Tactical Power Inverters

Powering the Future Fight

Tactical Inverter Overview Brief

PM (06) –
Expeditionary Energy & Sustainment Systems

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The Warfighter's Advantage

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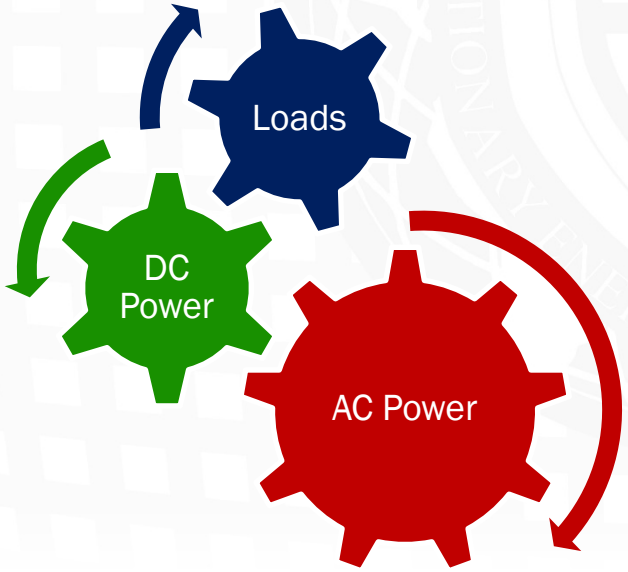
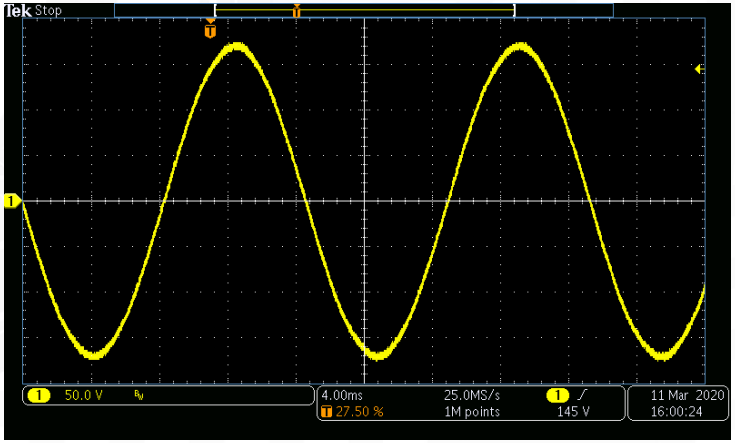
UNCLASSIFIED

INVERTERS

- What is an Inverter
- Why Inverters are Critical
- Inverter Applications
- Inverter Application Examples
- PM-E2S2's Current Solution
- Questions / Discussion

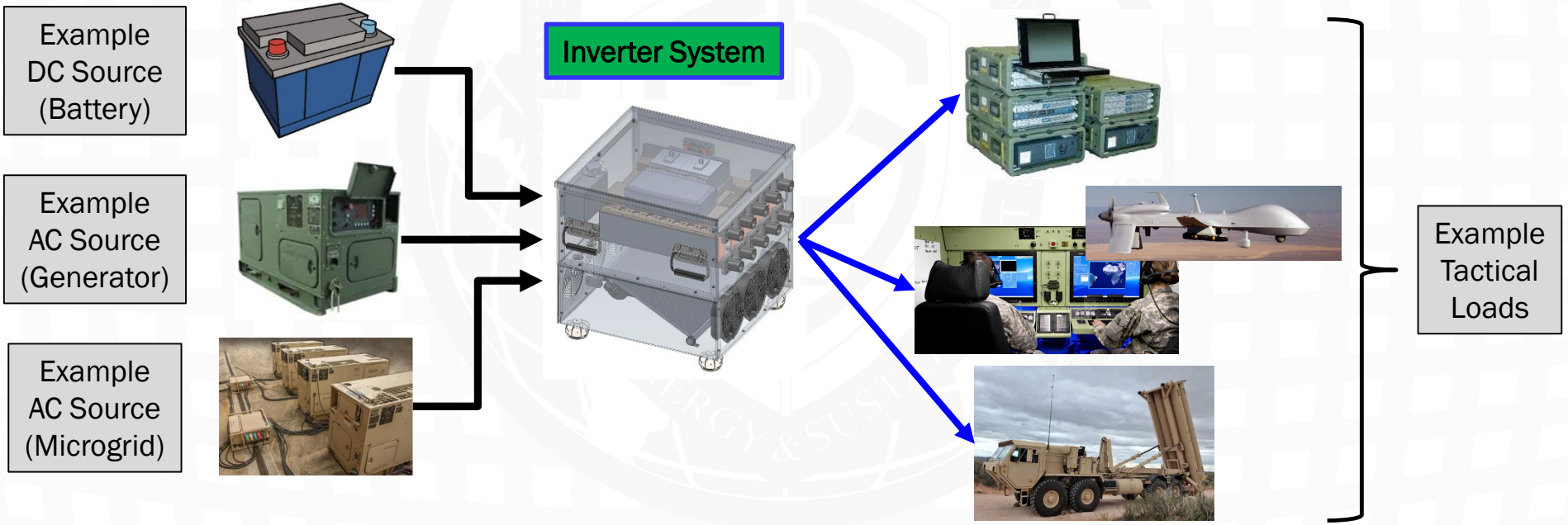




WHAT IS AN INVERTER
SYSTEM LEVEL

An **Inverter** is electrical device that converts Direct Current (DC) power to Alternating Current (AC) power or AC power to DC Power.

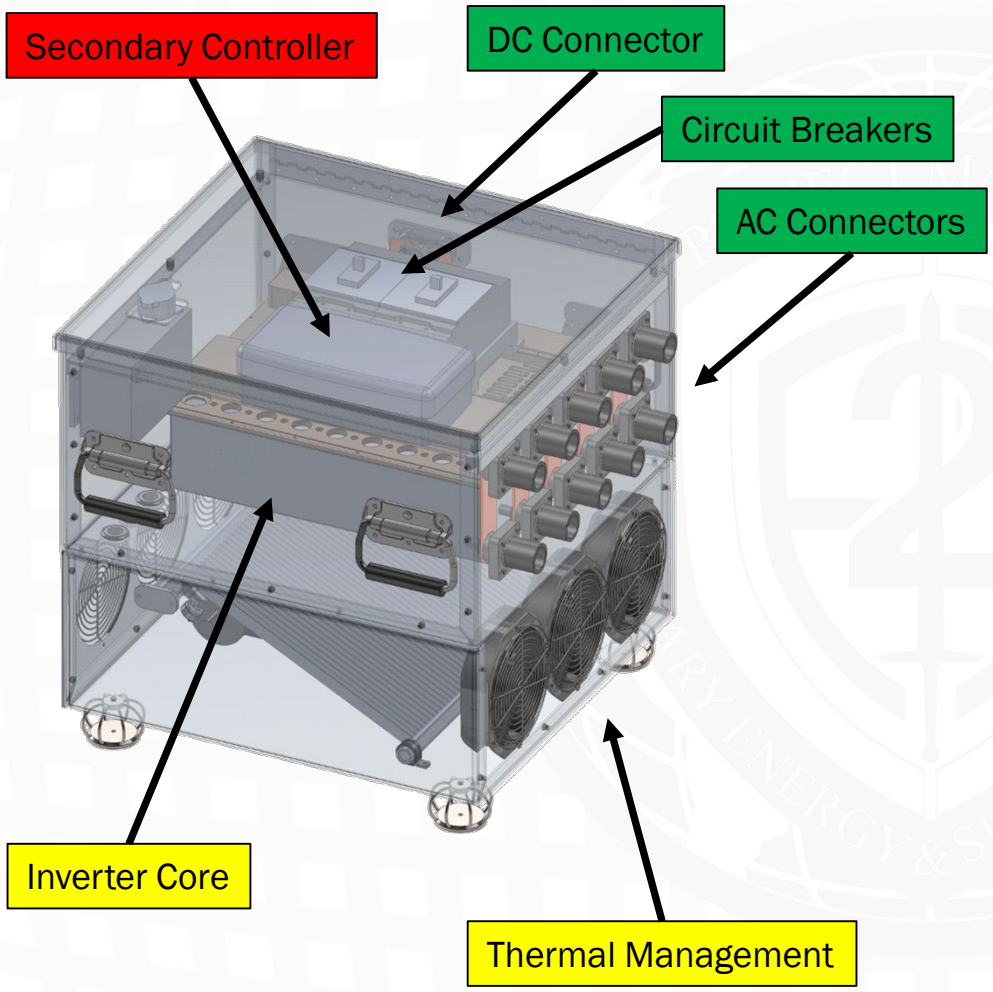
DC Sources	AC Sources/Loads
•Energy Storage •Batteries •Capacitors •Renewables •Fuel Cell •Vehicle Based	•Almost all tactical loads •Generators •Host Nation Power •Microgrids



Provides uninterruptable power, cleans dirty power, provides power surge mitigation, scalable/modular

WHAT IS AN INVERTER
SUB-SYSTEM LEVEL

Major components and their status today:



DC Connector AC Connectors Circuit Breakers	Mature
Thermal Management Inverter Core	Demonstrated
Secondary Controller	In Development

Secondary Controller enables all applications instead of just niche or single use solutions for the inverter system

Additional developmental work and/or funding needed based on application desired

WHY INVERTERS ARE CRITICAL

- Enables power source to handle large transient loads
  - Motor starts
  - Can use a smaller generator than was typically used in the past
- 'Cleans Up' poor power quality because of loads
  - Harmonics
  - Non-linear loads
- Corrects power factor
  - More efficient
  - Better for generator set
- Makes microgrids more efficient
  - More fuel efficient
  - Less run hours
  - Less logistic burden
- Improves power reliability / availability
- Ties together disparate grids/sources

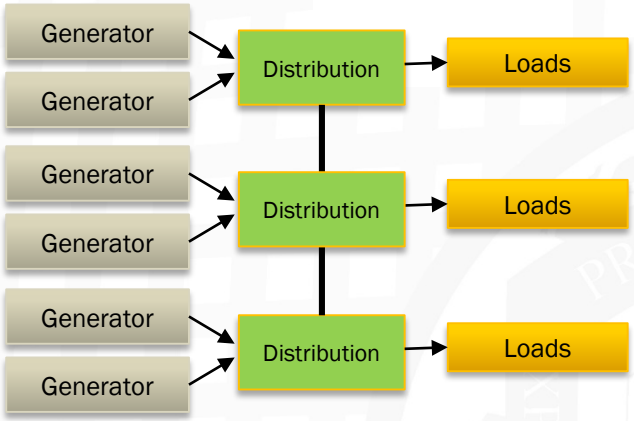
Impact of Use:

- Supports transition from bulk fuel dependency to electrification
- Ensures reliable operation: Power Quality / Conditioning
- Enables Mission Assurance and Availability

Enables the DoD to fill Operational GAPS

INVERTER APPLICATIONS
MICROGRID

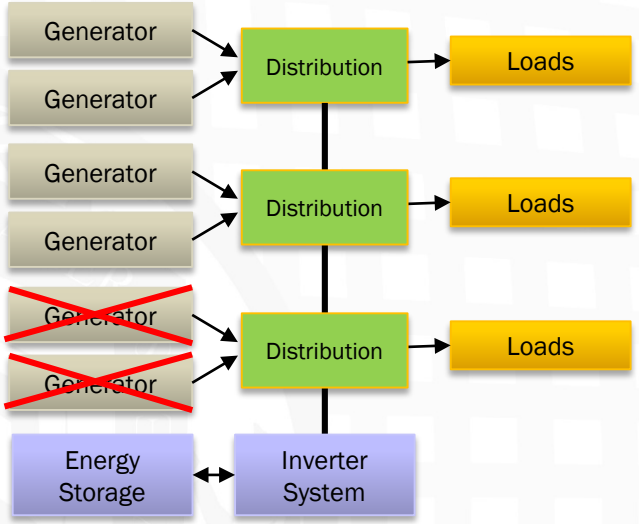
Without Inverter



Facts:
- Generators only run at most 80% capacity before next generator is started
- Potential for brown/black out on generator failure in some situations

Impacts:
- Increased run hours
- Increased fuel consumption
- Risk of power loss on generator failure

With Inverter

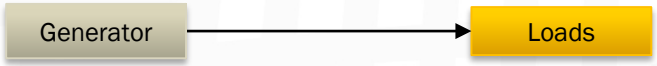


Facts:
- Generators can be run at 100% capacity
- Zero chance of grid brown/black out on generator failure
- Could take overload before starting next genset

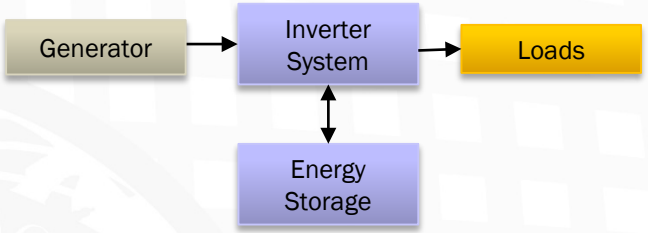
Impacts:
- Less Spinning Reserve: reduced run hours, maintenance, fuel; fewer gensets needed
- Grid Stabilization
- Peak Shaving

INVERTER APPLICATIONS
STANDALONE

Without Inverter



With Inverter

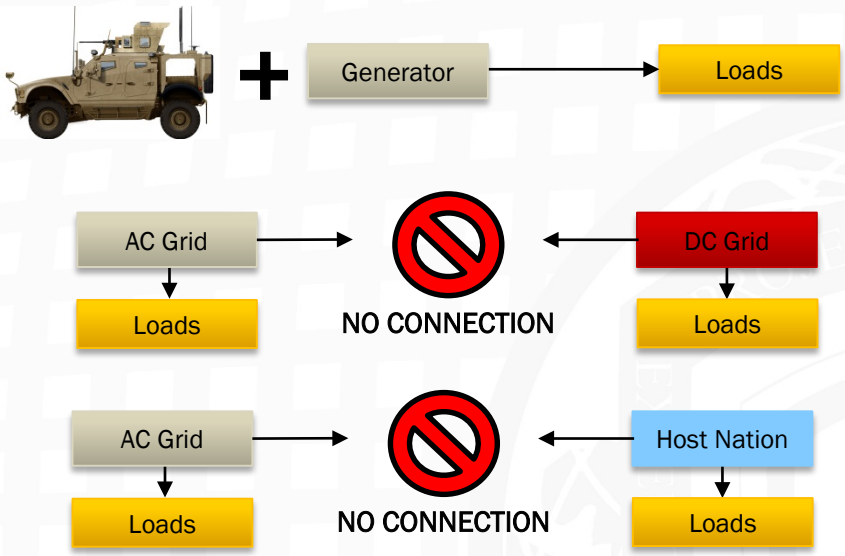


Application / Impact:

- Power Factor Correction
  - Reduces 'lost' power to provide better fuel efficiency and less stress on the generator
- Clean Power (Harmonic Reduction)
  - Reduce impact from non-linear loads and provides clean power to sensitive power loads
- Silent Watch
  - Provides ability to shutdown generator and power loads from just the silent energy storage
- Power Surge Handling
  - Inverter handles power surge to lessen impact on generator and provide ability to utilize a smaller generator then may have been used in the past
- Uninterruptable Power Supply
  - Inverter and energy storage provides power to load on generator failure to give time for backup power to come online

INVERTER APPLICATIONS
VEHICLE BASED & DISPARATE GRID TYPES

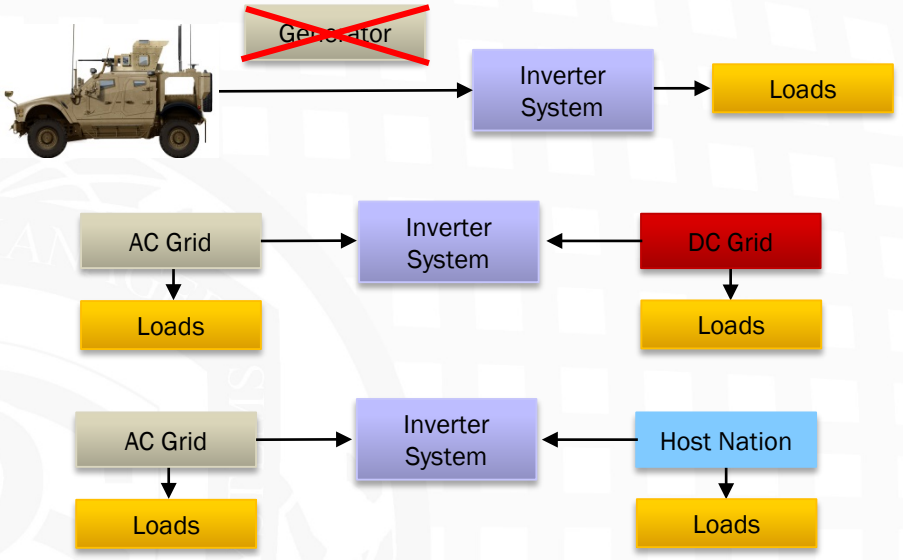
Without Inverter



Facts:
- Vehicles required to tow power source
- AC and DC (Vehicle) or US AC and Host Nation AC grids cannot share power between themselves

Impacts:
- Increased transport logistics, pintle count, & fuel consumption
- Cannot share power between separate grid types (AC/DC or AC/Host Nation AC)

With Inverter



Facts:
- Operate Loads from vehicles with transmission integral generator or energy storage
- Tie together different type grids

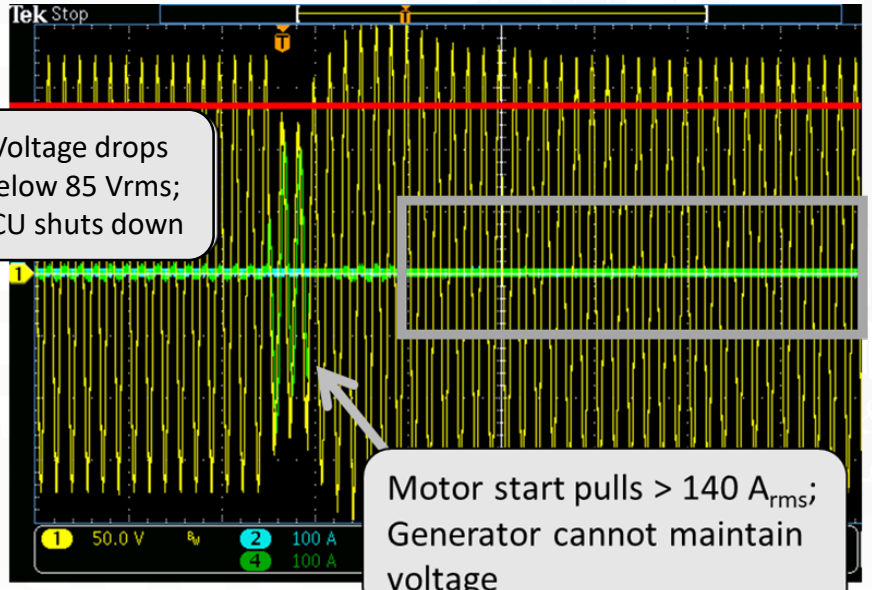
Impacts:
- Reduce the amount of generators in the field
- Realize efficiencies of typing together all available grids
- Increase power reliability / availability

INVERTER APPLICATION EXAMPLE
POWER SURGE MITIGATION

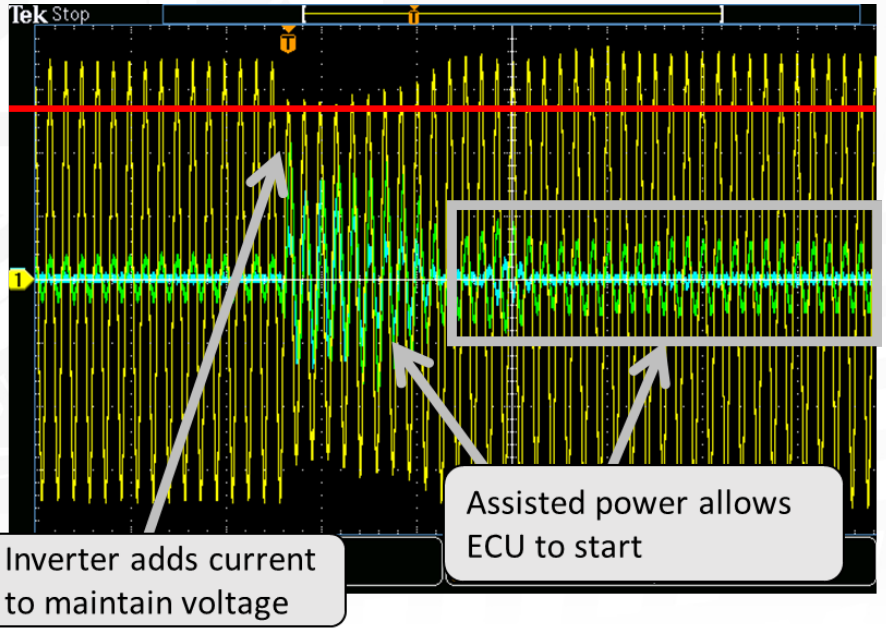
Power Surge Situation:

- Generator trying to start high power draw environmental control unit (ECU)
- 1st Attempt (Only Generator): ECU fails to start because voltage dropped too low because of overload on generator set
  - In past this meant provide a larger generator
- 2nd Attempt (Generator with Inverter): ECU successfully comes online
  - Inverter kept voltage within range by providing some power in conjunction with generator

Generator Fails to Start ECU



Inverter Assists Successful ECU Start



Voltage | Current, Generator | Current, Inverter

What is power quality?

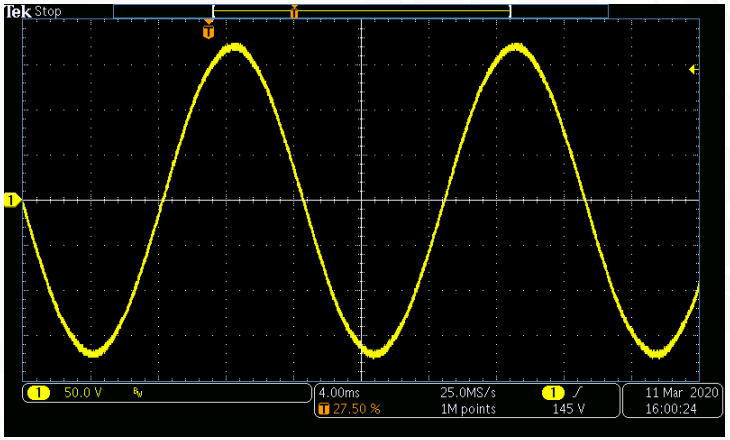
- GOOD: Smooth sine wave / No jagged edges or peaks
- BAD: Sine wave is not smooth

Impact of Bad Power Quality:

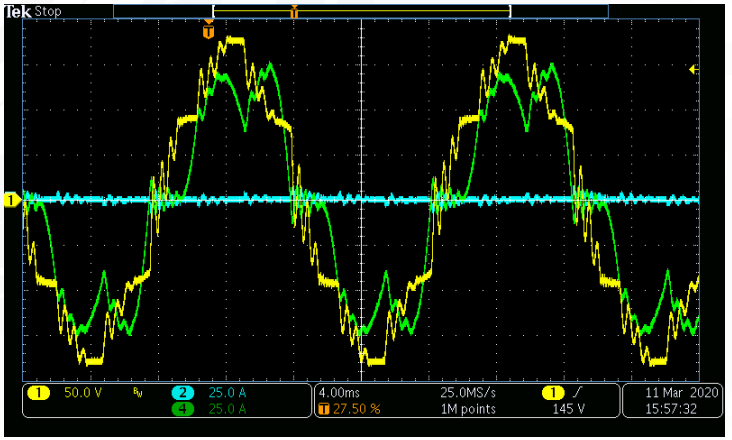
- Power efficiency losses
- Reduction in life of equipment
- Equipment failures
- Light flicker
- Equipment overheating

What causes bad power quality?

- Leading culprit is non-linear loads
- Common examples of non-linear loads include:
  - Electronic devices such as computers, printers, TVs, servers, LED lights, battery changers, and power supplies
  - Rectifiers
  - Variable-speed drives



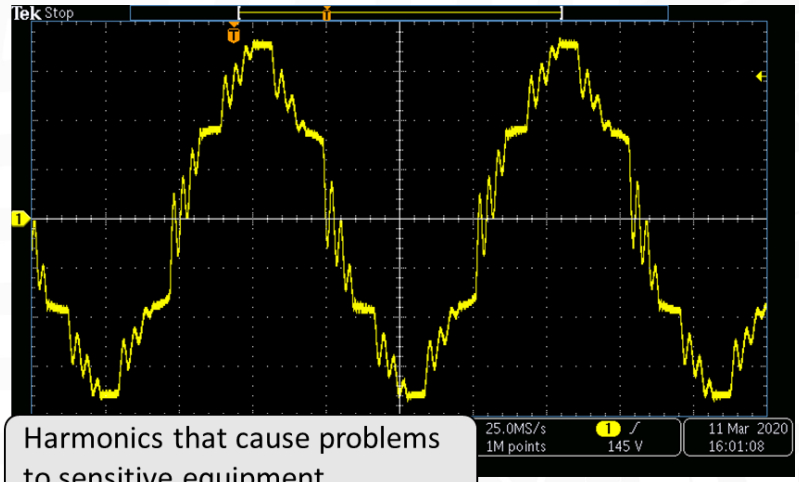
Good Power Quality



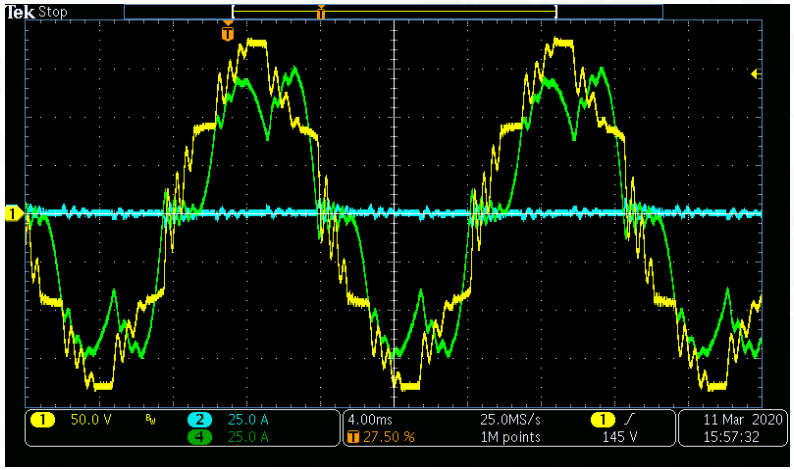
Bad Power Quality

30 kW Generator Supporting 18 kW Non-linear Load

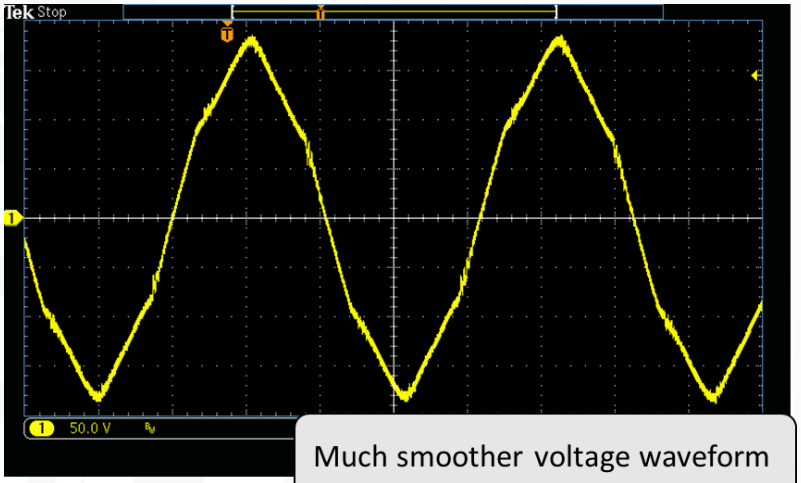
Generator ONLY



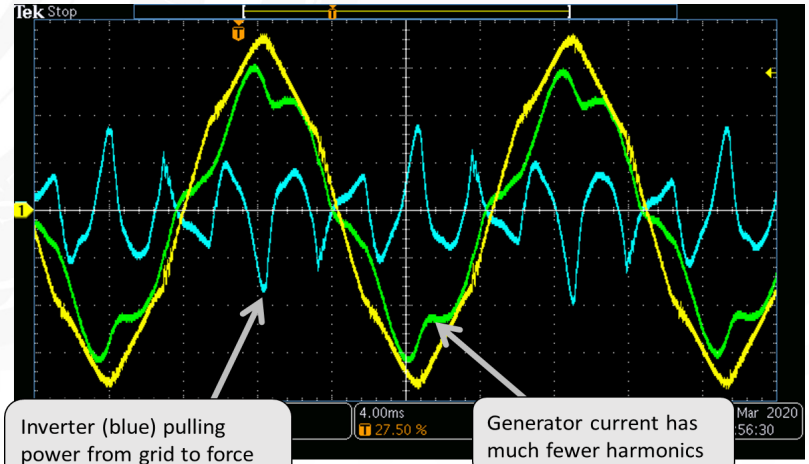
Harmonics that cause problems to sensitive equipment



Generator with Inverter System



Much smoother voltage waveform

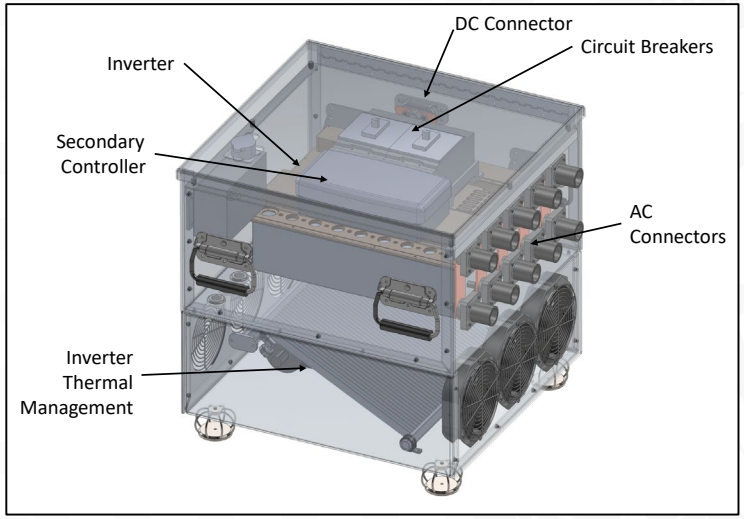


Inverter (blue) pulling power from grid to force voltage back to sine wave

Generator current has much fewer harmonics

THE DOD/ARMY SOLUTION

- 60kW Silicon Carbide Bi-Directional Tactical Inverter
  - Proof of Concept: delivered 24 January 2020
  - Electrical and Environmental Characterization Testing: begin April 2020.



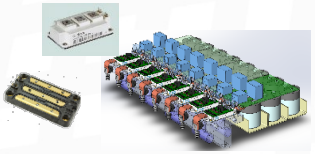
SPECIFICATION	VALUE
DC Input Voltage	400-650 VDC
AC Output Voltage	3-phase 208 VRMS
Nominal Power Output	60 kW
Transient Output Power	120 kW
Nominal Output Frequency	60 Hz
Inverter Weight	49.5 lbs.
Weight as shown above (wet)	147.5 lbs.
Size	22”x21”x21”
Thermal Management	Self-contained, liquid cooled
Operating Modes	Grid Forming (Voltage Source) Grid Feeding (Current Source) Grid Supporting (Stabilization)
Isolation	Non-isolated
Efficiency	>95%
Power Flow	Bi-directional

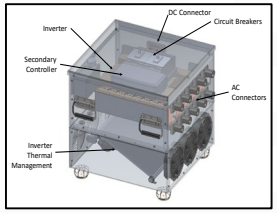
Questions & Discussion

Inverters: The lynchpin of all future power systems

Backup Slides

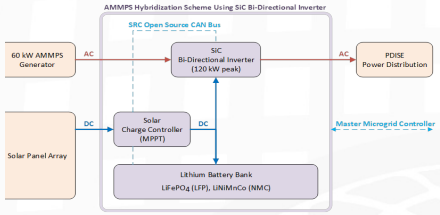
ARMY 6.3 INVESTMENT
SILICON CARBIDE BASED POWER ELECTRONICS
5 – 60 KW



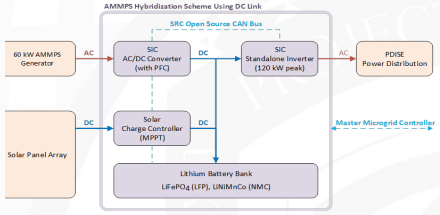


UPS Scheme: SiC Bi-Directional Inverter

A N D



Microgrid Scheme Using SiC Bi-Directional Inverter



Microgrid Scheme Using DC Link and Standalone Inverter

Technology / Product / Objective:

Technology: Silicon Carbide based Inverter with filters to address nonlinear loads

Product: Proof-of-concept Bi-Directional Silicon Carbide based Inverter (5 – 60 kW); Test Data/Draft Performance Spec supporting tech transition

Objective:

- Develop Standard Family of SiC Bi-Directional Inverters for grid & standalone
- Characterize hardware – set baseline for family of inverters
- Fabricate a technology demonstrator for interface with the AMMPS microgrid

So What?

- Enable Interoperability of DoD AC and DC grids for multi-domain operations
- Ensure Availability and Reliability of power
- Enhance Agility & Adaptability thru use of Modular Building Blocks and Monitoring/Metering

Key Participants:

- **Project Lead (PL):** C5ISR CPI – Fort Belvoir
- **Gov't Contributors:** PM SBIR; Army Research Lab
- **Transition Partners:** PM-E2S2; USMC/PM Expeditionary Pwr
- **Commercial Partners:** Hyperion, Spectrum Research: 5 – 60 kW
- **Other Partners:** Texas Tech University

Key Deliverables:

- **Reports:** Test data (electrical/environmental) and Safety Assessment Rpts
- **Hardware:** 5 - 60 kW Silicon Carbide based Bi-Direction Inverters
- **Interface Control Documents, Tech Data Package and Performance spec**
- **System Demonstrator** – Fort Belvoir/Fort Devens

Milestones Leading to Fielding

- **1QFY20:** Characterize inverter. Design operational interface with controller and DC/DC converter
- **2QFY20**: Lab demo 60 kW inverter
- **4QFY20**: SIL Demo of Software/ interchangeable Hardware
- **4QFY20**: Test/characterize hardware – prepare Performance Specification for PM E2S2

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