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INSTALLATION MICROGRID AND NETWORKED STANDBY POWER DESIGN CRITERIA (US DOD UFC 03-550-4)

Naval Post Graduate School
Defense Energy Seminar
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Course Outline

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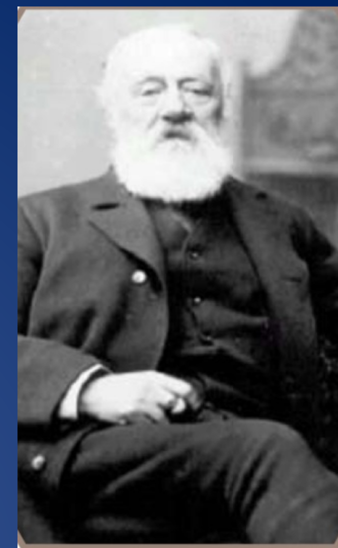
There is a popular comparison that underscores the pace of change – or lack thereof – regarding our nation's grid.

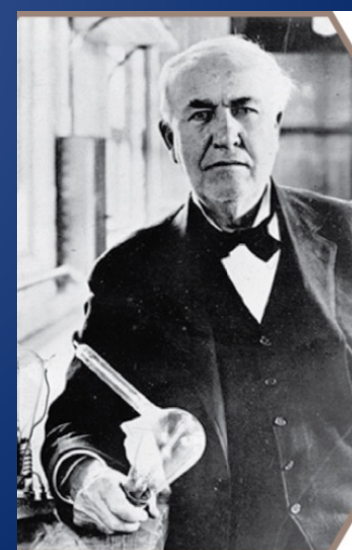


Bell

The story goes like this:

If Alexander Graham Bell were somehow transported to the 21st century, he would not begin to recognize the components of modern telephony – cell phones, texting, cell towers, PDAs, etc. – while Thomas Edison, one of the grid's key early architects, would be totally familiar with the grid.

Edison



Microgrids Support Elevated Mission Assurance

- Traditional power system technology for contingency (standby) at DoD installations has **not kept pace with technological advancements** for 21st Century Operations

- Most critical facility loads use dedicated diesel generators to provide spot generation (US DOD - UFC 340-01)

- In vast majority of cases, **contingency power systems are oversized (under utilized)**

- Primary benefit of networking energy infrastructure at an installation is **elevating the level of mission assurance.**

"Military installations are almost completely dependent on a fragile and vulnerable commercial power grid, placing critical military and Homeland defense missions at unacceptable risk of extended outage."

- Defense Science Board Task Force (2008)

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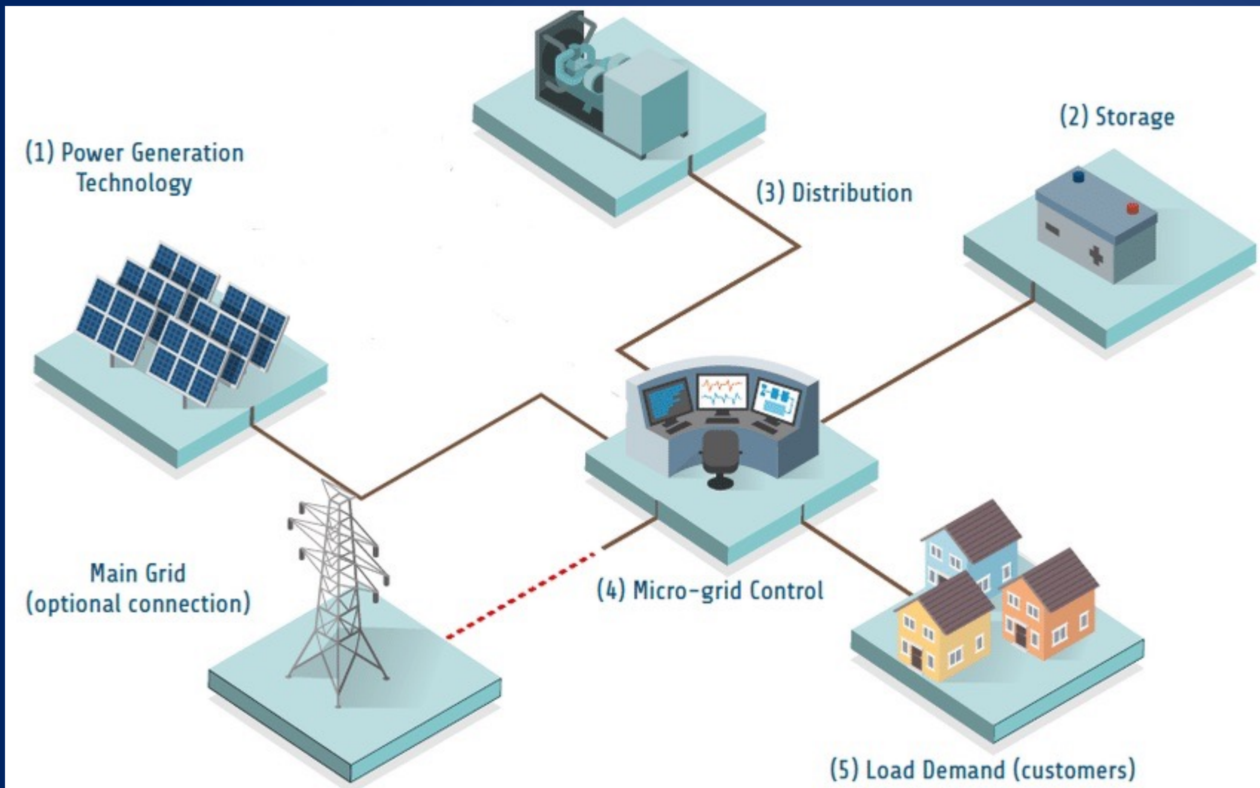
Technical Definition



Architecture and Source Agnostic

A microgrid is a decentralized group of electricity sources and loads …. but is able to disconnect from the interconnected grid and to function autonomously in "island mode"

- Wiki

The operational mode for stand-alone power production … that is disconnected from an electric power production and distribution network or other primary power source.

- NEC Article 705

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Major Components

1. **Sources** – Generation (Distributed or Centralized) including turbines, engines, photovoltaic, fuel cells, hydro-power, etc

2. **Loads** – Facilities, Operations Centers, or other Installation Energy Consumers

3. **Distribution** – Electrical Distribution between installation substation and facility transformer

4. **Switchgear** – Distribution level switches, electrical breakers, and paralleling gear

5. **Point of Common Coupling** – the point of demarcation between the bounded microgrid and the external grid or interconnection (there may be more than one depending on the design).

6. **Secure Controls** – Utility Control Hardware, Software, and Human- Machine Interface (Require Cybersecure Controls)

7. **Energy Storage (Optional)** – Chemical Storage (batteries), Hydrogen, or Fuel-based Storage

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History of Microgrid Development in DoD

Research Phase (2005-2010) → **Fielding and Demo Phase (2010-2015)** → **Integration Into Real Property Infrastructure Phase (2015-2021)** → **Mass Adoption Phase (2022 → Present)**

Research Phase (2005-2010)

- Basic Research and Applicability to Installation Power Systems
- Lab scale/Bench Scale Testing
- Modeling, simulation

Fielding and Demo Phase (2010-2015)

- Initial Fielding to US-based Installations
- US DOD - Smart Power Infrastructure Demo for Energy Reliability and Security
- Performance Validation

Integration Into Real Property Infrastructure Phase (2015-2021)

- Microgrid Projects Integrated into Military Construction (MILCON) and Energy Savings Performance Contracts (ESPC)

Mass Adoption Phase (2022 → Present)

- US DOD Tri-Service Unified Design Criteria (in Draft)
- Army Climate Strategy Calls for 140 Microgrid Systems on Installations
- Navy/Marine Corps Accelerated Design

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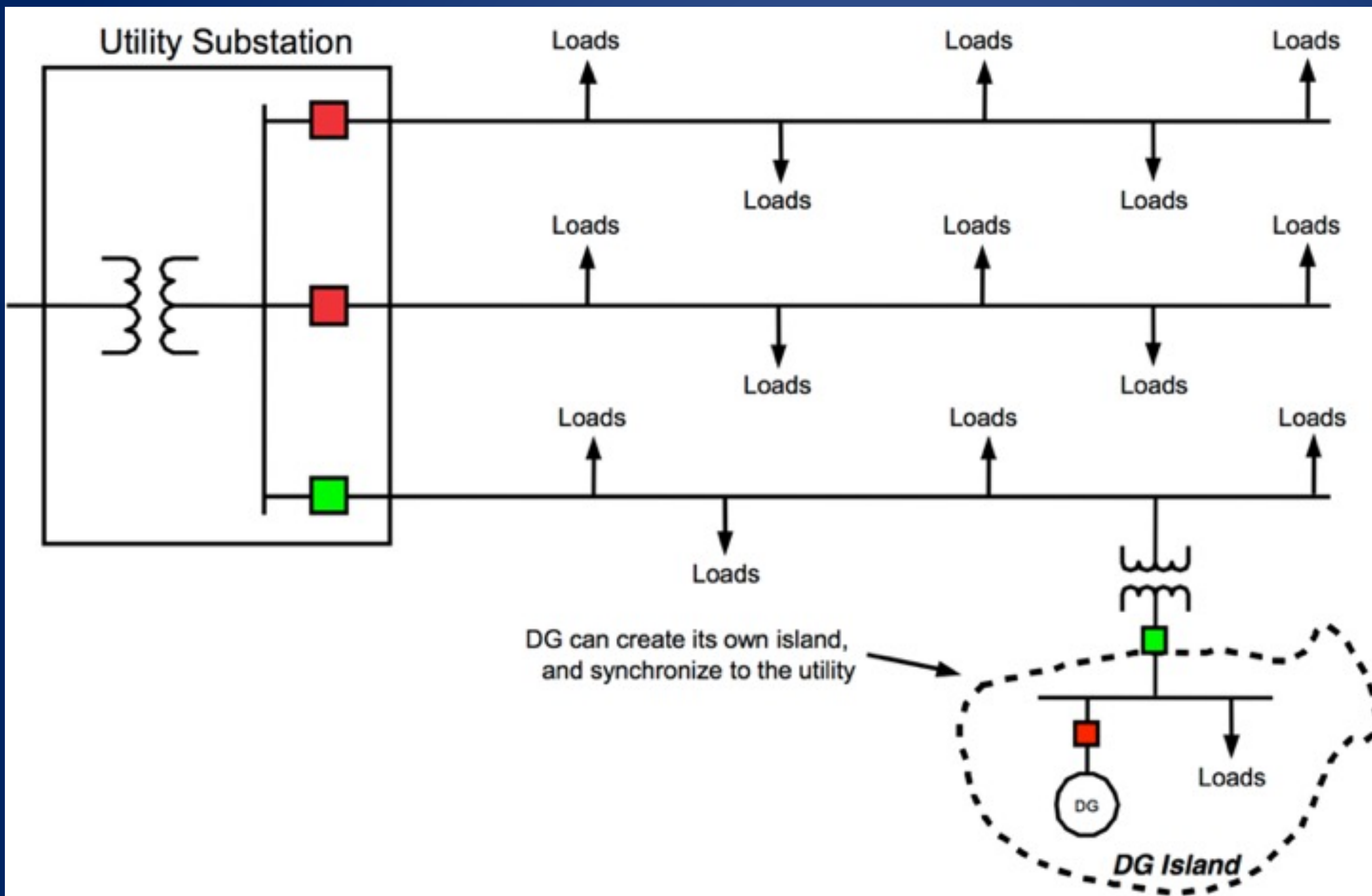
Defined Boundary, Autonomous Operation



- ✓ Optimized Resilience
- ✓ Climate Friendly (Renewables) Integration
- ✓ Streamlined Cybersecurity

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How Microgrids Address Installation and Operational Requirements

Installation Microgrids

Energy Security/Resiliency

- Maximize Off-Grid Mission Endurance
- Isolate & service Critical Facility Loads
- Fully Automated CONOPS, Rapid Restoration,
 and Optimized Operational Visibility

Sustainable, Renewable Energy

- Enable Renewables to Support mission during outages without utility signal
- Allow Renewables to defer consumption of valuable fossil fuel during contingency operation

Cybersecurity

- Air gapped ICS systems
- Cyber Sustainability with Platform Approach to ICS Hardening and IA Accreditation
- Cyber security hardware, software, system integration into RMF

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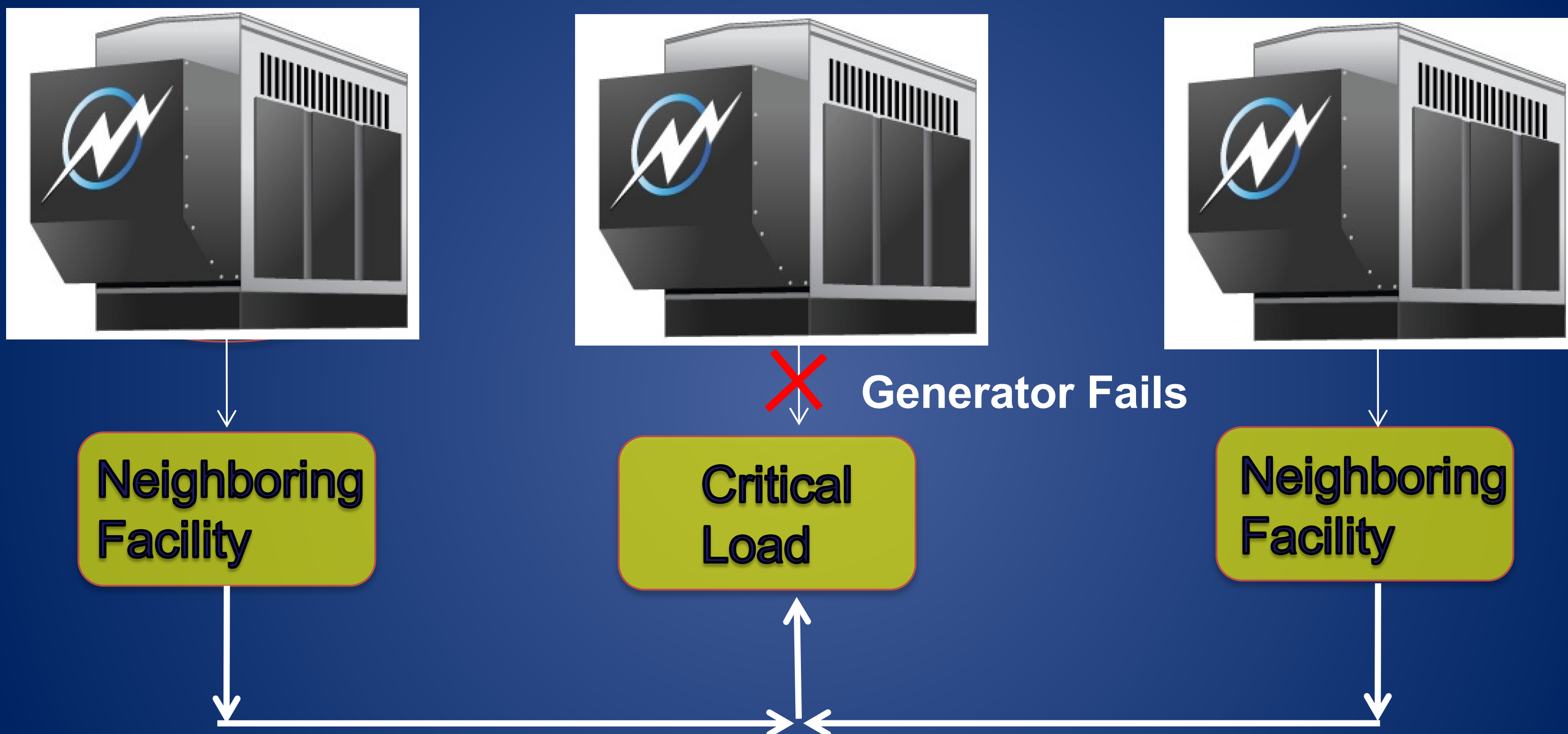
Operational Flexibility



Eliminate single points of failure and route power throughout the microgrid for maximum operational flexibility

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Performance Metrics

- OFF-GRID SYSTEM ENDURANCE - total duration the microgrid can carry the peak critical load without the return of commercial power or refueling service
- PEAK CRITICAL LOAD SERVED - capacity to support the peak-load demand of critical systems when they are engaged in normal mission activity.
- LOAD SHEDDING - capacity of the design to shed load to maximize endurance of higher priority mission operations.
- RESTORATION TIME AND SOFT TRANSITION - Time to supply power to all critical loads in the network; the time required for the system to island at all points of interconnection, and deliver power to the designated critical load
- OPTIMIZED LOAD FACTOR - Extent to which the design minimizes low load factor operation including operation of assets in spinning reserve
- DEGREE OF RENEWABLE ENERGY CONTRIBUTION - Extent to which the system leverages new and existing renewable energy technology
- EXPANDABILITY AND RECONFIGURABILITY - Extent to which system design accommodates load growth or mission expansion with minimal design reconfiguration, reprogramming, and recurring engineering costs.
- POWER QUALITY - Extent to which system delivers consistent power quality and high grid stiffness

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Sequence of Operations

1) **Normal Operation -** Grid-Connected, Stand-By

2) **Islanding** - Isolation from External Utility

3) **Black Start and Formation** (Soft transition or Black Start)

4) **Islanded Operation** (Optimized Operation for Resilience and Endurance)

5) **Re-Synchronization -** Reconnect Back to External Utility (Soft Transition Only)

6) **Testing and Diagnostics -** Supports Regularly Scheduled Loaded Testing, Troubleshooting

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Draft Unified Design Criteria

- ✓ Architecture and Source Agnostic
- ✓ Allow for the widest "aperture" of design solutions and acquisition vehicles,– minimize restrictive/prescriptive statements
- ✓ Open, Performance-based Design Standard (not prescriptive)
- ✓ Standby back up power is complementary to traditional, facility-dedicated back up (defense-in-depth concept for energy resilience)

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Criteria Technical Highlights

To be in technical compliance of the specified criteria, the design must provide the following:

1. **Be a Bounded System with autonomous generation, distribution, and controls**

2. **Be capable of islanding *with ability* to parallel and network more than one disparate source of generation**

3. **Black Start: Be capable of grid-independent, autonomous black start**

4. **System Balancing: Contain grid-independent ability to energize critical loads and optimize load factor**

5. **Contain sufficient inverter-based sources and spinning reserve to meet the peak critical load within the system boundary**

6. **Fail-Safe Operation – deliberate return to load dedicated operation following loss of communication or other network impact**

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Criteria Technical Highlights

To exceed the specified criteria, the design may include the following:

1. **Soft, "blinkless" Transition**
   - Be capable of re-synchronization and soft (seamless) transition *to islanded operation*
   - Be capable of re-synchronization and soft (seamless) transition *back to the external grid*
2. **Energy Storage** – paralleling, forming, improved renewables utilization, improved power quality, blinkless transition, peak shaving or other grid incentives
3. **Grid Connected Operation** – for load curtailment, demand response or grid services
4. **Redundant** (min 2) grid forming assets (generator or inverters)
5. **Redundant** (min 2) HMI Visualization Front-Ends
6. **Redundant** (min 2) Independent Black Start Sources)
7. **Load Shedding** Capability or Prioritized load restoration

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End of Microgrid Course

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Installation Power Quality

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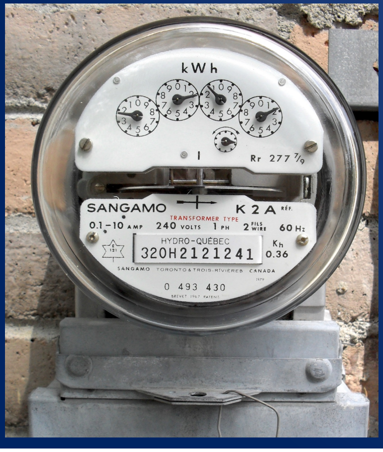
Major Transitions in Installation Metering

Legacy → **2010-2020** → **2022 →**

Legacy

Facility Level/Discrete Metering

Bulk Energy Consumption, typically at installation or building level for cost accounting



2010-2020

Smart Meters/AMI/Digital Relays

Energy Trending
Informs Energy Audits and Reduction Targets
Report *energy usage*, typically at 15-min resolution

Delivers raw data only, no warfighter relevant information

2022 →

Future of Power Metering

Mission-relevant power data analytics at Thousands of samples/sec

Interpret battlespace condition through power data analytics

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Why Does Power Quality Matter

- **Power quality analysis** is a vast reservoir of actionable operational battlespace information
  - One of the greatest areas of unharnessed potential to provide information to battlespace operation
- **Digitally-dependent forces** are **at greater mission risk** due to complex, interconnected operational platforms
- Current enterprise energy metering **does not deliver usable information**; presents unmanaged risk
- DoD POWERS Platform delivers optimal integration of hardware and software to **capture big data analytics and convert into warfighter relevant information**

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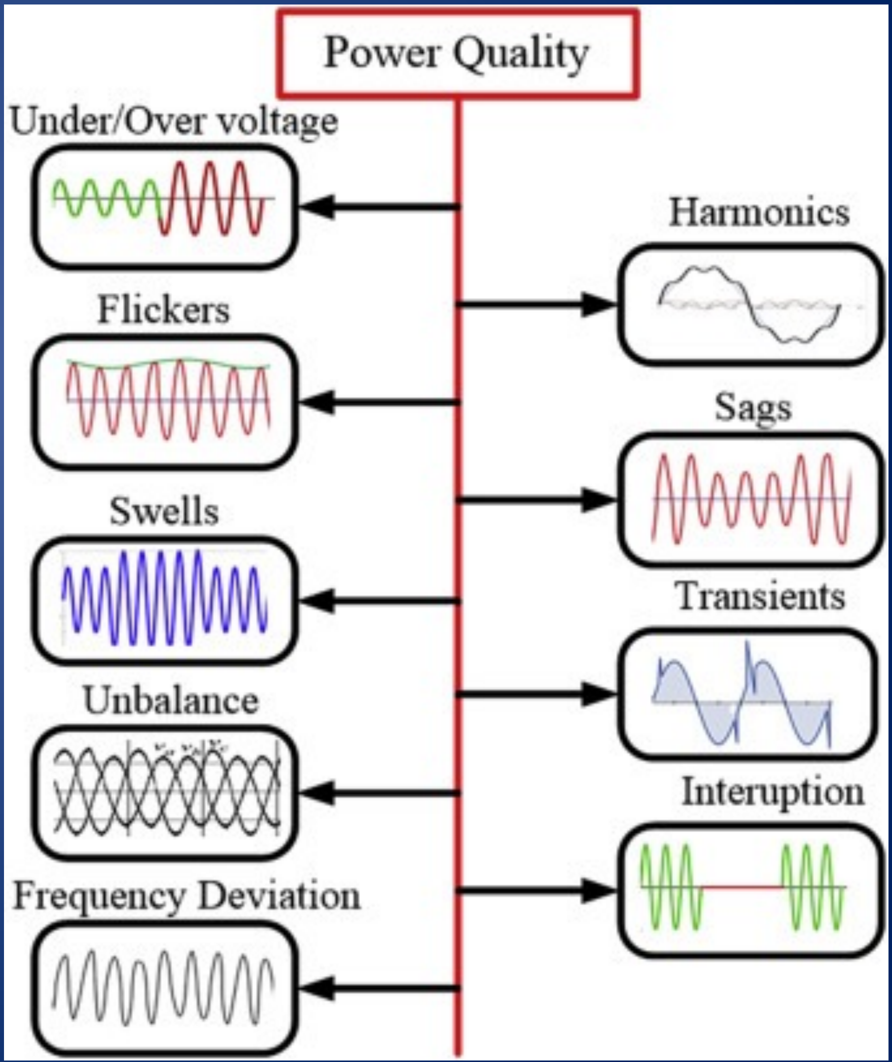
Classes of Power Quality Events

Classes of Events

- Voltage Based
- Frequency Based
- Harmonic
- Transients, Surges, and Oscillatory



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Classes of Power Quality Events

Sag or Undervoltage

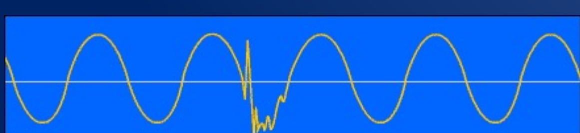
•**Description:** A decrease in voltage
•**Duration:** Milliseconds to a few seconds, under voltages are sags that are longer than a few seconds

Swell or Overvoltage

•**Description:** An increase in voltage

Transient, Impulse, or Spike

•**Description:** A sudden change in voltage up to several hundred to thousand volts.
•**Duration:** Microseconds

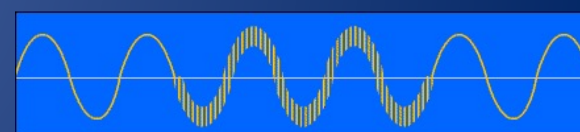


Notch

•**Description:** A disturbance of opposite polarity from the
•**Duration:** Microseconds

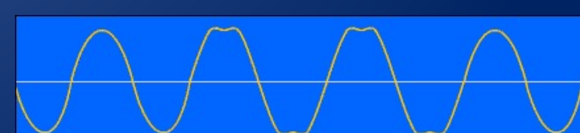
Noise

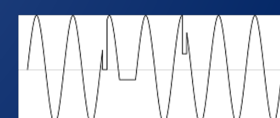
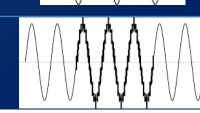
•**Description:** An unwanted electrical signal of high frequency from other equipment
•**Duration:** Sporadic



Harmonic Distortion

•**Description:** An alteration of the pure sine wave (sine wave distortion), due to non-linear loads, on the power supply
•**Duration:** Sporadic



Classification	Event Type	Waveform Behavior
Voltage Based	Under/Over Voltages	
	Sags	
	Unbalanced Phases	
Frequency Based	Frequency Variation	
Harmonic	Harmonic Waveform Distortion	
Transient and Oscillatory	Notching	
	Short Impulse	
	Signal Noise	

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DoD POWERS Platform

Power and Operational Warfighter Electronic and Resilient Sensing System

Mobile Unattended Ground Sensor (MUGS)

Miniaturized, redesigned, outdoor enclosure

- True Operational Power Visibility
- Deep Integration of Hardware, Software, and DoD IP
- Years of Development and Remote Sensing/Power Analytics Research Supported by Intel Agencies
- Developed at US Combat Capabilities Development Command Army Research Laboratory (CCDC-ARL), Adelphi, MD (Sensor and Electronic Device Directorate)

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DoD POWERS Platform

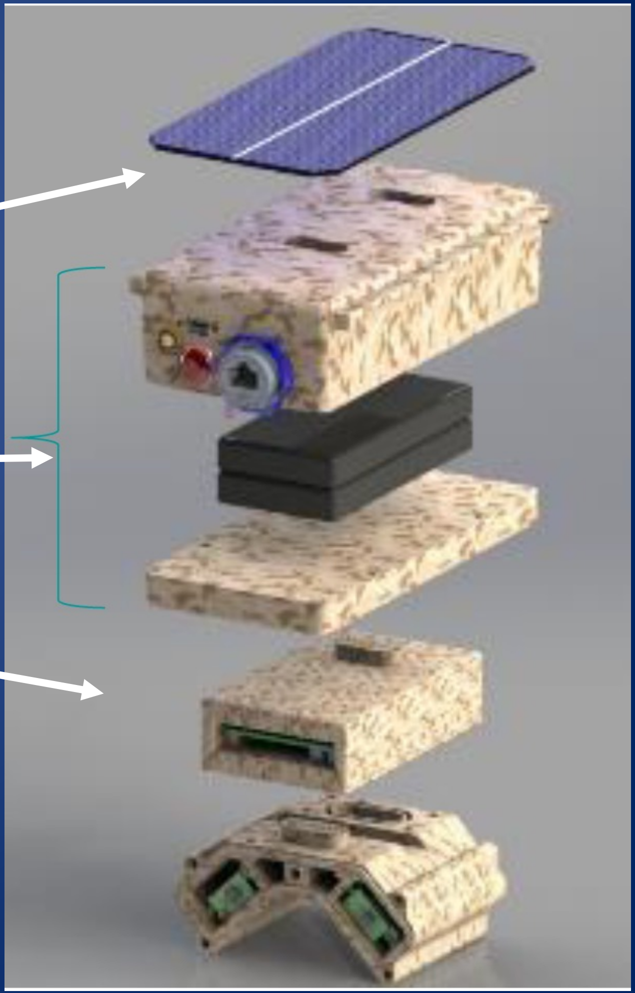
Power and Operational Warfighter Electronic and Resilient Sensing System

- **Modular, Scalable, Hardened, Futureproof**
- **AI-Based Detection, Classification, and Interpretation of Battlespace**

Power

Processing

Sensors



PQ Data → Warfighter Relevant Information

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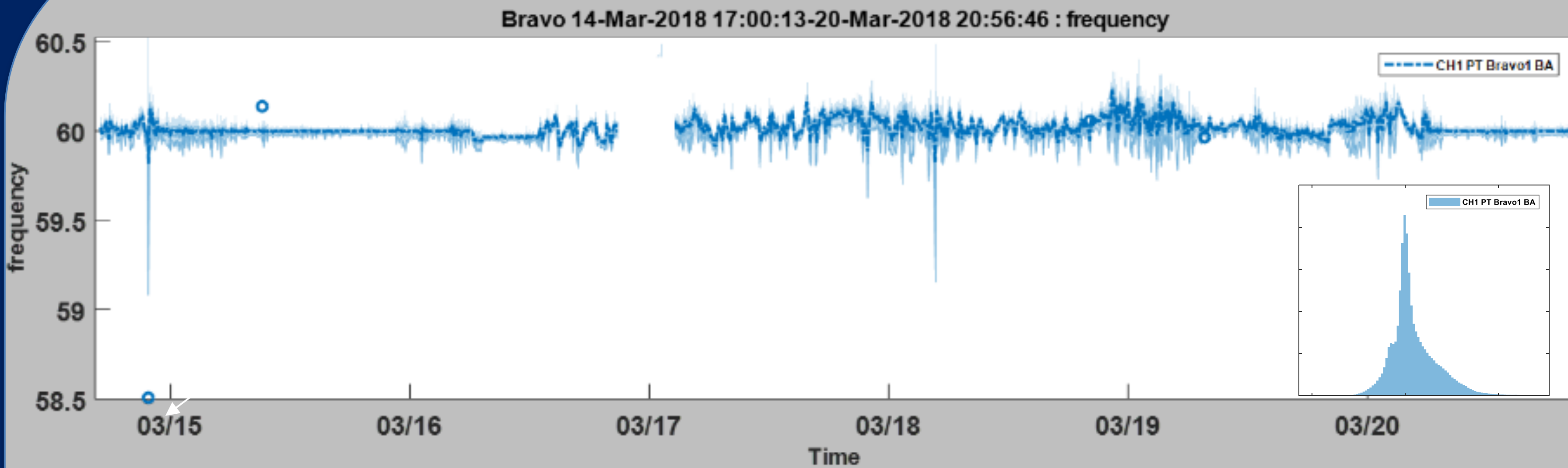
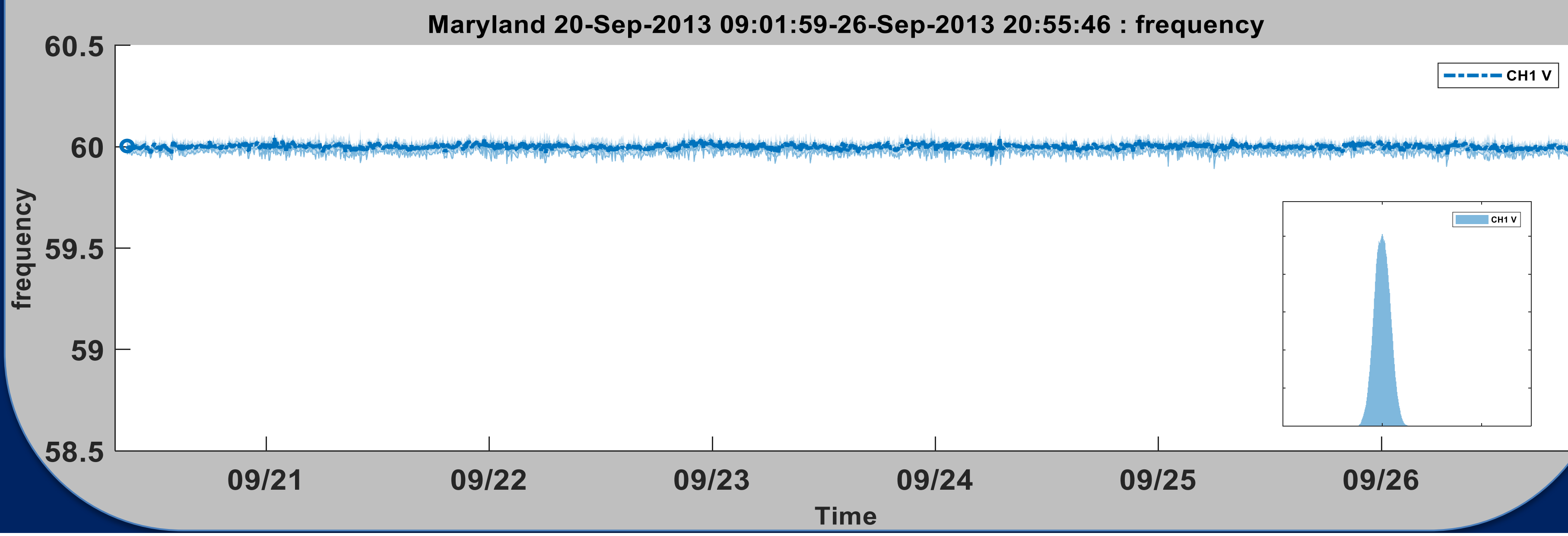
Prognostication of Warfighter Impact





References and Standards

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ANSI C84.1 – Standard for Electric Power Systems and Equipment – Voltage Ratings

IEC 61000 – Electromagnetic Compatibility

IEEE 519 - Recommended Practices and Requirements for Harmonic Control in Electric Power Systems

IEEE 1100 (Emerald Book) - Recommended Practice for Powering & Grounding Electronic Equipment

IEEE 1159 - Recommended Practice for Monitoring Electric Power Quality

IEEE 1250 - Guide for Service to Equip Sensitive to Momentary Voltage Disturbances

IEEE 1346 - Recommended Practice for Evaluating Electric Power System Compatibility with Electronic Process Equipment

IEEE 1453 - Recommended Practice for Measurement and Limits of Voltage Fluctuations and Associated Light Flicker on AC Power Systems

IEEE 1531 - Guide for Application and Specification of Harmonic Filters

IEEE C2 – National Electrical Safety Code

IEEE C62.41 - Recommended Practice on Surge Voltages in Low-Voltage AC Power Circuits

IEEE 1433 – Standard Glossary of Power Quality Terminology

IEEE 1531 – Guide for the Application and Specification of Harmonic Filters

IEEE 1564 – Guide for Voltage Sag Indices

NEMA LA 1 – Surge Arresters

NEMA LS 1 – Low Voltage Surge Protection Devices

NEMA PE1 – Uninterruptible Power Systems

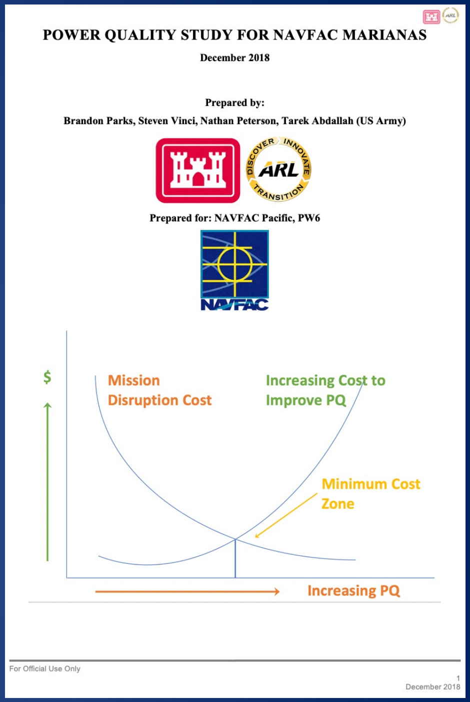
NFPA 70 – National Electrical Code

NFPA 780 – Lightning Protection Code

UL 96A - Standard for Safety Installation Requirements for Lightning Protection Systems

UL 1283 - Standard for Safety Electromagnetic Interference Filters

UL 1449 - Surge Protective Devices


POWER QUALITY STUDY FOR NAVFAC MARIANAS
December 2018

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