Homeland Defense & Security Information Analysis Center

Microgrid Solutions for DoD Mission Energy Assurance

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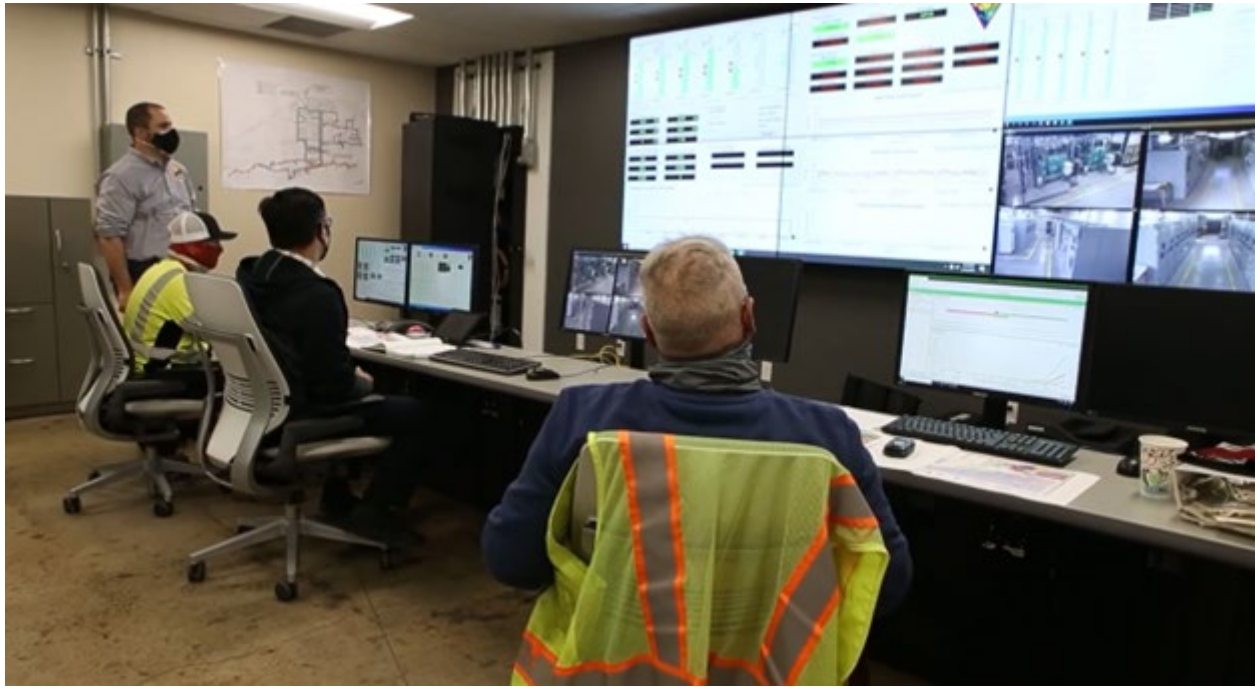
Introduction

This webinar reviews the findings of a state-of-the-art report in progress by HDIAC, which surveys the scope of commercial, governmental, and academic research and development in microgrid-enabling technologies like control algorithms and distributed generation.

Special attention is paid to microgrid controllers, standardization, and organizational considerations for DoD implementation.

"MCAS Miramar to the Rescue"

- The microgrid at Marine Corps Air Station (MCAS) Miramar is one of the largest and "most-watched" DoD energy projects
- Generation: landfill gas (3.2 MW), solar photovoltaic (1.3 MW), flow battery (2 MW), natural gas (3 MW), prime-rated diesel (4 MW)
- Summer 2022—provided power assistance to San Diego Gas & Electric



Inside the Energy & Water Operations Center (EWOC) at MCAS Miramar, February 2021

Source: Hess, D. "Control Room." Screengrab from video ID 788150, Defense Visual Information Distribution Service, https://www.dvidshub.net/video/788150/control-room, 18 February 2021.

Vulnerabilities in Electric Power Supply

- The U.S. national grid system is prone to outages, extreme weather events, physical and cyber-attacks, and basic component failure
- DoD preparation for large-scale combat operations calls for strengthening homeland installation protections
- Garrison commanders routinely cite domestic power disruptions as a top threat to military readiness

A main thoroughfare at Fort Hood during Winter Storm Uri, February 2021

Source: Cruz, B. "Lessons learned from '21 help Fort Hood prep for winter storm." U.S. Army, https://www.army.mil/article/253867/lessons_learned_from_21_help_fort_hood_prep_for_winter_storm, 10 February 2022.

Enter: Installation Microgrids

- The ability to “island” and power critical loads independently is what defines a microgrid—and is the source of its resilience benefits
- Most grid-tied microgrids remain connected to the utility grid >99% of operating hours
- DoD has roughly 15+ installation-grade microgrids operating in the homeland, mostly powered by diesel and increasingly natural gas

A 250-kilowatt section of distributed solar PV modules serve double duty at MCAS Miramar

Source: National Renewable Energy Laboratory. “NREL Enhances Energy Resiliency at Marine Corps Air Station Miramar.” https://www.nrel.gov/energy-solutions/partner-mcas-miramar.html, retrieved 15 September 2022.

Energy Resilience

- Military microgrids primarily seek to bolster an installation's *energy resilience*, which both statute and DoD define as:

  > "the ability to avoid, prepare for, minimize, adapt to, and recover from anticipated and unanticipated energy disruptions in order **to ensure energy availability and reliability sufficient to provide for mission assurance and readiness**, including mission essential operations related to readiness, and to execute or rapidly reestablish mission essential requirements." (10 U.S.C. § 101(e)(6))

- Other benefits include energy cost savings, greenhouse gas emissions reductions, positive revenue generation, and building shared resilience among base-adjacent host populations

Microgrids in the Spotlight

- Microgrid systems for military bases are more attractive than ever before, due to three recent trends:
  - Improvements in the economics of distributed energy resources (DERs)
  - An expansion of U.S. power manufacturing and microgrid energy services activity
  - R&D led by DoD and the Department of Energy has pivoted away from pilot projects and towards work on microgrid systems integration issues
- The U.S. Army has taken notice, and plans to install a microgrid on every Army base by 2035

Fort Hunter Liggett breaks ground on its new microgrid project, May 2011

Source: Croft, J. "Fort Hunter Liggett breaks ground on Microgrid project [Image 5 of 5]." Photo ID 6673925, Defense Visual Information Distribution Service, https://www.dvidshub.net/image/6673925/fort-hunter-liggett-breaks-ground-microgrid-project, 25 May 2021.

Study Methods & Scope

Challenges

- R&D in microgrids is global in scope and overwhelming in volume
- A microgrid is not a single coherent technology, art, or field of practice, but a "system of systems"
- Not all commercial microgrid or DER technology is relevant to the DoD use case

Not evaluated

- Remote/expeditionary microgrids; cybersecurity; economic considerations

Approach

- Evaluated scientific, government, academic, industry, and gray literature (~2019 to present)
- Conducted virtual interviews with 24 subject matter experts, including active DoD base energy/utility managers
- Reviewed recent DOE Microgrid R&D Program "Peer Review" white papers
- Reviewed R&D projects funded by the DoD Environmental Security Technology Certification Program (ESTCP)

Current State of U.S. Microgrids

Concept Maturity, Repeatability, and Renewables Penetration

Finding #1

The microgrid concept has been proven and is mostly commercialized—although its constituent technologies will continue to evolve and mature.

- Microgrid systems are a somewhat mature but not-yet-stabilized suite of technologies and practices
- DoD is not a prime mover in the microgrids or renewables space

Finding #2

Almost all grid-tied microgrid deployments are unique—and costly because of it.

- Few microgrids have repeatable designs, standardized protocols, or modular components
- "When you've seen one microgrid…you've seen *one* microgrid."

Finding #3

Renewable generation sources (especially solar PV paired with battery storage) will continue to see rapid adoption rates—and are robust enough for DoD installation use.

- Microgrid solar + storage penetration is expected to double in the near term
- Renewable inverter-based systems are already used in heavy industry

Visions for Future Microgrids

Standardization, Interoperability, and Closer Connection

Finding #4

Future microgrids will become increasingly standardized, interoperable, and flexible in their design, control architecture, and operation.

- Efforts at interoperability and standardization aim to reduce costs and counter "vendor lock"
- Customers will grow more sensitive to costs as the market expands

Finding #5

The relationship of future microgrids to the macrogrid (and to each other) will trend toward closer connection.

- The networking of microgrids is an active area of research and could deliver substantial resilience benefits
- Microgrids will provide more power services to the utility grid and better respond to changing conditions

Vulnerabilities & Benefits

Emergency Power Reliability, and Measuring Resilience

Finding #6

Diesel generator systems used for emergency backup power are difficult to maintain, often unreliable, and not designed for use in extended outages.

- Emergency diesel generators (EDGs) are poorly maintained and match their loads inefficiently
- A microgrid of networked EDGs has been shown to be more resilient than their standalone use

Finding #7

While it is evident that microgrids can sustain critical loads while islanded, DoD could benefit from more nuanced quantitative measures of installation energy resilience.

- Electricity “availability” measurements guide DoD policy for base energy resilience
- Resilience indices that account for mission impacts and recovery can be useful for evaluating military microgrid performance

Microgrid Design, Forecasting, Modeling, and Simulation

Improving the Design Process, Tool Selection, and Preparing for Extremes

Finding #8

The planning, design, and modeling of a microgrid is in many respects the most important step in its deployment.

- Complex systems like microgrids fall into technological path-dependency once built
- Efforts are underway to allow microgrid design tools to “close couple” their analyses

Finding #9

While no single tool is regarded as best for designing a microgrid, this is indicative of a healthy field rather than a lagging R&D sector.

- There is a plethora of viable and field-tested design tools available to DoD and its contractors
- Selection of a microgrid design and planning tool often depends on the specifics of an installation site

Finding #10

Future approaches will seek to standardize or streamline the design process, better plan for changing operations, and anticipate extreme outage events.

- Design and planning tools are likely to better account for a base's wide range of mission scenarios
- A microgrid's design must also presume that the system will face extreme long-duration outage events

Microgrid Control & Architecture

Theories of Control, Commercial Systems, and Microgrid Optimization

Finding #11

While microgrid controllers (MGCs) and control systems currently receive the lion's share of R&D interest, commercially available MGCs meet DoD needs in the near term.

- Commercially-available controllers vary only marginally in efficiency or capability
- "There is no literature more opaque than the control literature."

Finding #12

Algorithms and control schemes for microgrids will continue to grow in sophistication, likely allowing automatic optimization during "blue sky" and islanded operations, and seamless control of subordinate systems.

- Control research has shifted away from stability/forecasting and towards multi-objective optimization
- Future control architectures will improve monitoring, black-start, and other systems management capabilities

Finding #13

“Distributed control” concepts hold promise for boosting overall system resilience but remain unproven—and are hindered by cybersecurity concerns.

- Distributed control schemes could provide more flexible and a near-instant response to power-condition changes
- Control solutions may ultimately converge on a hybrid, semi-distributed control approach

Organizational Considerations

Tacit Knowledge, Mission Scope, Project Financing, and Operator Training

Finding #14

The success of a DoD microgrid depends more on organizational actions and the "tacit knowledge" accumulated by project leaders than any cutting-edge equipment or system.

- A microgrid is more a "form of a sophisticated construction project" than an advanced technology
- The execution of Energy Resilience Readiness Exercises (ERREs) is critical to generating useful technical microgrid knowledge

Finding #15

A microgrid's funding—and the contracts it lets to industry—can greatly affect its design, operations, and long-term sustainment.

- A microgrid project's technical scope and its real-world financing are often disconnected
- Ready access to dedicated operations and maintenance (O&M) funds is critical for long-term sustainment

Finding #16

Shifts in DoD's approach to deploying installation microgrids will influence what technologies and R&D are most useful to the department.

- Microgrid market growth and the prospect of increased funding has dimmed the appeal of DoD networked microgrids to some
- System and campus maintenance plays an outsized role in sustaining uptime

Finding #17

Providing the DoD energy management workforce with accessible training, professional networking opportunities, and highly immersive microgrid training simulators is of paramount importance to the long-term sustainment of military microgrids.

- Experienced microgrid operators are in short supply, and training remains often outdated and difficult to access
- There is a critical need for “flight simulator”-esque immersive training environments for DoD microgrid operators

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