaho
Wyoming
South Dakota
New York
Vermont
New Hampshire
Chicago
Iowa
Nebraska
Illinois
Pennsylvania
Massachusetts
Ohio
New York
Rhode Island
Nevada
United States
Utah
Colorado
Indiana
Kansas
Missouri
West Virginia
Connecticut
A
California
Kentucky
Virginia
New Jersey
Los Angeles
Oklahoma
Tennessee
North Carolina
Delaware
Arizona
Arkansas
Maryland
New Mexico
Dallas
Mississippi
South Carolina
San Diego
Phoenix
District of Columbia
Alabama
Texas
Georgia
Louisiana
San Antonio
Houston
Florida
Gulf of California
Monterrey
Gulf of Mexico
Mexico
Havana

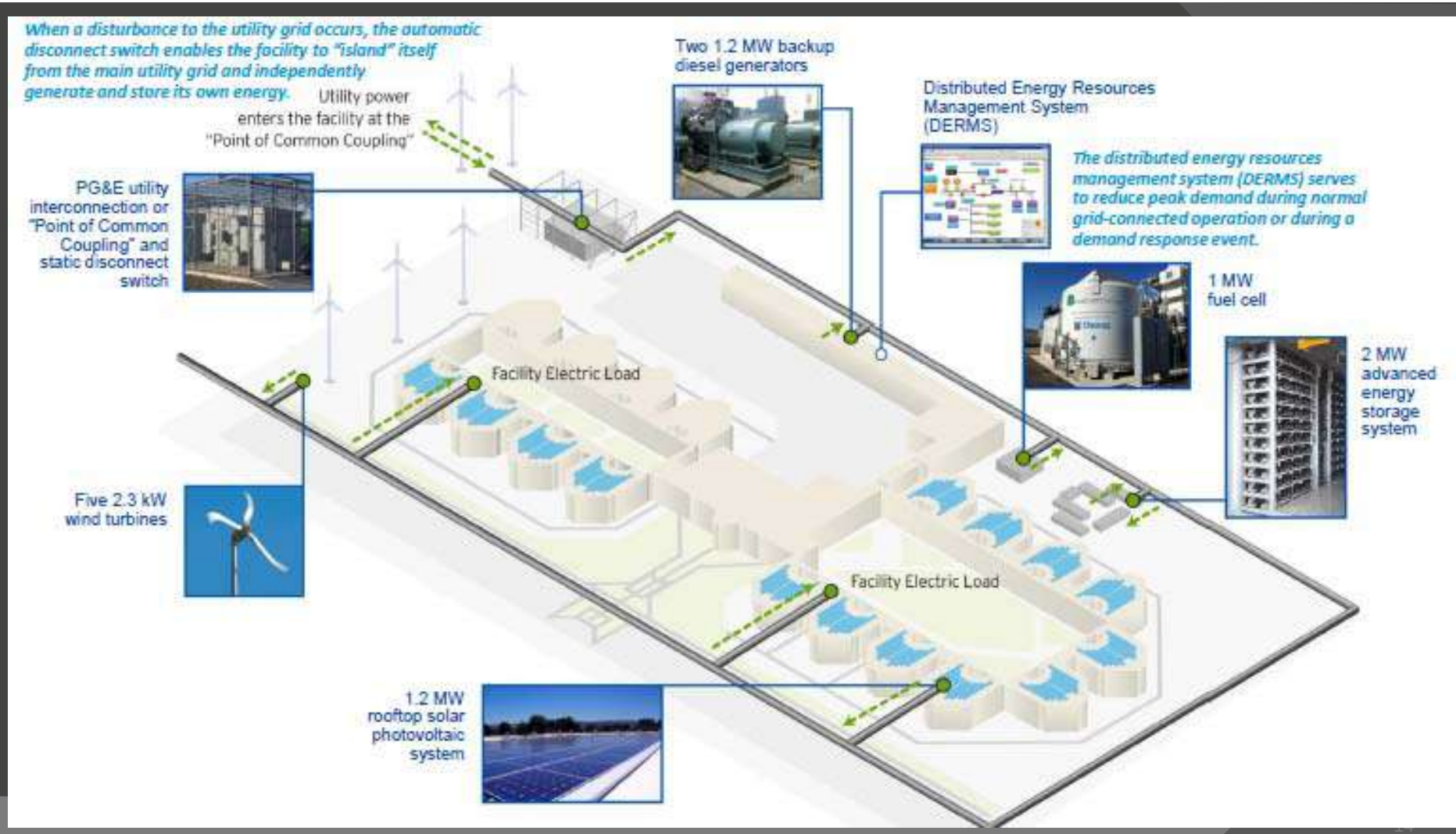

Petaluma
Marconi Conference Center State Historic Park
Novato
Ignacio
Vallejo
Suisun Bay
Micke Grove Country Park
Lodi
Martinez
Pinole
Antioch
Lakeview
Stockton
San Rafael
Concord
Richmond
Walnut Creek
Brentwood
Mill Valley
Marin City
Berkeley
French Camp
Danville
San Ramon
Manteca
San Francisco
Alameda
Gulf of the Farallones Marine Sanctuary
Tracy
Daly City
Hayward
Livermore
Caswell Memorial State Park
Pacifica
Union City
San Mateo
Fremont
Rancho Corral de Tierra
San Carlos
Palo Alto
Milpitas
Mountain View
Berryessa
San Jose
Portola Redwoods State Park
Campbell

Santa Rita Jail

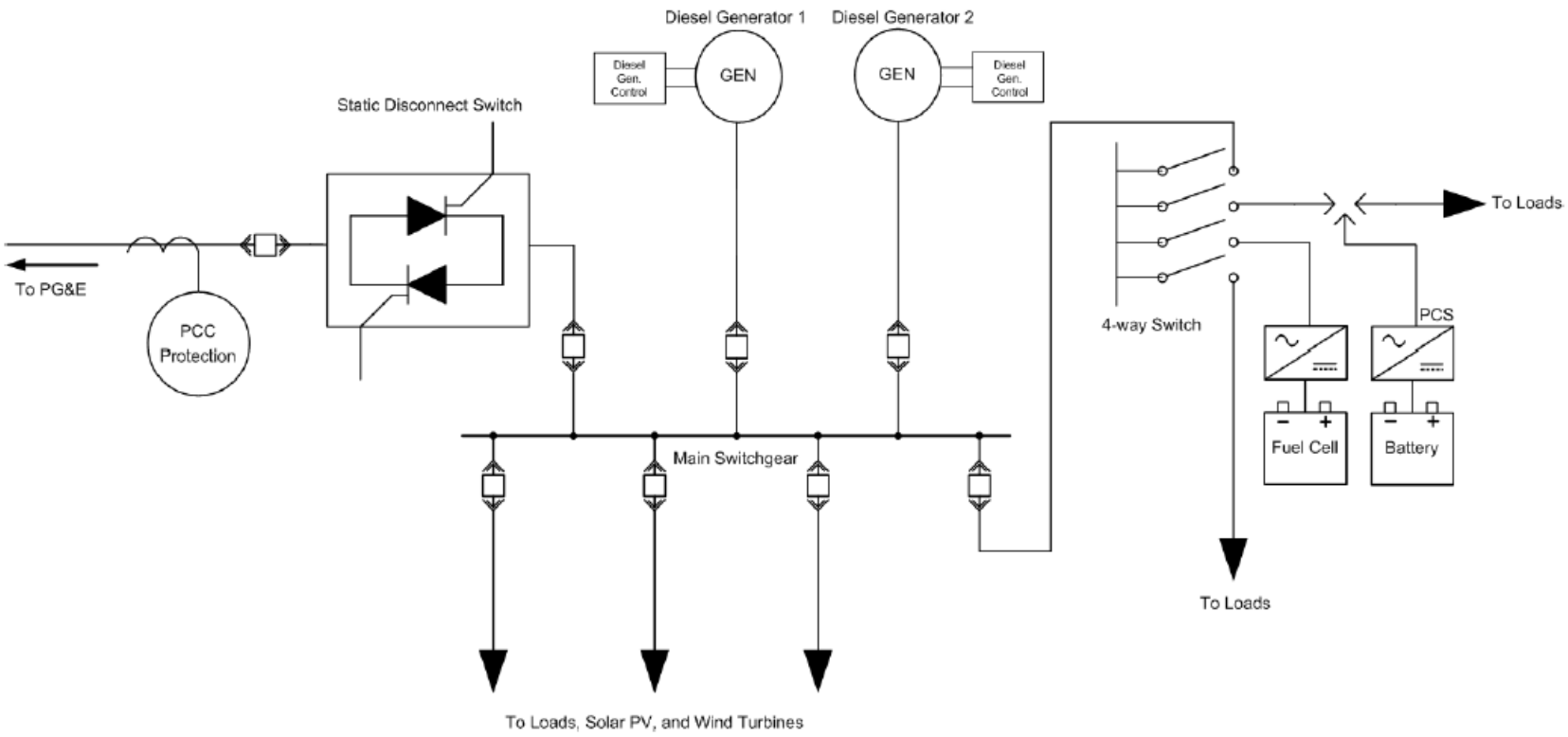
- Grid-connected dynamically islanding 4MW micro-grid with multiple on-site generation sources and 2MW Battery Energy Storage System
- On site generation includes
  - Diesel Generators
  - Fuel Cells
  - Wind Turbines
  - Solar (PV)
  - Lithium Ion Battery

Project Purpose

- Demonstrate CERTS Micro-grid
- Demonstrate a viable integration of renewable, distributed energy resources
- Use commercially available technology
- Reduce peak load of utility distribution feeder
- Increase grid efficiency and security
- Meet critical customer reliability requirements


When a disturbance to the utility grid occurs, the automatic disconnect switch enables the facility to "island" itself from the main utility grid and independently generate and store its own energy.
Utility power enters the facility at the "Point of Common Coupling"
PG&E utility interconnection or "Point of Common Coupling" and static disconnect switch
Two 1.2 MW backup diesel generators
Distributed Energy Resources Management System (DERMS)
The distributed energy resources management system (DERMS) serves to reduce peak demand during normal grid-connected operation or during a demand response event.
1 MW fuel cell
2 MW advanced energy storage system
Facility Electric Load
Facility Electric Load
Five 2.3 kW wind turbines
1.2 MW rooftop solar photovoltaic system

SRJ Simplified Single Line Diagram



PV Solar

- 1.2MW or rooftop solar
- 1.2MW of “tracking” solar

Fuel Cells

- Natural Gas
- 1MW Power output
- First MW scale fuel cell in USA
- 8,000,000kWh of power p/a
- 1.4MMBtu of heat (18% of Jails needs

Wind Turbines

- 24kW total
- 10 x 2.4kW Turbines
- Main reason for existence is to test the integration with micro-grid

Diesel Generators

- 2.4MW total
- 2 x 1.2MW sets
- Started when battery SOC falls below threshold
- Stopped when battery SOC reaches 100%
- Also used as “2nd layer” backup

Battery

- Manufactured by BYD
- Lithium Iron Phosphate
- 2MW, 4MWh
- 4 x 500kW Modules
- Battery Management System by BYD

S&C Purewave 2MW SMS “ties it all together”

- CERTS Algorithm for integration of distributed generation sources, electrical protection and seamless transfer to and from utility grid
- Voltage Support
- Frequency regulation
- Sophisticated diesel generator integration
- Peak shaving to reduce demand tariff
- Store excess generation from renewables
- Arbitrage
- Bi-Directional power flow at PCC

Dynamic Islanding

- UPS like functionality
- Seamless transfers (8ms) to and from the Utility grid
- High Voltage (12kV) Static Switch provides fast disconnection and re-connection to utility grid
- S&C PureWave® SMS
  - Synchronises load to grid
  - Ramp-loads grid & micro-grid

Dynamic Islanding Challenges

- Island must be created very quickly
- Protection of down-stream loads with low fault current
- Load sharing between generators
- Voltage control
- Frequency control
- Load shedding

Distributed Energy Resource Management System DERMS –Commercially driven controls

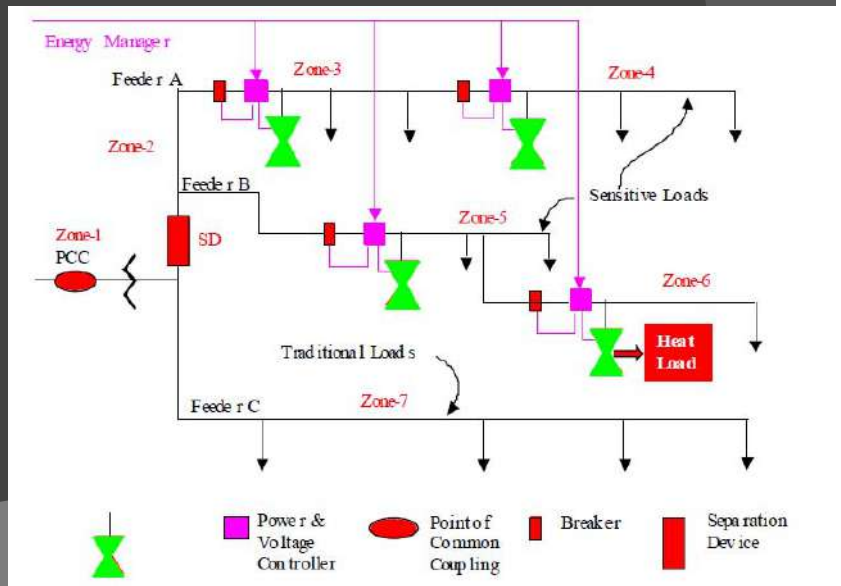
- Estimates energy output of Distributed Energy Resources for upcoming time-of-use period
- Estimates stored energy available for upcoming time-of-use period (peak and partial peak)
- Estimates energy required to charge storage system in upcoming time-of-use period (off peak)
- Estimates energy required from utility for upcoming time-of-use period
- Controls power flow at utility PCC or energy storage system to minimize energy and demand charges

CERTS Micro-Grid

- Consortium for Electrical Reliability Technology Solutions
- Formed in1999
- Consortium members
  - Electric Power Group
  - Lawrence Berkeley National Laboratory
  - Oak Ridge National Laboratory
  - Pacific Northwest National Laboratory
  - National Science Foundation's Power Systems Engineering Research Center
  - SandiaNational Laboratories.

What is the CERTS Micro-Grid concept

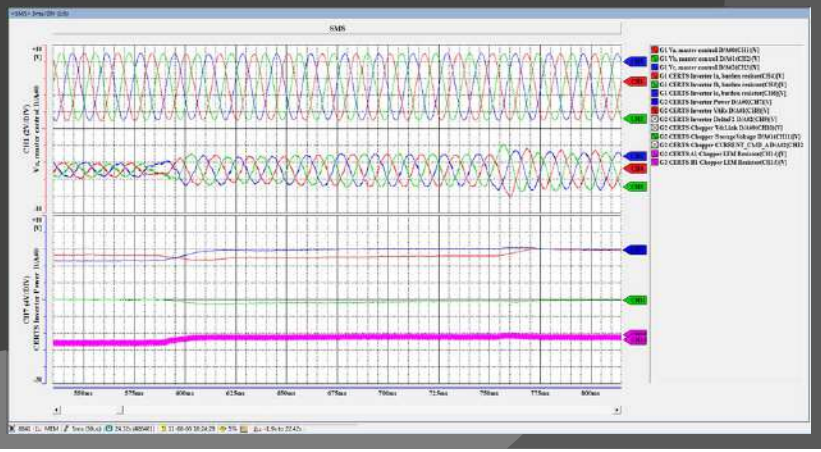
- Algorithms and Protocols for the integration of Distributed Energy Resources (DER) into the grid
- Enables Miro-grid to present itself to the distribution grid as a single, self controlled entity
- Anti-islanding v's islanding
- Peer to peer
- Plug and play



3 Advanced DER integration techniques

Technique 1.

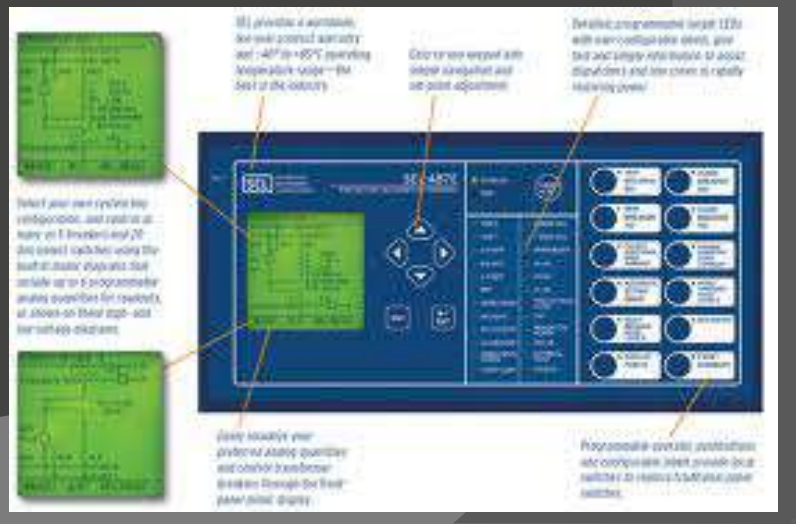
- Automatic and seamless transfer between grid-connected and islanded modes of operation
  - Grid connected with DER in voltage source mode at all times
  - HV Static Switch for fast disconnect
  - Seamless return to the grid achieved by frequency difference



3 Advanced DER integration techniques

Technique 2.

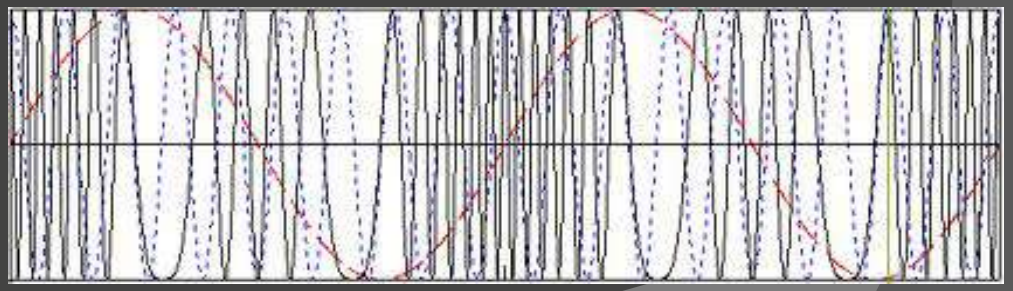
- Electrical protection within the micro-grid
  - During grid connect operation, allow time for static switch to disconnect from the utility
  - During Islanded mode, protection that is <u>not</u> based on detection of high fault current must be employed
  - Load shedding using protection devices



3 Advanced DER integration techniques

Technique 3.

- Voltage and frequency stability under islanded conditions
  - Voltage is regulated at each source connection
  - Sources rely on frequency droop to share load
  - Theoretically an infinite number of sources can be added to the micro-grid



Conclusion

- Grid connected Battery Energy Storage is about a lot more than just the battery.
  - Large scale grid and micro-grid integration is complex
  - Renewables integration is equally challenging with large systems
  - Recognising the commercial benefits of Energy Storage is complex
  - Intelligently controlled inverters offer many benefits other than just charging and discharging the battery for peak-shaving
  - Most electrical utilities and industry analysts agree that Battery Energy Storage will form an integral part of future grids

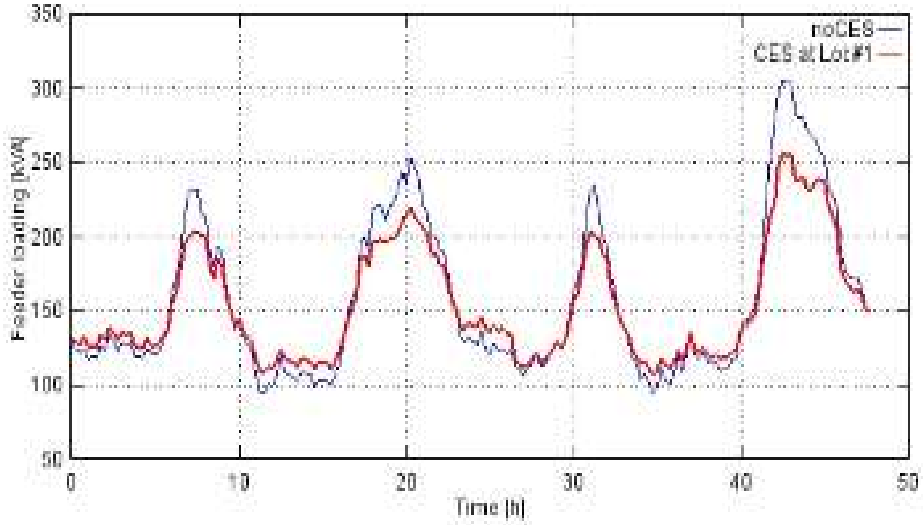
Supporting SWER lines with Energy Storage

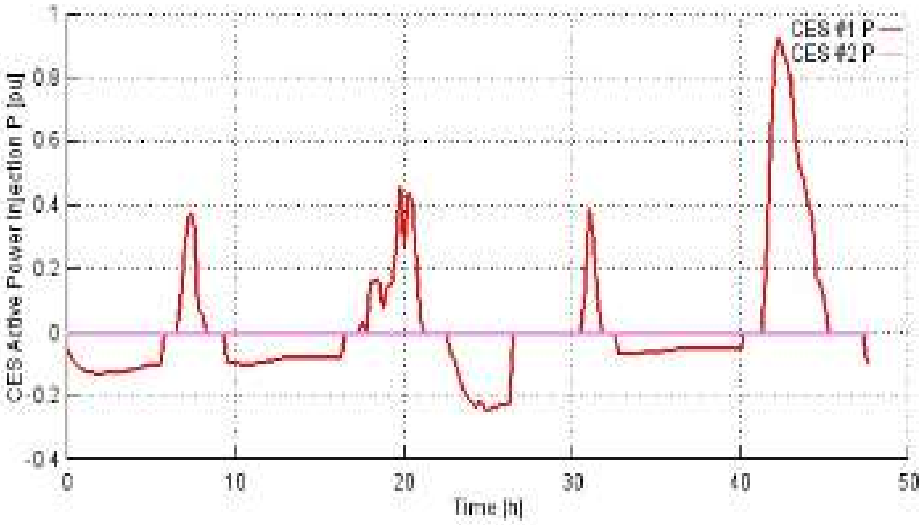
- SWER problems –Power Quality
  - Highly resistive conductor
  - Long runs
  - Loads are becoming more lumpy
  - Rooftop PV
  - Overloading
- Traditional solutions are VERY costly
  - Additional poles and wires over long distances
  - Splitting of SWER network
  - Islanded/off-grid networks

SWER Line Support using Energy Storage

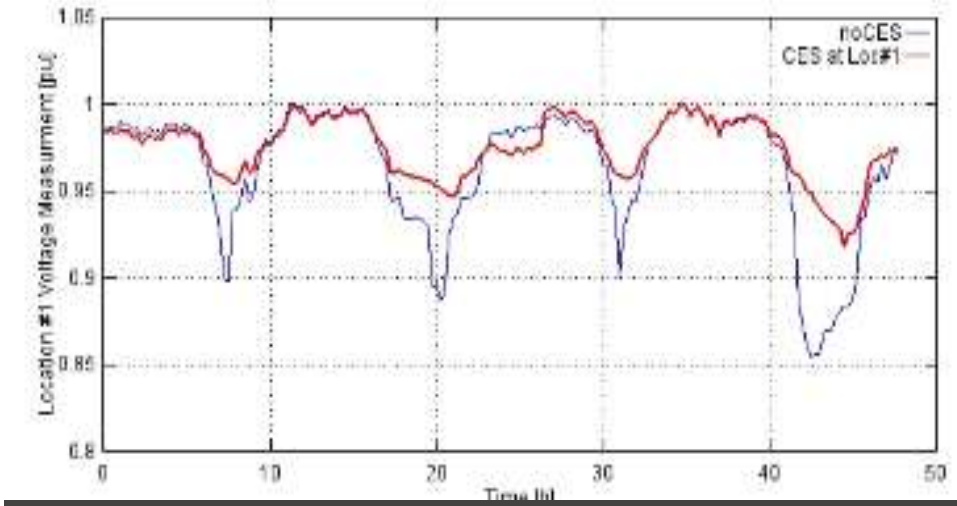
- One of, if not THE most commercially viable application for Battery Energy Storage at this point in time
- Battery used for peak-shaving and capture of PV energy
- Voltage control through reactive AND real power
  - Use VAR's to control voltage where possible
  - Use battery when necessary
  - 4-quadrant inverter enables real and reactive power at the same time
- Dynamic Islanding –UPS like functionaliy

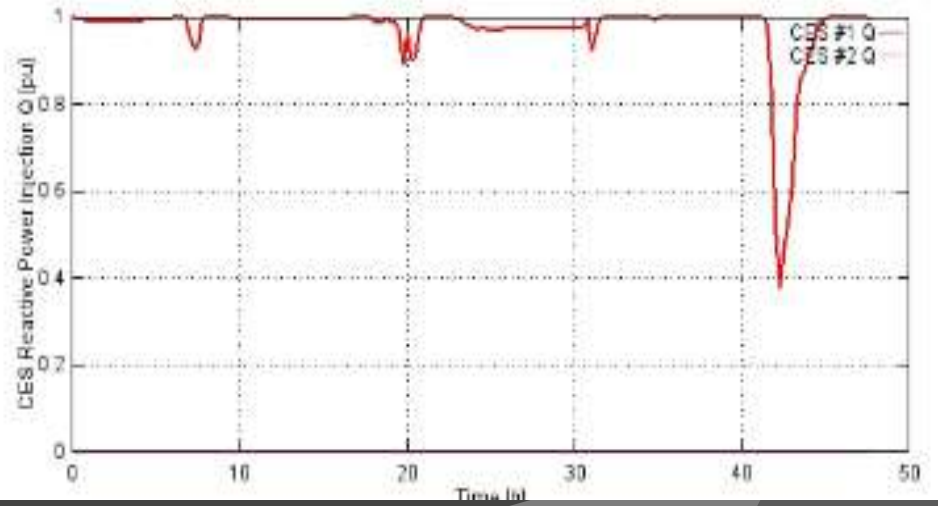
Peak Shaving on SWER line



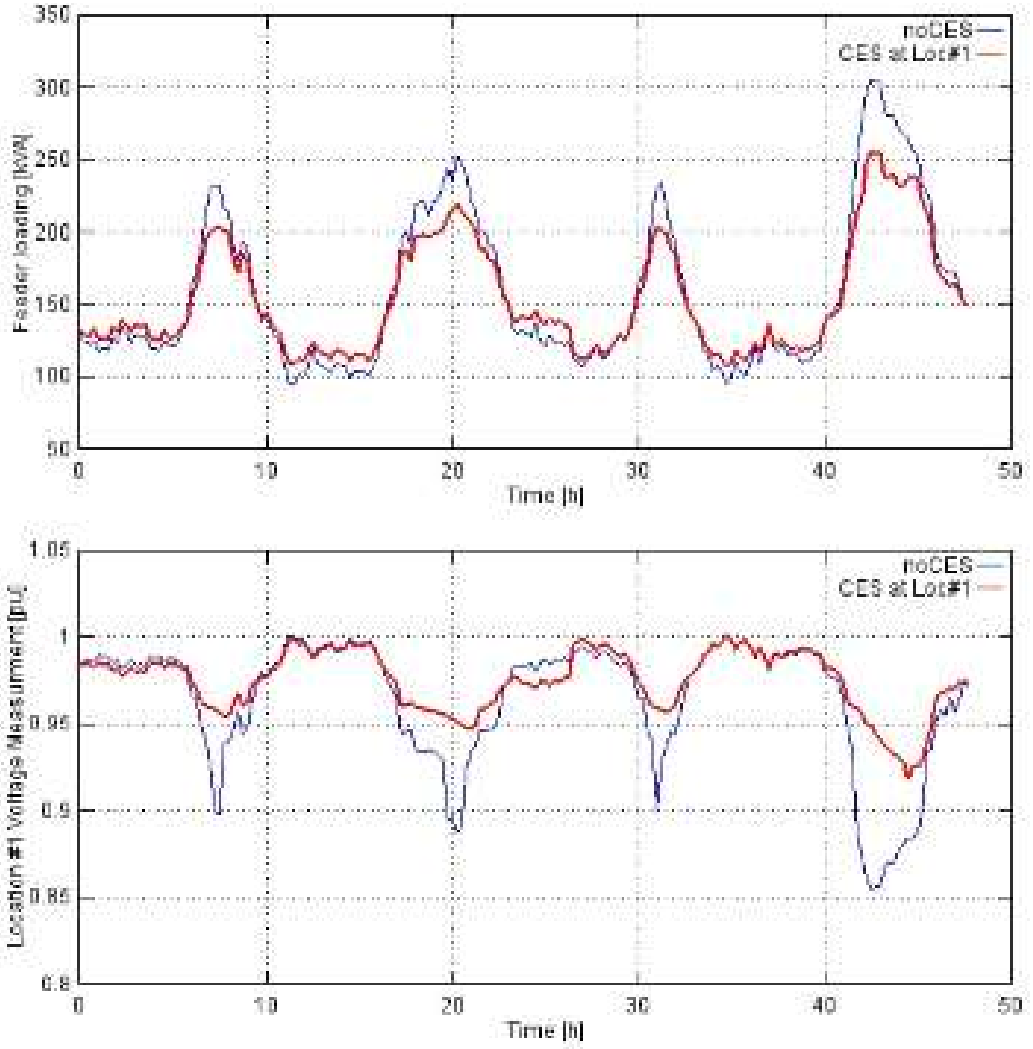


Voltage Support on SWER line



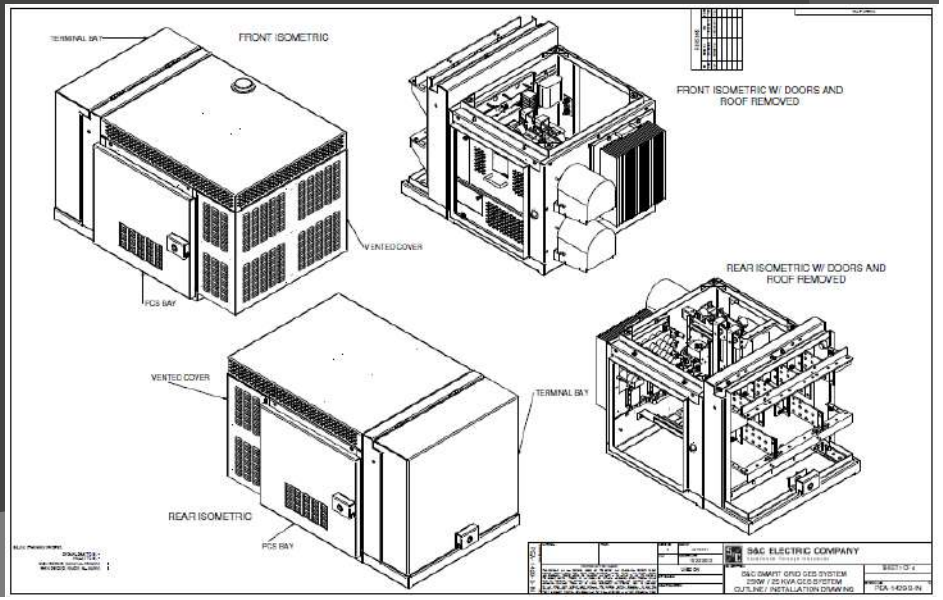


Combination of Real & Reactive power to Peak Shave AND Control Voltage



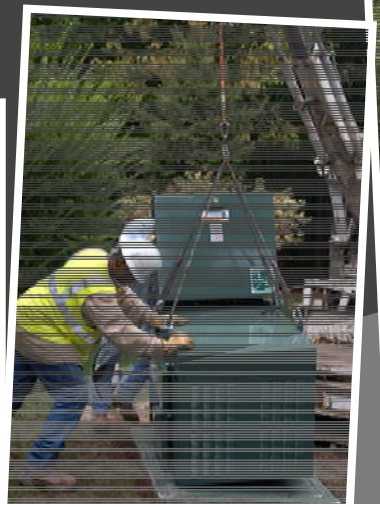
SWER Line Support using S&C CES

- Ride through outages (UPS like islanding functionality)
- Multiple units on one SWER line can communicate to cooperatively support line
- Capture energy generated through PV and use it to stabilise the line



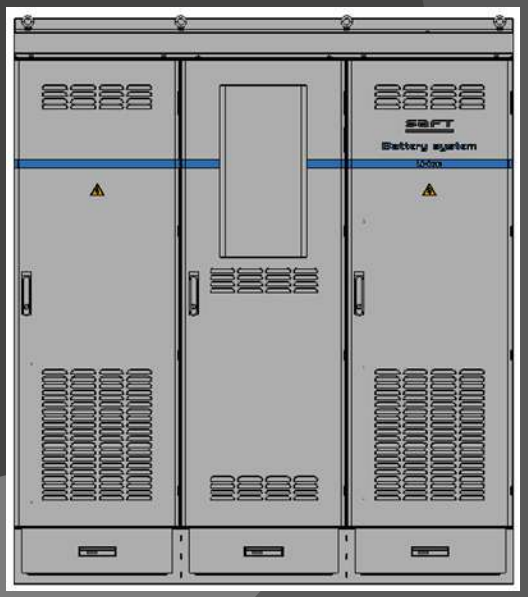
Multiple battery options

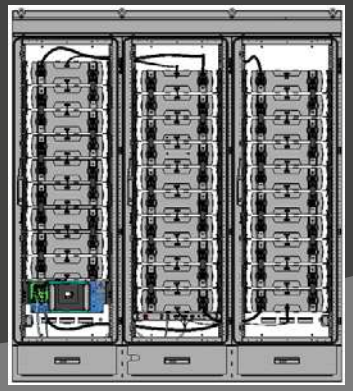
- Underground Lithium Ion by Kokam
  - Totally sealed, submersible battery tank
  - No moving parts
  - Minimise temperature cycles, maximising battery life



Multiple battery options

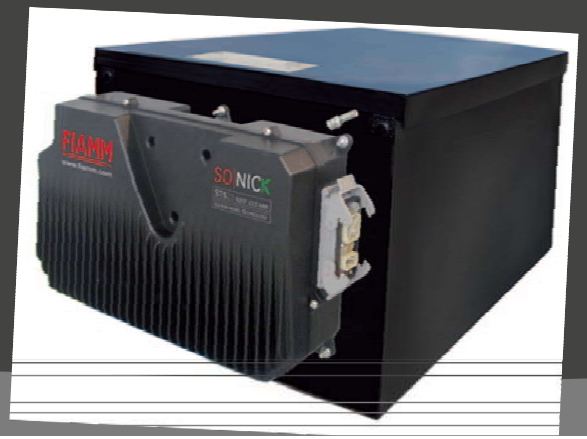
- Above ground Lithium Ion by SAFT
  - Rated up to 50 degrees Celsius ambient
  - Fan cooling –No A/C
  - IP54 Stainless Steel enclosure

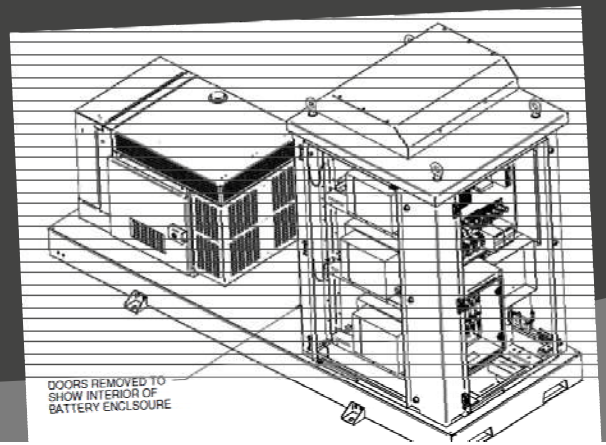




Multiple battery options

- Above ground Sodium Nickel Chloride
  - Convection cooled –no moving parts
  - Can withstand ambient temperature of +60C
  - Proven technology with 15+ year life





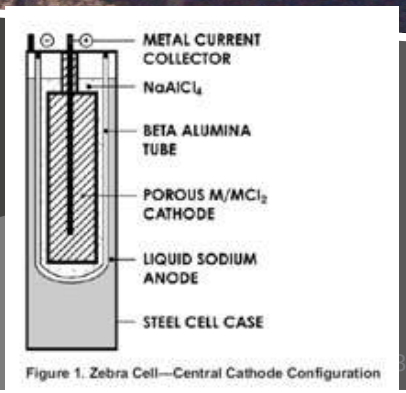


Figure 1. Zebra Cell—Central Cathode Configuration

Questions?