Exceptional service in the national interest

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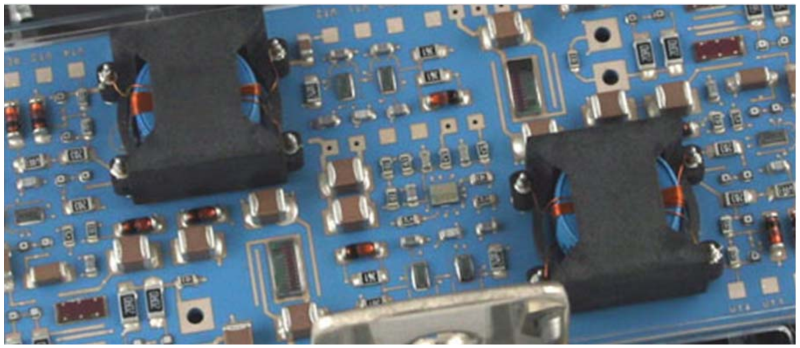

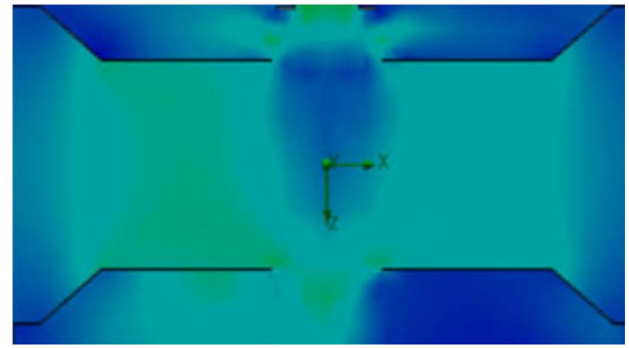

Renewable Energy & Efficiency for Alaska Native Villages

Stanley Atcitty (Stan), Ph.D.

Wind Energy Technologies Dept.

Anchorage, AK

Oct 16-17, 2012

U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

DOE Energy Storage Program

Program Manager: Dr. Imre Gyuk

- Mission:
  - Develop, in partnership with industry, advanced electricity storage and power conversion system technologies, for modernizing and expanding the electric supply to improve the quality, reliability, flexibility, and cost effectiveness of the existing system.

- The Program is led by Sandia National Laboratories.

Energy Storage Systems Program Goals

- Develop and evaluate integrated energy storage systems
- Develop batteries, SMES, flywheels, electrochemical capacitors, and other advanced energy storage devices
- *Improve multi-use power conversion system, controls, and communications components*
- Analyze and compare technologies and application requirements
- Encourage program participation by industry, academia, research organizations, and regulatory agencies

In short, develop a broad portfolio of demonstrated storage technologies for a wide spectrum of applications.

Benefits of Electricity Storage

- Maintain quality power and reliability
- Provide customer services — cost control, flexibility, and convenience
- Improve T&D stability
- Enhance asset utilization and defer upgrades
- Increase the value of variable renewable generation

Types of Technologies for Grid Storage

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- Mechanical
  - Flywheel Energy Storage
  - Compressed Air Energy Storage (CAES)
  - Hydroelectric Energy Storage (Pumped Hydro)
- Electrical
  - Electrochemical Capacitors
  - Superconducting Magnetic Energy Storage (SMES)
- Electrochemical
  - Batteries (Lead-acid, Lithium-ion, Nickel-cadmium, etc.)
  - Flow batteries (Zinc-bromine, Vanadium Redox Flow battery, etc.)

Energy Storage Applications by Category

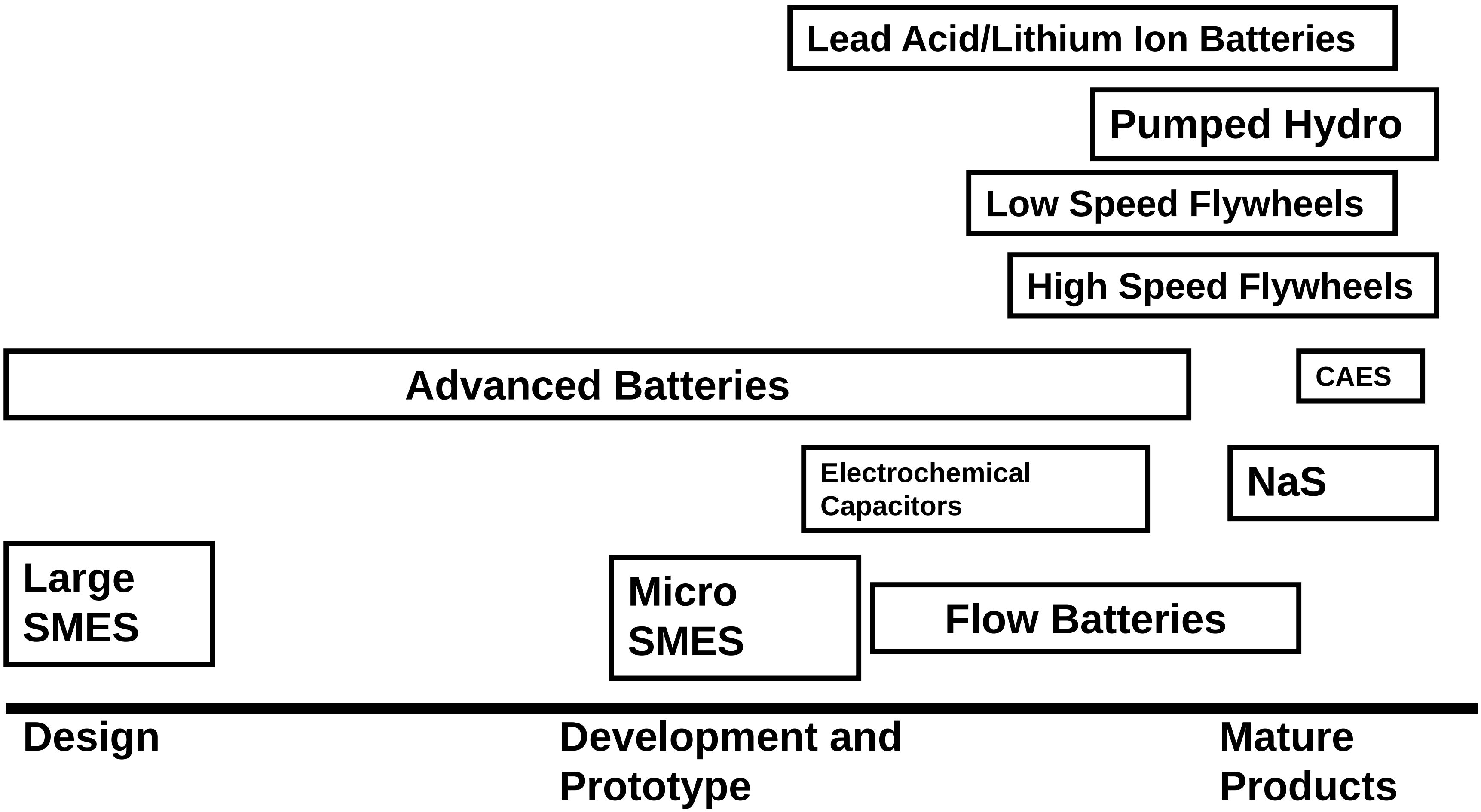
Technology	Advantage	Disadvantage	Power Applications	Energy Applications
Flywheels	High Power	Low Energy Density	Fully capable and reasonable	N/A
Electrochemical Capacitors (ECs)	Long Cycle Life	Very Low Energy Density	Fully capable and reasonable	N/A
Traditional Lead-acid	Low Capital Cost	Limited Cycle Life	Fully capable and reasonable	Feasible but not practical
Advanced Lead-acid with Carbon-enhanced Electrodes	Low Capital Cost	Low Energy Density	Fully capable and reasonable	Fully capable and reasonable
Sodium Sulfur (Na/S)	High Power and Energy Density	High Cost and Restrictive Operating Parameters (high-temperature operation)	Fully capable and reasonable	Fully capable and reasonable
Lithium-ion (Li-ion)	High Power and Energy Density	High Cost and Extensive Control Circuitry	Fully capable and reasonable	Reasonable
Zinc Bromine (Zn/Br)	Independent Power and Energy	Medium Energy Density	Reasonable	Fully capable and reasonable
Vanadium Redox	Independent Power and Energy	Medium Energy Density	Reasonable	Fully capable and reasonable
CAES	High Energy, Low Cost	Special Site Requirements	N/A	Fully capable and reasonable
Pumped Hydro	High Energy, Low Cost	Special Site Requirements	N/A	Fully capable and reasonable

Ref: Electricity Storage Association and Sandia National Laboratories 2010

Energy Storage Applications

	Power		**Energy**
Load	PQ, Digital Reliability	DER Support for Load Following	Peak Shaving to Avoid Demand Charges
Grid	Voltage Support, Transients	Dispatch ability for Renewables, Village Power	Mitigation of Transmission Congestion, Arbitrage
	Seconds	*Minutes*	*Hours*

Technology Maturity



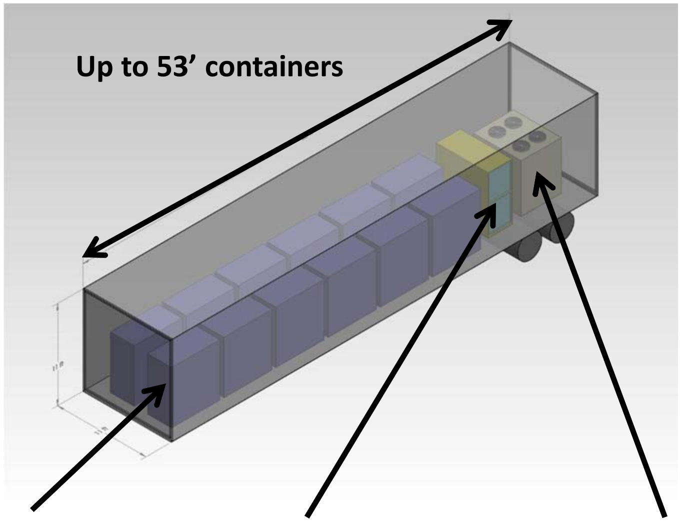
Ref: G. P. Corey, "Recent Advances in Energy Storage", APEC 21st Century Renewable Energy Development Initiative, Honolulu, HI, May10-12, 2004

Summary of System Costs (US $)

System Identification	System Description	Total Cost $/KW	Storage Cost	PCS Cost	Balance of System Cost
Puerto Rico	20-MW/14-MWh BES	1,102	22%	27%	51%
Chino	10-MW/40-MWh BES	1,823	44%	14%	42%
Vernon	3-MW/4.5-MWh BES	1,416	32%	19%	49%
Hawaii Electric - HELCO	10-MW/15-MWh BES	1,166	34.5%	18.5%	47%
Cresent	500-kW/500-kWh BES	1,272	41%	40%	19%
SDG&E	200-kW/400-kW BES	8,150	16%	23%	61%
PM250	250-kW/167-kWh BES	1,500	20%	50%	30%
Anchorage Municipal L&P	30-MVA/375-kWh SMES	1,467	45%	45%	10%

Ref: A. Akhil, S. Swaminathan, and R. Sen, "Cost Analysis of Energy Storage Systems for Electric Utility Applications," SAND97-0443, February 1997.

Transportable Systems

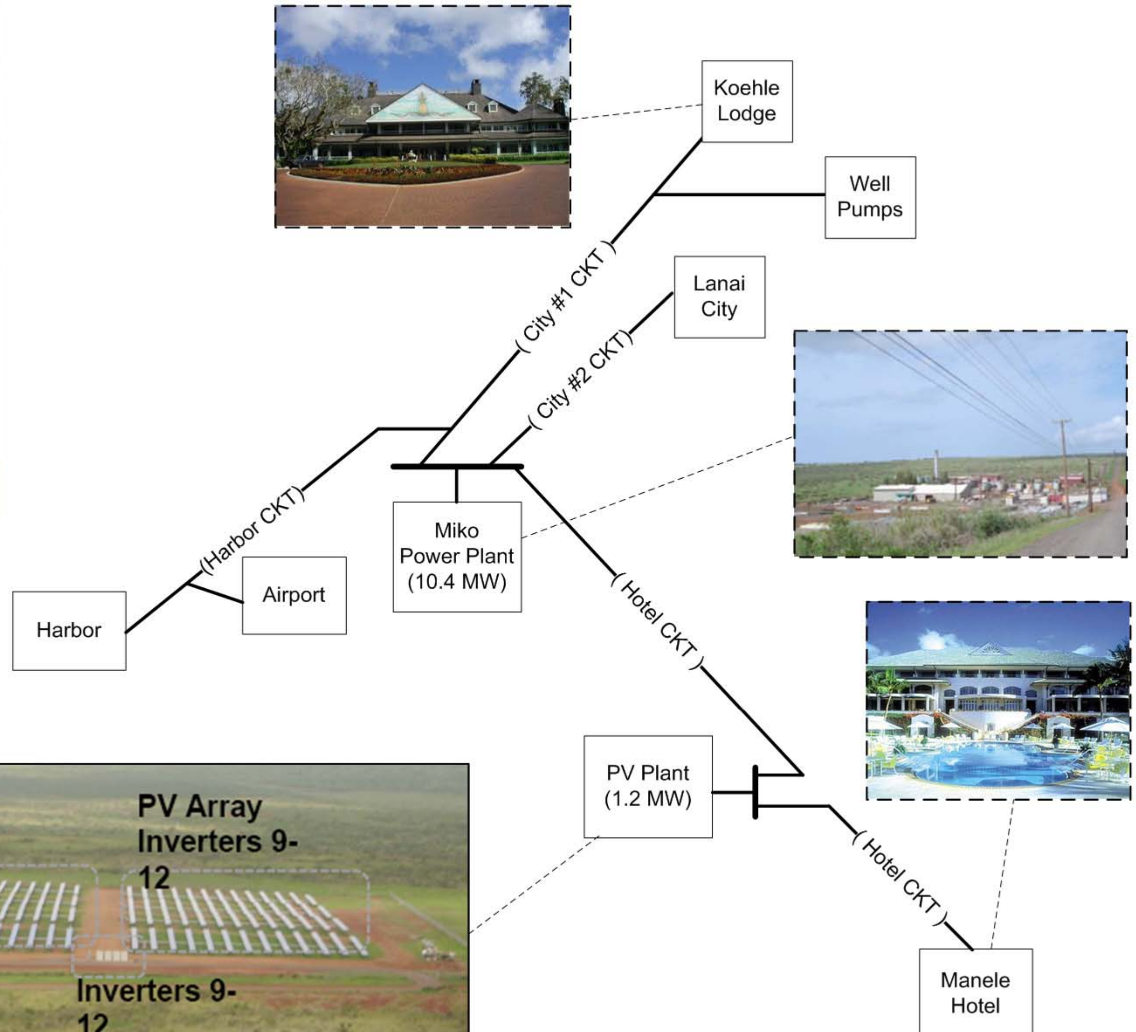


Typical Applications
- Grid stabilization
- Frequency regulation
- Renewable integration
- Peak shaving
- Voltage support

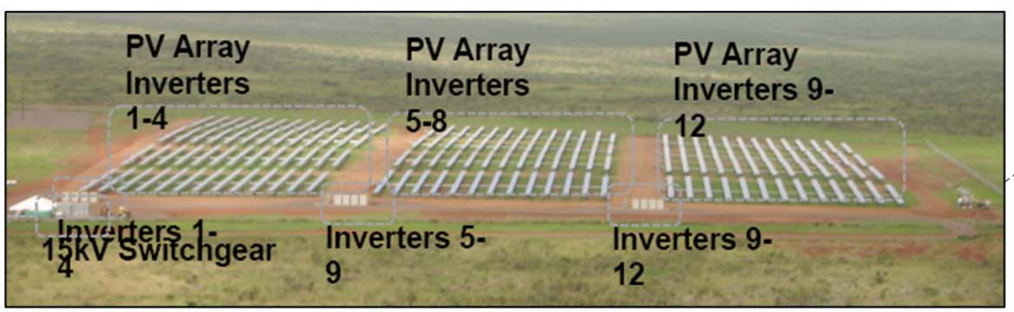
Typical portable power conversion system
- PWM voltage sourced converter
- Silicon-based power electronics
- Water cooled (*complex, bulky, and expensive*)

Benefits of portable storage
- Low installation cost
- Short time from installation to operation
- System is optimized for use at multiple sites

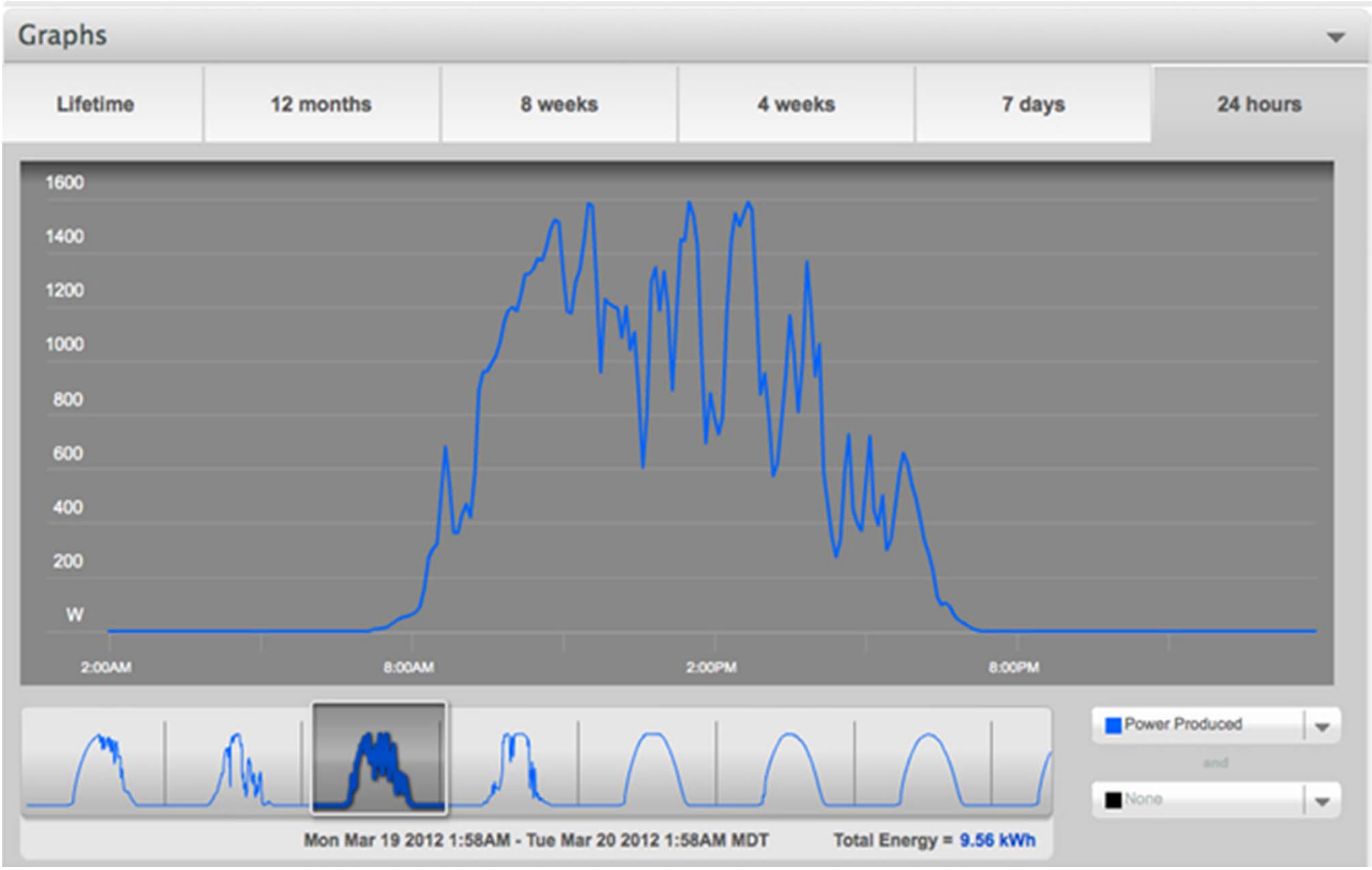
Lanai Grid Energy Storage Control Project



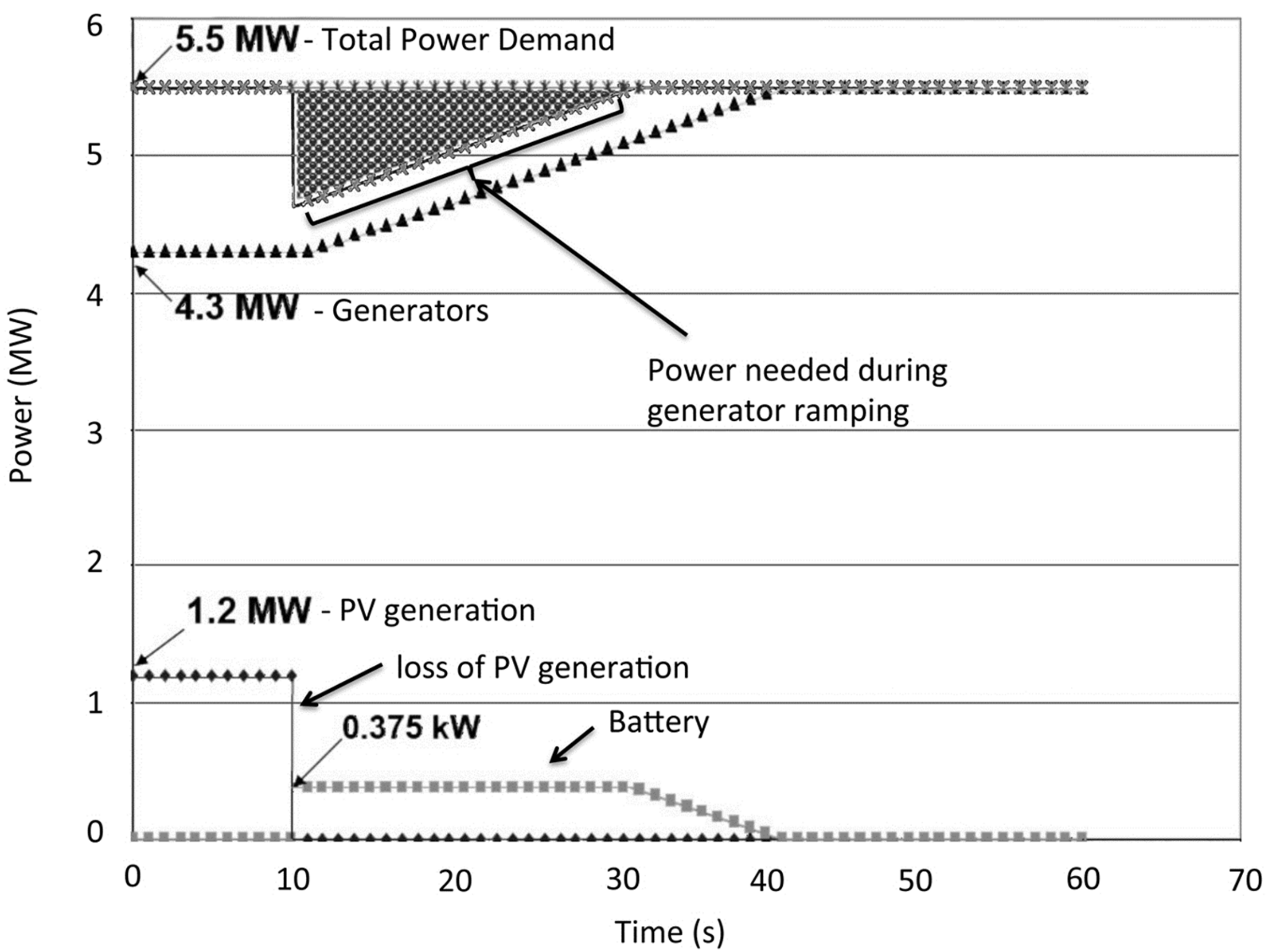
12-135kW SatCon Inverters



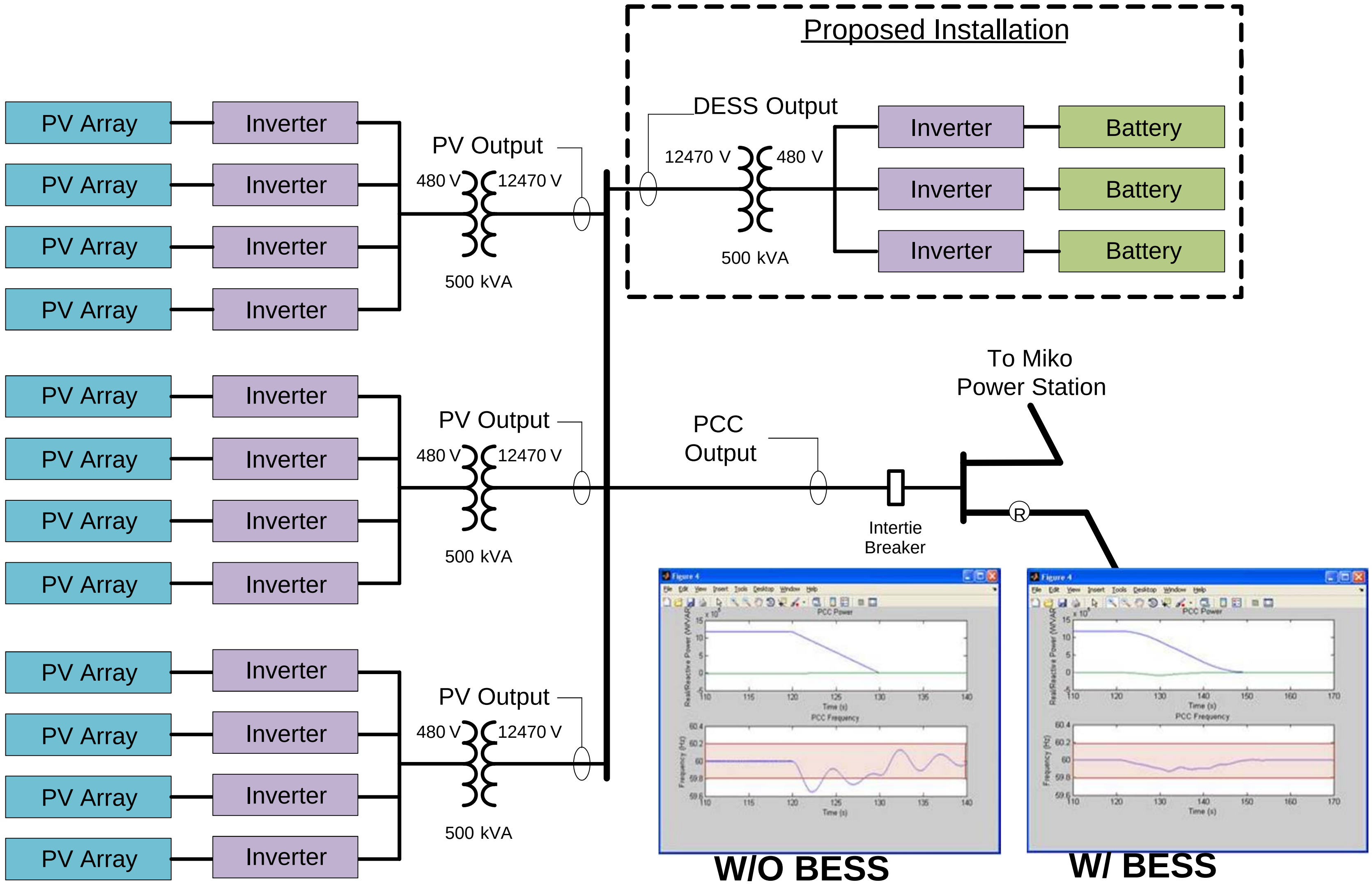
Variable PV output power



How Energy Storage Smooths PV

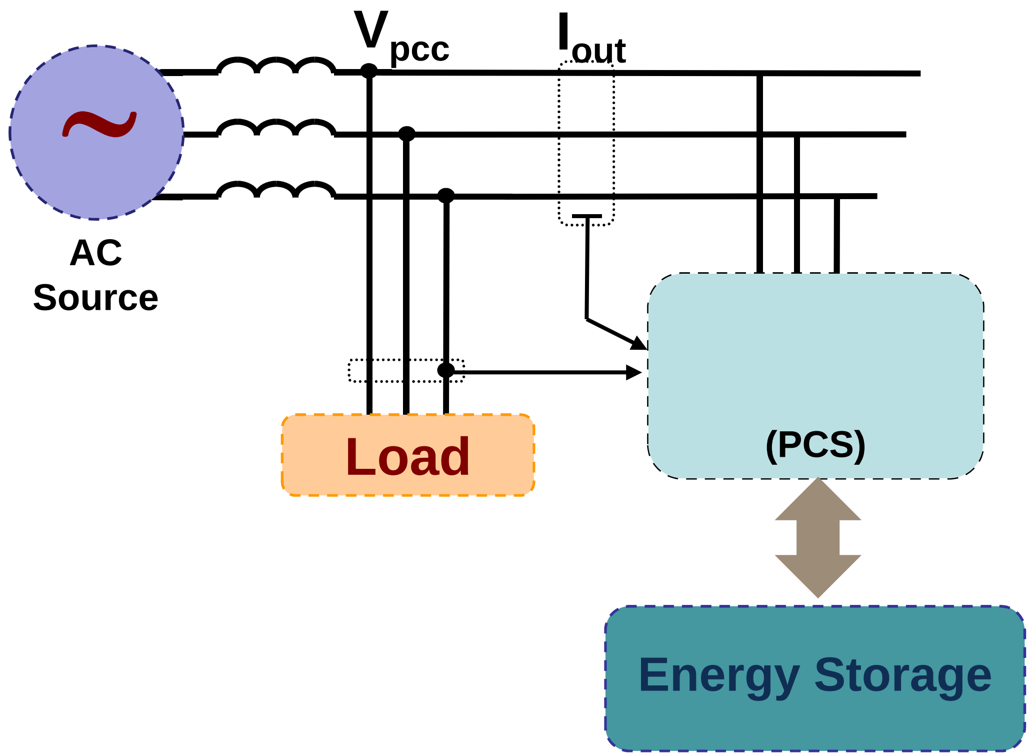


Lanai Grid Energy Storage Control Project



Energy Storage Power Electronics

- Needs:
  - Reduce install cost/kW
  - Decrease size and weight especially for transportable systems
  - Improve integration control
  - Increase reliability
  - Increase efficiency



The PCS is a key component of the energy storage system. It can represent 20 to 60% of the total system cost.

Sandia's Current PE Application Focus

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5 kW to 10's MW PCS

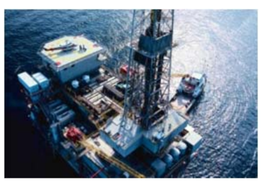
	seconds	minutes	hours
LOAD	PQ, Digital Reliability	DER Support for Load Following	Peak Shaving to Avoid Demand Charges
GRID	Voltage Support, Transients	Dispatchability for Renewables, Village Power	Mitigation of Transmission Congestion, Arbitrage

POWER Applications — ENERGY Applications

Energy Storage Power Electronics

- Micro-inverters: 100's W
- Residential : 1-6 kW
- Commercial : 20 – 100's kW
- Utility Scale 100's kW - >1 MW

Photovoltaics & Distributed Generation



Logging & Drilling Tools

- High Density
- High Temp > 200 ^{0}C
- >2 kW

Geothermal Technologies

- Type 3 & 4 PE
- Sensors
- Advanced Controls

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Power Electronics

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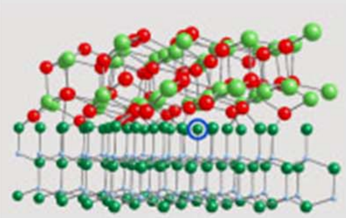
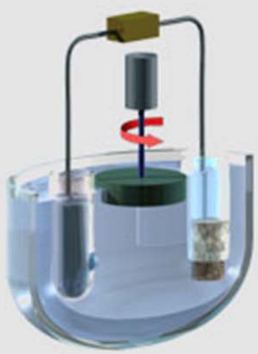
Materials R&D

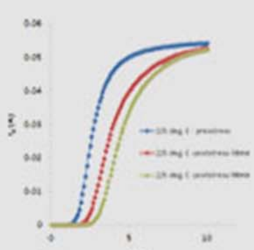


- Gate Oxide R&D
- Bulk GaN



Semiconductor Devices

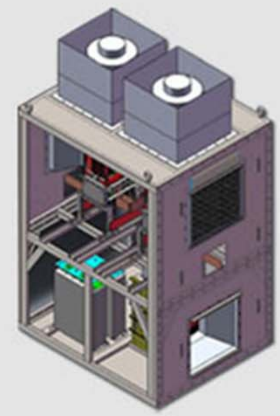
- Post Si Characterization & Reliability
- SiC Thyristors
- ETO



Power Modules

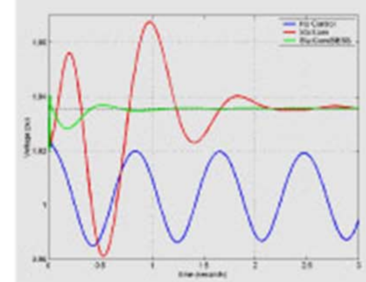
- High Temp/Density Power Module

Power Conversion System

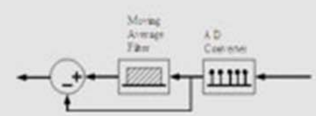


- Dstatcom plus energy storage for wind energy
- Optically isolated MW Inverter
- High density inverter with integrated thermal management
- High temp power inverter

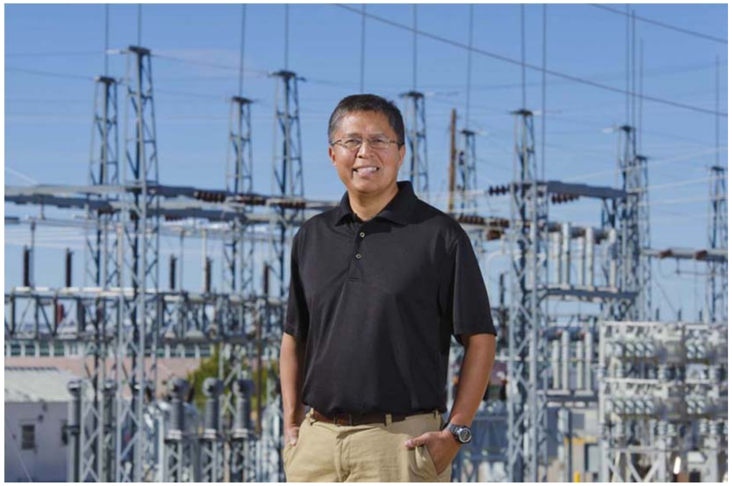
Applications



- Power smoothing and control for renewables
- FACTS and Energy Storage



Contact



Stanley Atcitty (Stan), Ph.D.

Principal Member of Technical Staff

Wind Energy Technologies Dept.

Sandia National Laboratories

Phone: 505-284-2701

Email: satcitt@sandia.gov