Aalborg 2015 Symposium of Microgrids
Aalborg, Denmark
27-28 August 2015

U.S. MARINE CORPS BASE CAMP PENDLETON FRACTALGRID DEMONSTRATION

California, United States

CLEANSPARK

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2011 U.S. SOUTHWEST BLACKOUT

- Five utilities affected:
  - San Diego Gas & Electric (SDG&E)
  - Imperial Irrigation District
  - Comisión Federal de Electricidad (CFE)
  - Arizona Public Service (APS)
  - Western Area Power Administration
- Seven million people without power
- Outage occurred
  - Days before the tenth anniversary of the September 11 attacks
  - Hours before the US Department of Homeland Security warned of a potential terrorist attack
- Cause:
  - Mistake by a technician: 500 kV line was cut between substations in Arizona
  - Cascading effect

U.S. MARINE CORPS BASE CAMP PENDLETON

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Aalborg 2015: Camp Pendleton
FractalGrid Demonstration

U.S. MARINE CORPS BASE CAMP PENDLETON

- Daytime Population: 100,000
- Temperatures
  - Mean high: 74.4ºF (23.6ºC)
  - Mean low: 50.4ºF (10.2ºC)
- Elevation: 62 ft (19 m)
- Land Area: 125,000 acres (505 km^2)

FOR COMPARISON

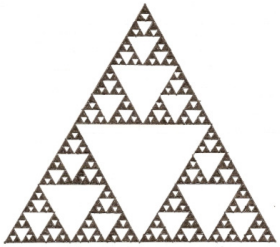
1. Vatican City (0.44 km^2)
2. Monaco (1.95 km^2)
3. San Marino (61 km^2)
4. Liechtenstein (160 km^2)
5. Malta (316 km^2)
6. Andorra (468 km^2)
7. **Camp Pendleton (505 km^2)**

CAMP PENDLETON FRACTALGRID DEMONSTRATION

Program Objective	Technical Objective	Relevant Use Cases
Energy Management	Utility Footprint Energy Reduction	Islanding Local Generation
	Utility Footprint Power Reduction	Peak-Shaving Load-Shifting Load-Leveling
	Carbon Management	Local Generation Peak-Shaving Load-Shifting Load-Leveling
Security	Islanding	Islanding Robust Data Collection

FRACTALGRID

- **fractal** is a self-similar recursive pattern that allows for a microgrid-inside-microgrid solution
- **fractalgrid**
  - (usually) community scale but allows for indefinite scalability with well bounded complexity of O(n)
  - makes use of standards and commercial-off-the-shelf (COTS) equipment when available
  - units can operate autonomously and collaboratively



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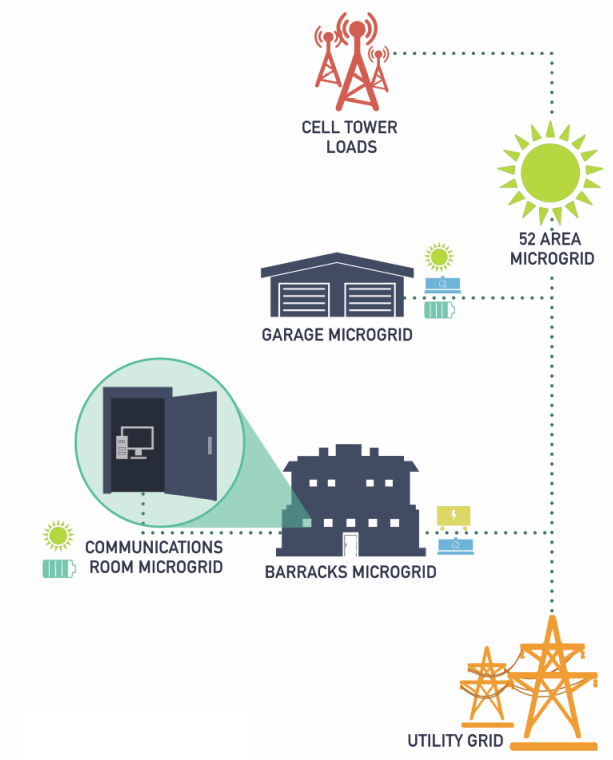
CAMP PENDLETON FRACTALGRID



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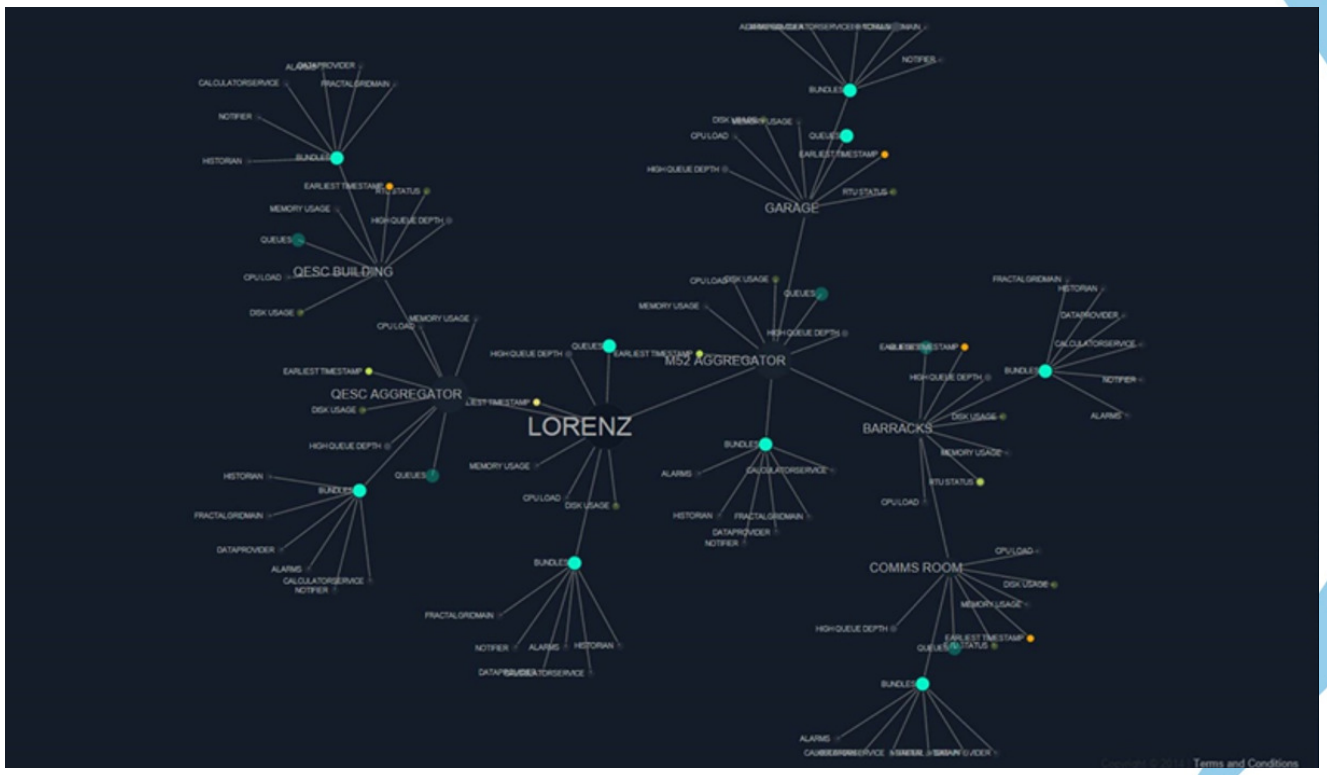
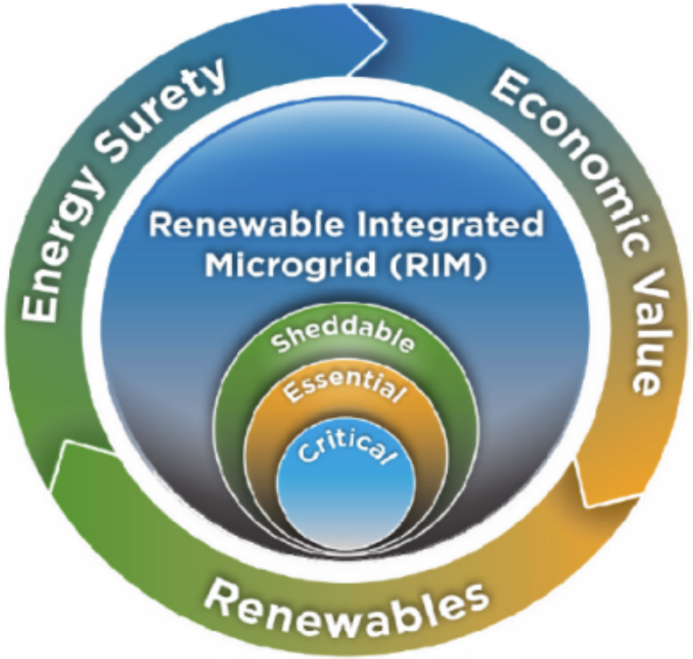
FRACTAL ARCHITECTURE: HEALTH MONITOR



MICROGRID SPECIFICATIONS

	52 Area Microgrid	Garage Microgrid	Barracks Microgrid	Comm Room Microgrid
SCADA System	CleanSpark	CleanSpark	CleanSpark	CleanSpark
Critical Loads	3 cell towers and support components	Parking structure, emergency lighting	Arms rooms, lighting, elevators -- isolated with emergency circuit	Server and communications equipment
Energy Requirements for All Loads	21,325 kWh/mo	6,920 kWh/mo	77,280 kWh/mo	1,500 kWh/mo
Energy Requirements for Critical Loads	21,325 kWh/mo	500 kWh/mo	3,240 kWh/mo estimated	750 kWh/mo
Non-critical Loads	Barracks building except mBarr	Non-critical lighting and receptacles	None	None
Parent Microgrid	SDG&E Utility	m52	m52	mBarr
Child Microgrids	m5.2, mBarr	None	mComm	None
Renewable Energy	300 kW PV 233 kW CPV	2 kW PV	None	2 kW PV
Main Energy Storage	Child microgrids	1 flywheel, Batteries (AGM)	1 flywheel	Batteries (Gel)
Total Energy Storage	See child microgrids	118 kWh per cycle average	100 kWh per cycle average	10 kWh per cycle average
Emergency Power	None	None	250 kW Diesel generator	None

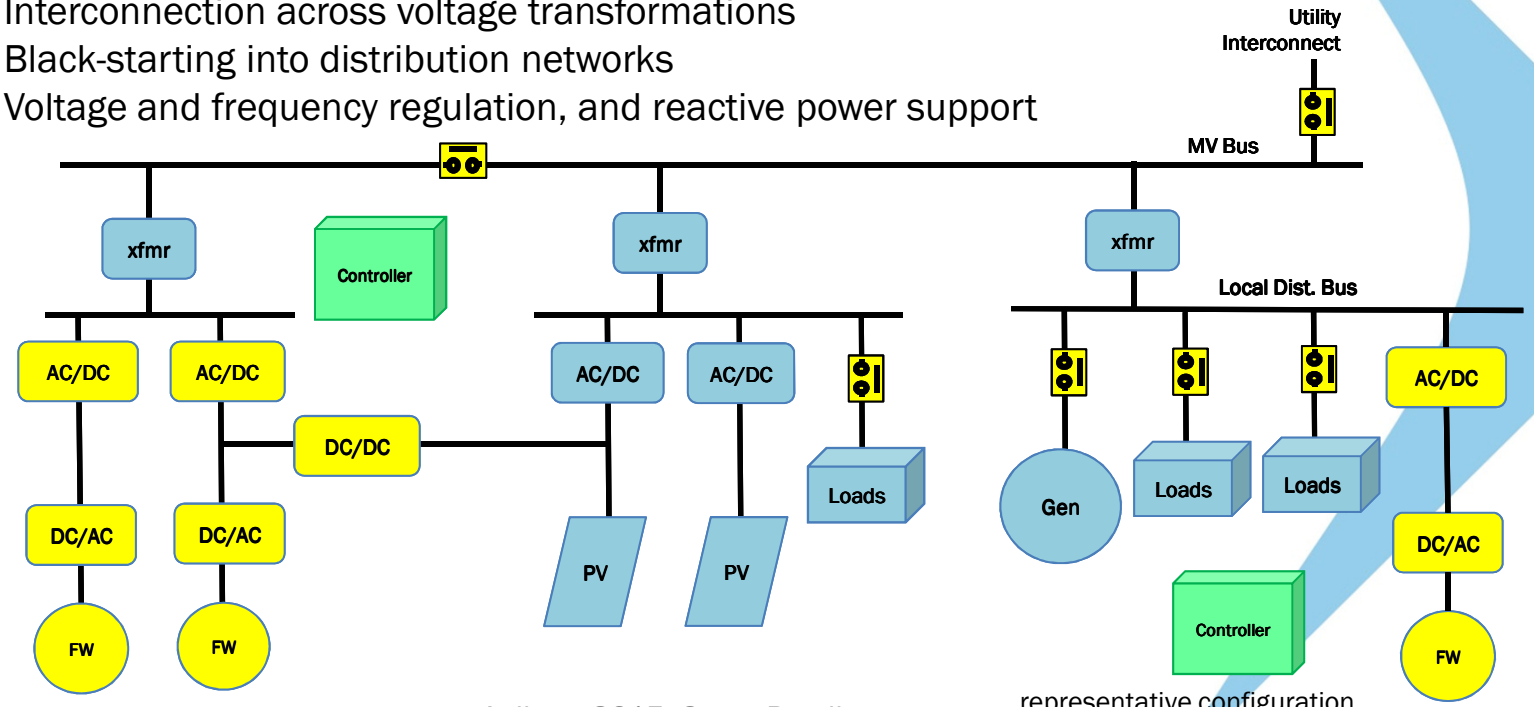
NREL LOAD CLASSIFICATIONS



NREL: United States National Renewable Energy Laboratory

ELECTRICAL NETWORK

- Power conversion building blocks to expand and flow power as needed
- Provide the grid foundation for other sources and loads.
  - Interconnection across voltage transformations
  - Black-starting into distribution networks
  - Voltage and frequency regulation, and reactive power support



representative configuration

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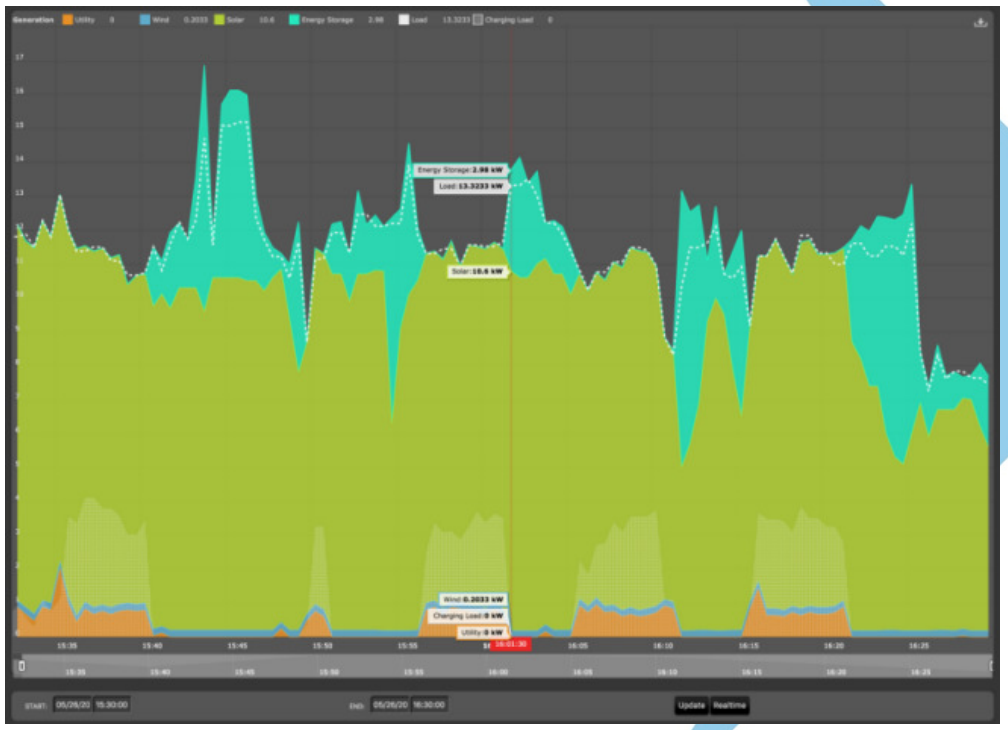
DATA NETWORK: FRACTALNODE™



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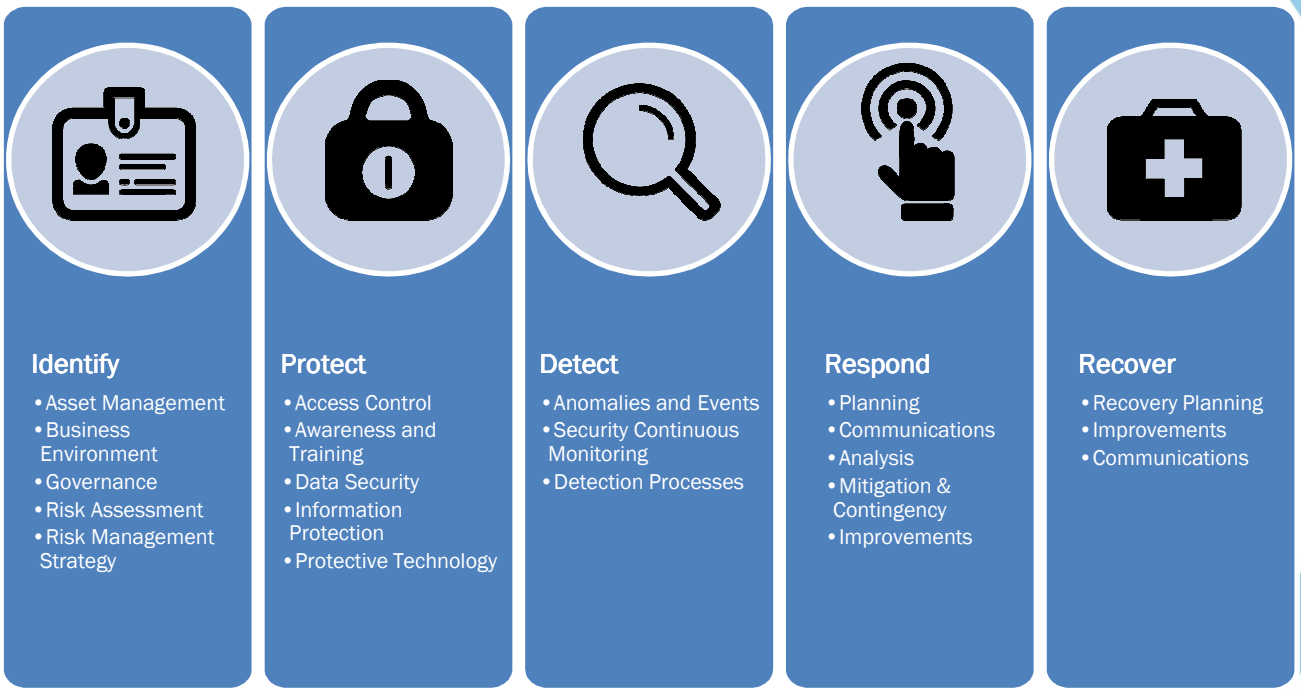
SOFTWARE TENETS

- Modern, open, standard protocols
  - AMQP, XMPP, HTTPS, SFTP, etc.
- Secure
  - Encrypt all communication, PKI authentication
  - Input checking
- Scalable
  - Asynchronous, event-driven communications
- Resilient
  - No data lost if communication lost
  - Automatic system recalibration
- Modular
  - Isolate functionality
  - Minimize dependencies
- Framework-driven
  - Separate execution from algorithms

GRID INTERACTION

- OpenADR 2.0b
  - Automated demand management
  - Selective event participation based on customer's goals
  - Custom client implementation
  - XMPP and HTTP based communication
  - Third-party tested
- Energy Markets
  - Eligibility for various ancillary service programs based on current availability and response time
  - Automated demand management

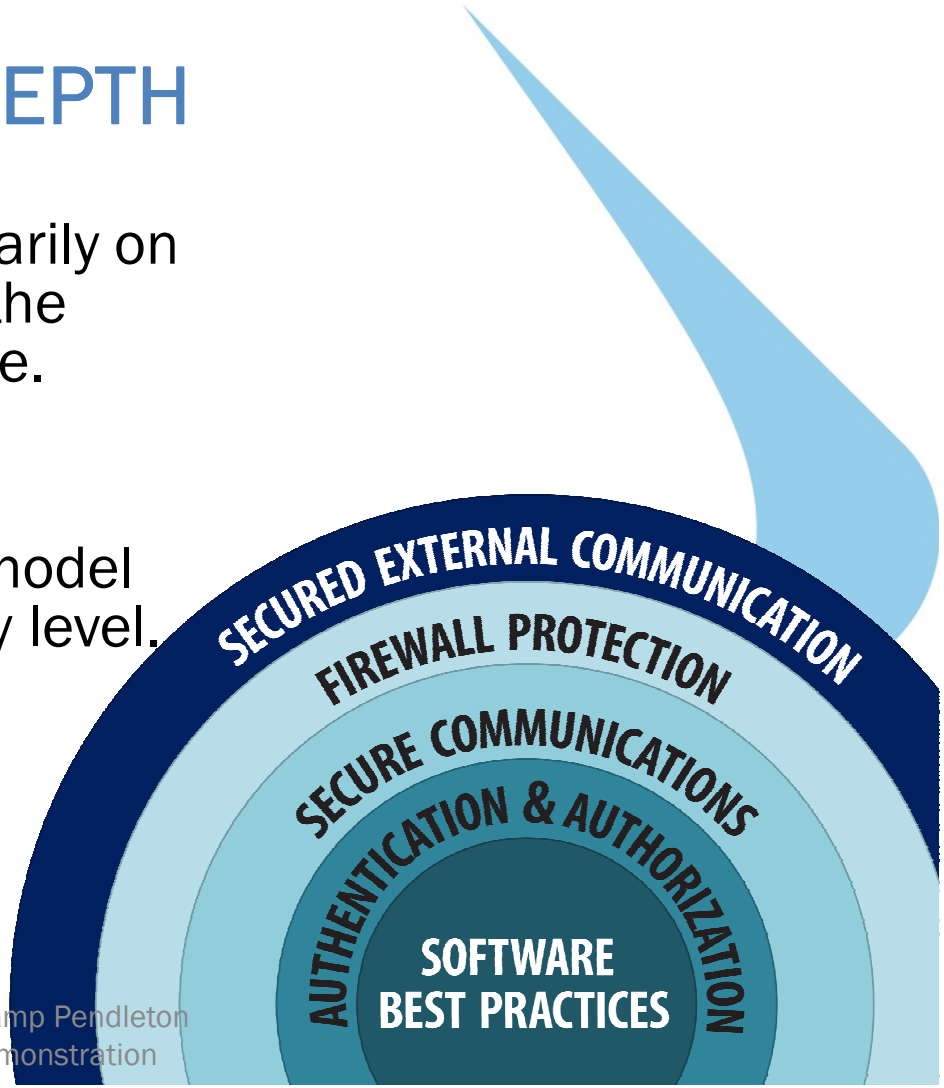
NIST CYBERSECURITY FRAMEWORK



NIST: United States National Institute of Standards and Technology

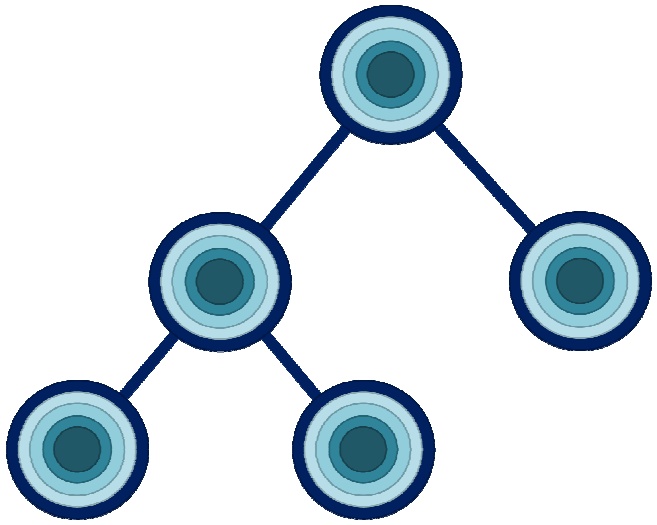
DEFENSE IN DEPTH

- Early security models rely primarily on the “gumball” model, hard on the outside but hollow on the inside.
- More recent models are called “Defense in Depth”
- CleanSpark has a very dense model that allows for defense at every level.



SECURE SYSTEM OF MICROGRIDS

- When each microgrid implements a Defense In Depth strategy, breaking one layer or even one microgrid doesn't allow access to all.



- Microgrids equipped to automatically reject data and energy sharing with another node when a cybersecurity incident is identified.

RESULTS

	mComm	mBarr	m5.2	m52
Islanding	COMPLETED	COMPLETED	COMPLETED	Developing outside grant
Consumption Reduction	COMPLETED	COMPLETED	COMPLETED	COMPLETED
Peak Load Management	Not applicable	COMPLETED	COMPLETED	COMPLETED
Carbon Management	COMPLETED	COMPLETED	COMPLETED	COMPLETED

REALCOMM ARTICLE: CAMP PENDLETON MICROGRID

Next Generation Microgrids - Is Camp Pendleton The Most Advanced in the World?

Author: Jim Young, Co-Founder & CEO, Realcomm

Brand new technologies often start out as a trend, the 'next new thing'. There was speculation that the energy around microgrids was coming from a large influx of capital from state and local governments, as well as the utilities. Like many new ideas, microgrids rose in popularity and then suddenly disappeared. After the hype phase died down, the topic of microgrids did not disappear, but rather the noise went away and the serious got down to work.

One aspect that seemed ambiguous was defining what microgrids actually are; there are many different names and interpretations. Are they simply local co-generation systems, or a radical augmentation? In extreme cases, could they replace the current electric grid operated by the utilities?

There is a definite need for microgrids and they have a unique relationship with smart buildings if we really want to achieve the ultimate efficiency for the built environment.

Early this year, we were invited to tour the FractalGrid Demonstration project at Camp Pendleton. A very advanced project conceived over ten years ago, this project was completed in partnership with the private sector and the Navy. The goal was simple: to make sure Camp Pendleton would remain fully functional in the event of a utility grid interruption. The result was extraordinary, with multiple microgrids strategically arranged to follow a fractal or recursive pattern. Concentrated and PV solar, combined with an advanced flywheel storage system, utilization a state-of-the-art enterprise management platform based on the Intercontinental Ballistic Missile System ICBM (needed for almost instantaneous response), all tightly integrated into smart building automation systems.

The result was possibly the most advanced microgrid / smart building project in the world, which generated 140% of the required electricity for the project. Following is the Executive Overview of the project.

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FractalGrid Demonstration

BACKUP

ART VILLANUEVA, CEA
CTO, CSO, CleanSpark

Art Villanueva is the Chief Technology Officer and Chief Sustainability Officer for CleanSpark. As a technologist, he immerses himself in the intersection of energy, environment, defense, consumer electronics, and mathematics. Mr. Villanueva's most recent roles include serving as Principal Investigator for the California Energy Commission's Camp Pendleton FractalGrid Demonstration, serving as the Chief Architect and Lead Systems Engineer of the Navy's $638M Consolidated Afloat Networks and Enterprise Systems (CANES) program, and serving as Principal Investigator for an Independent Research & Development (IRAD) project for the development of the model-based systems engineering infrastructure used by multiple $500M+ programs.

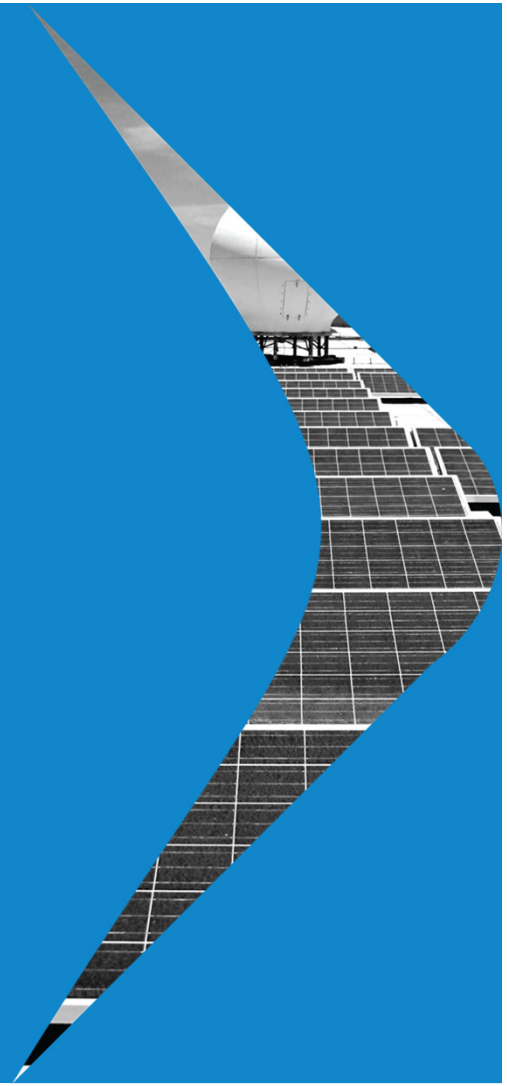
Mr. Villanueva has a Master's degree in Architecture-based Enterprise Systems Engineering from UCSD (Architecting Critical Infrastructure Protection for the Energy Sector and Beyond), a Bachelor of Science in Applied Mathematics with Specialization in Computing from UCLA, and a Master of Science (abt) in Computer Science (Multimedia Systems) from UCSD coupled with coursework from Harvard University's Master's program in Sustainability and Environmental Management.

JEFF TRUEBLOOD, PE

Director of Electrical Engineering, CleanSpark

Jeff Trueblood is the Director of Electrical Engineering for CleanSpark, responsible for the design and implementation of the electrical systems that make the fPS system possible. Mr. Trueblood has over 18 years electrical engineering experience specializing in building systems design including medium-voltage, line-voltage, emergency, stand-by, multiple low-voltage systems including telephone, data, fire alarm, nurse-call, specialty alarm systems and security. Jeff has worked on numerous multi-discipline facility projects including commercial, residential, industrial, OSHPD, LEED and government building standards. Jeff has received lighting awards with the IESNA and taught southern California IES chapters on lighting controls and efficiency.

Thank You



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