ENERGY ACADEMIC GROUP
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SURGE

ENERGY ACADEMIC GROUP QUARTERLY NEWSLETTER SPRING 2020

Highlights

NEW EAG TEAM MEMBERS
CONTINUITY PLANNING
SUSTAINABLE MICROGRID
U.S. VIRGIN ISLAND CASE STUDY
POWER SYSTEM ARCHITECTURE

ENERGY RESEARCH

Army Installations Test Energy Resilience

Forts Knox, Stewart, Greely, and Bragg initiated "lights out" exercises to test energy resilience capabilities during a power grid outage.

By Hon. Alex Beehler, Assistant Secretary of the Army (Installations, Energy and Environment)

PENTAGON—Current multi-domain operations require U.S. Army installations to have secure and reliable access to energy to achieve mission objectives. The Army installation objectives of maintaining world-class training facilities, the ability to project power or surge the industrial base, and command and control are not achievable without secure and resilient access to energy.

It is imperative for all Army installations to maintain a high level of energy resilience in order to support mission critical facilities, and thus support the Army's number one priority, readiness.

Energy resilience is the ability to anticipate, prepare for, and adapt to changing conditions—and withstand, respond to, and recover rapidly from power disruptions.

With rare exception, installations rely on venerable commercial utilities outside the gate, which can be taken down by infrastructure failure, acts of nature, or acts of terrorism.

Testing energy resilience by cutting commercial power to the entire or segments of U.S. Army installations is an undeniable means of bringing to light the impact an unexpected power outage can have on that installation's ability to achieve its mission.

In collaboration with the Department of Defense, the Army began testing installation energy resilience through planned Energy Resilience Readiness Exercises (ERRE) by purposely shutting off the power. These exercises reveal an installation's ability to maintain operational capabilities during an extended utility outage.

The exercises also shape conversations among energy managers, garrison commanders, and Army leadership.

A full-scale test includes operating all associated emergency and standby energy generation systems, infrastructure, equipment, and fuel at full operational loads while completely separated from the primary source of power.

Thus far, the Army has formally tested installation energy resilience by shutting off electric power to: Fort Stewart, Georgia; Fort Greely, Alaska; Fort Knox, Kentucky; and Fort Bragg, North Carolina. Several other installations have utilized planned power outages to test

Continued on page 2

FROM THE CHAIR

Dan Nussbaum, Chair of the Energy Academic Group

Two years ago, in *Surge*, I wrote *"I've been reading/re-reading a number of energy geopolitical texts,"* and I used these texts to *"leverage these into a discussion of 'what are the BIG issues?' In other words, what questions should we to be thinking about for the next three to five plus years regarding energy'?"* My purpose at the time was to *"get people thinking about... big energy issues and to engender a conversation and perhaps a research roadmap".* At the time the major topics that emerged were energy supply, energy demand, energy diversification, and their consequences.

I may have been premature in asking this question; rather I should have said *"here are readings that ought to be on your shelf if you want to start out in this discipline."* So herewith is a list, including authors and websites you ought to be familiar with. I have no doubt that you have your own favorites, so I do encourage you to let me know what I left off the list.

Here are the books that I find most relevant to gain an understanding of the geopolitics of the larger energy arena:

Daniel Yergin
The New Map; The Prize; The Quest

Brenda Shaffer
Energy Politics, Beyond the Resource Curse

Peter Ziehan
The Absent Superpower; The Accidental Superpower

Meghan L. O'Sullivan
Windfall

Additionally, for a good overview of maritime security in the Persian Gulf see **Professor Gawdat Bahgat's** article in Middle East Policy (Vol 26, #4 , Winter 2019; https://mepc.org/journal/maritime-security-persian-gulf).

As always, Gawdat writes clearly, providing a good tour d 'horizon which others can use when they need to understand the larger context of geopolitical oil and gas issues.

Here are my favorite websites, the ones I go to when I'm looking for information:

International Energy Agency
- https://www.iea.org

U.S. Energy Information Administration
- https://www.eia.gov
- http://energy.mit.edu
- https://www.nps.edu
- https://energy.stanford.edu

The EXXONMOBIL Energy Outlook
- https://corporate.exxonmobil.com/Energy-and-environment/Looking-forward/Outlook-for-Energy

The BP Energy Outlook
- https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/energy-outlook/bp-energy-outlook-2016.pdf

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Continued from page 1

their energy resilience. Such exercises not only highlight successes, but also identify gaps in resilience, which can then be addressed.

Army installations are not immune to energy and water grid vulnerabilities. This year, installations reported over 1,100 utility outage events comprising 22,082 hours, an increase of nearly 5 percent from hours reported in fiscal year 2018. Over 90 percent of the offline hours occurred during outages lasting eight hours or more. Equipment failure and acts of nature account for the majority of outages.

Severe weather continues to be the most frequent cause of utility system outages. Notable storm events also continue to increase in both frequency and impact. However, as noted in the National Defense Strategy, installations are targets for terrorists and malicious cyber activity aimed at our infrastructure. Army installations are served by public electricity, natural gas, and water utility systems that are at risk of disruption from bad actors.

Planning, exercises, and system improvements will minimize the likelihood of utility outages as well as minimize their impact when they occur. Regardless of cause, additional emphasis is needed to reduce energy and water vulnerabilities to facilities and infrastructure supporting critical missions.

Chief of Staff of the Army, Gen. James C. McConville, in a message to the Army Team said, "We must be the Army of tomorrow, today. The changing operational environment is altering installation energy requirements, and we must modernize our infrastructure and equipment."

LEARN MORE
Email Mr. J.E. 'Jack' Surash, P.E. at **john.e.surash.civ@mail.mil**

Energy Academic Group Welcomes Four New Team Members

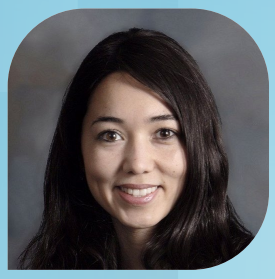
EAG is proud to introduce four new faculty members to its team this year: Karen Flack, Tahmina Karimova, Kristen Fletcher, and Jake Wigal.

These talented people increase EAG's capability and reach across all three pillars upon which our academic group was built: curriculum, research, and outreach—and bring added expertise in areas like environmental energy and Geographic Information Systems (GIS).

By expanding our subject matter expertise and human resources, EAG continues to maintain NPS as a Navy center of excellence for energy in graduate education, actively supporting the operational mission of the Navy and Marine Corps and exploring energy educational and research partnerships across the full spectrum of DoD-related organizations, the U.S. government, academia, industry, NATO allies, and international partners/military.

Karen Flack

Karen Flack is a visiting scholar on sabbatical from the United States Naval Academy (USNA), Department of Mechanical Engineering. At USNA, Professor Flack coordinates a multi-disciplinary course in energy security and has an active research program in wind and tidal energy. With EAG, Professor Flack will focus on energy curriculum which supports the operational mission of the Navy and Marine Corps.



Tahmina Karimova

Tahmina Karimova joined the EAG in December 2019 as Faculty Associate-Research. Karimova's previous decade-long experience at NPS encompassed management of security cooperation engagements, research, curriculum building, and execution of in-residence courses for the U.S. and allied forces. With the EAG, Karimova will focus her effort on energy security, critical infrastructure resilience and defense as well as international outreach.

Kristen Fletcher

Kristen Fletcher joined the EAG in January 2020 as Faculty Associate-Research. Fletcher has more than 22 years experience in ocean and coastal law and policy, including teaching law and masters students and managing nonprofits and small businesses. With the EAG, Fletcher will focus on climate, environment and security through research, policy, and curriculum development.

Jake Wigal

Jake Wigal joined the EAG in January 2020 as Faculty Associate-Research. Wigal is a recent graduate from the University of Texas at Austin with expertise in Geographic Information Systems (GIS) and graphic design. In support of EAG, Wigal will specialize in geospatial data modeling and visualizations, data management, and development of educational material.

Advancing mission continuity of operations for core capabilities, such as those provided by the F-35, is key to enhancing Air Force mission assurance.

The Mission Must Go On: Getting Continuity Planning Right

By Douglas Tucker, Director Air Force Installation Energy Policy & Programs Office of the Deputy Assistant Secretary (Environment, Safety & Infrastructure)

To create a more ready and lethal fighting force, the Department of the Air Force (DAF) Office of the Deputy Assistant Secretary for Environment, Safety, and Infrastructure is focused on making its operations more resilient. While the uncertainty of a changing threat environment makes predicting impacts difficult, considering what *should* be made resilient instead of simply what *can* be made resilient is critical when making investments that best maintain key organizational functions regardless of the nature or duration of a threat.

The decision to invest in resilience must first be informed by an examination of what that investment is meant to serve: Business Continuity of Operations (BCO) or Mission Continuity of Operations (MCO). Constrained resources have led the DAF to shift its priority toward resilience investments that advance MCO, and in doing so, enable the continuity of enterprise core functions for mission success.

To ensure its resilience investments support MCO, the DAF is employing a variety of tools and processes that help break down mission operations and requirements to more clearly identify where investments can increase mission assurance. Recent DoD mandates such as Installation Energy Plans and Energy Resilience Readiness Exercises take an MCO approach to resilience planning and investments. The DAF is also developing its own tools to further integrate MCO considerations into its resilience efforts.

THE DECISION TO INVEST IN RESILIENCE MUST FIRST BE INFORMED BY AN EXAMINATION OF WHAT THAT INVESTMENT IS MEANT TO SERVE: BUSINESS CONTINUITY OF OPERATIONS (BCO) OR MISSION CONTINUITY OF OPERATIONS (MCO).

The ability to distinguish between MCO and BCO priorities is important in making smart, strategic decisions, and it's an approach that can benefit all U.S. military services.

LEARN MORE

Email Douglas Tucker at **douglas.k.tucker.civ@mail.mil**

STUDENT ENERGY RESEARCH SPOTLIGHT

3-Phase Microgrid

By CDR Charles Y. Hirsch, USN

Sustainable power at the forefront of Department of Defense operations is paramount on the battlefield as well as at naval installations across the world, and microgrid technology enables the deployment of renewable energy sources.

CDR Hirsch's research included a three-phase microgrid set up with three commercial-off-the-shelf (COTS) inverters and a battery bank as its energy storage system.

This thesis develops a physics-based model of a three-phase microgrid set up with three commercial-off-the-shelf (COTS) inverters and a battery bank as its energy storage system. Both the model and the laboratory microgrid can be operated in grid-tied or in islanding mode. The microgrid's voltage waveforms, spectra, total harmonic distortion and current waveforms are predicted by simulations and measured in the laboratory. Institute of Electronic Engineers (IEEE) Standard 519 and the manufacturer's performance standards provide the metrics for the power quality analysis.

Comparisons of performance of the model to experimental laboratory data determine that the COTS units conform to IEEE Standard 519 and are suitable for further studies into microgrid expansion, management and employment.

CDR Charles Hirsch, USN

About the author

CDR Charles Hirsch, USN is a student of Electrical Engineering at the Naval Postgraduate School. Contact Dr. Giovanna Oriti at **goriti@nps.edu** for more information about this research.

CASE STUDY

Will New Power Poles and Underground Lines Prevent Blackouts? A Case Study in the U.S. Virgin Islands

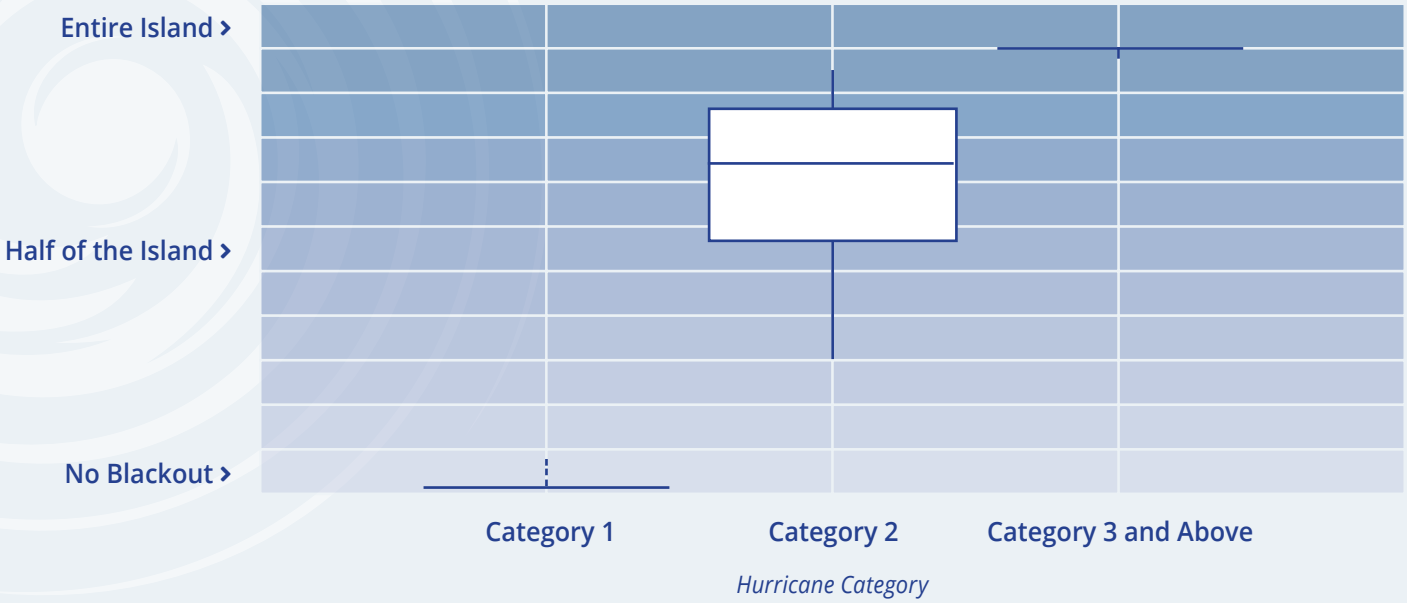
By Dan Eisenberg, PhD,
Department of Operations Research,
Naval Postgraduate School

The U.S. Virgin Islands. Photo by NASA Earth Observatory.

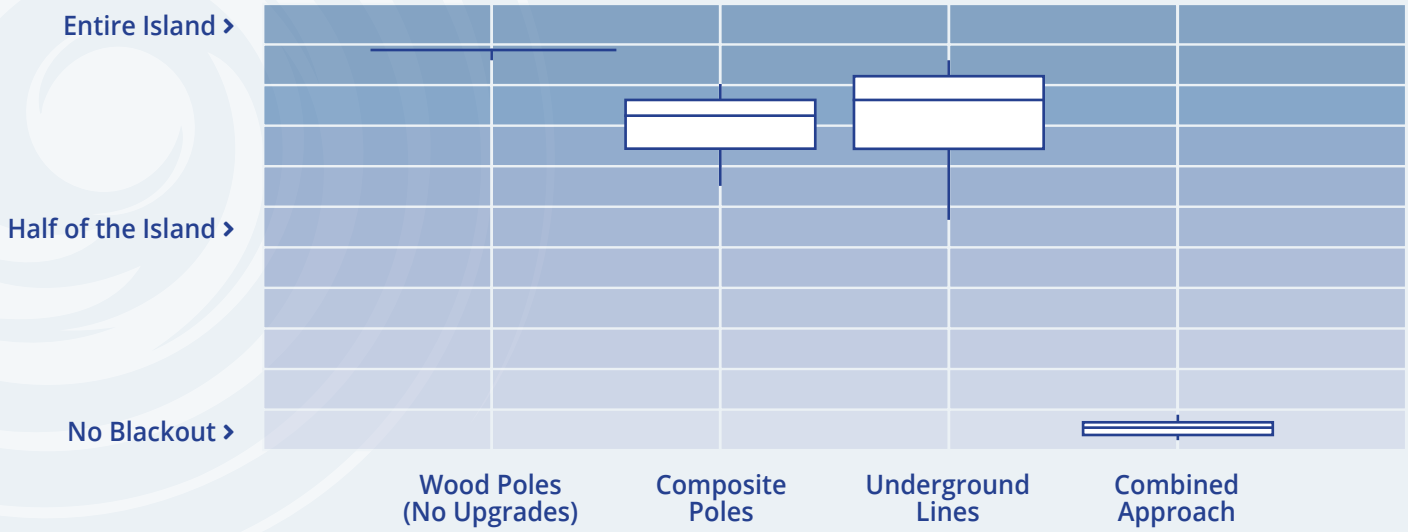
In September 2017, Hurricane Irma struck the islands of St. Thomas and St. John in the northern part of U.S. Virgin Islands (USVI), and Hurricane Maria struck St. Croix just two weeks later in the south. Together, these storms devastated local infrastructure and communities[1]. Since this catastrophic event, the Federal Emergency Management Agency (FEMA) has funded a Naval Postgraduate School (NPS) team led by Drs. David Alderson and Daniel Eisenberg of the NPS Center for Infrastructure Defense and Operations Research Department with colleagues in the NPS Energy Academic Group, USVI Territorial Government, U.S. Department of Energy, U.S. National Labs, University of the Virgin Islands (UVI), and Territorial infrastructure providers to ensure communities are resilient to the next big storm.

Recent work led by Maj. Dominik Wille of the German Army and his advisor Dr. Eisenberg measures the vulnerability of the USVI power system to future storms and identifies possible ways to keep the lights on after a hurricane[2]. Immediately after Irma and Maria, the USVI power system was rebuilt using wooden power poles known to be vulnerable to hurricane-force winds. Working with the University of the Virgin Islands, Sandia National Labs, and the Virgin Islands Water and Power Authority (VIWAPA), Wille was able to measure the benefit of installing composite poles and underground power lines that may survive future hurricanes. The analysis

Expected Blackout Size on St. Croix During a Hurricane (with Wooden Power Poles)



Expected Blackout Size on St. Croix During a Category 3 Storm (with and without Upgrades)



focused on St. Croix communities by using a computer model of the St. Croix power system provided by VIWAPA and Sandia National Labs, and subjecting it to simulated storm events to see what infrastructure might break and what communities might lose power.

Analysis shows how a hurricane may cause future blackouts on St. Croix. Specifically, communities should expect above ground, wooden power poles to fail in a Category 2 storm and that the majority of St. Croix will lose power. Analysis also shows that communities should expect a complete, island-wide blackout for a more extreme event (Category 3 and above). In contrast, even with debris strikes, storm surge, and flooding, replacing wooden poles with composite poles will ensure some communities still have power after a Category 3 storm.

Still, not all composite poles are expected to survive, and some communities will lose electricity even in the best-case scenarios. This is because composite poles are rated for high winds but are still vulnerable to flying debris that can strike and break them, which was experienced when Hurricane Dorian struck the USVI as a mere Category 1 storm last September, and some composite poles did not survive.

Underground power lines provide similar benefits as composite poles, but in different areas. This is because the buried part of the power grid is expected to survive the storms, but the secondary lines connecting the grid to your house may not.

If done right, a combined approach with composite poles and buried power lines is expected to prevent blackouts during Category 3 storms and above. This combined approach buries systems in areas surrounded by potential debris like forests and uses composite poles near customers to protect low-voltage household connections and above ground equipment.

Despite the possibility of a nearly stormproof power system, the federal government is paying to install the infrastructure, and system operators at VIWAPA who must maintain the system into the future need to consider whether these benefits are worth it for St. Croix communities.

No infrastructure is invulnerable, and we should expect at least a few composite poles or underground lines to require replacement after any hurricane season. These infrastructures are expensive—a composite power pole costs upwards of 50 times a wooden power pole to install in the Territory. Consideration of these future costs of system recovery and blackout need to be accounted for prior to deciding which part of the power system to harden. Cheaper power poles may be better in communities that are already used to living with blackouts. Critical services provided by hospitals and police stations may require hardened systems. Moreover, benefits to other utility services should also be accounted for, such as improving telephone and internet connectivity by hardening cables that hang alongside power lines on the same poles.

LEARN MORE

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REFERENCES

[1] Alderson, D. L., B. B. Bunn, D. A. Eisenberg, A. R. Howard, D. A. Nussbaum, and J. Templeton. "Interdependent Infrastructure Resilience in the US Virgin Islands: Preliminary Assessment." Naval Postgraduate School Technical Report NPS-OR-18-005 (2018).

[2] Wille, Dominik. "Simulation-Optimization for Operational Resilience of Interdependent Water-Power Systems in the US Virgin Islands." Master's Thesis., Monterey, CA; Naval Postgraduate School, 2019.

Defense Energy Certificate Awardees

Dr. Dan Nussbaum and the Energy Academic Group congratulate the awardees of the second cohort of the Distributed Learning (DL) Certificate program in energy. EAG's DL Energy Certificate program is a graduate-level accredited certificate program, consisting of four courses, offered one per quarter for four consecutive quarters. The program is open to all federal civilian employees who are U.S. citizens and qualified uniformed officers, and provides those working military and civilian employees of the Department of Defense (DoD) the opportunity to understand the complex issues facing the Operational and Installation Energy segments of DoD. Additionally, EAG congratulates recent awardees of the Resident Certificate program in energy.

For more information or to apply: email Kevin Maher at kjmaher@nps.edu.

DISTRIBUTED LEARNING

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Defense Energy Seminar Series

NPS' academic programs in Defense Energy are supplemented by a seminar series which provides a forum for leading voices within the field, practitioners, and other Defense Energy influencers. These professionals give presentations, engage in brown bag discussions, and facilitate informal gatherings that encourage Defense Energy faculty and students to discourse over current issues in Defense Energy, supplementing classroom teaching with practical, professional experiences. The Defense Energy Seminars Series is a permanent part of NPS' Defense Energy program, and a key to its real-world relevance.

LEARN MORE
Please see the Calendar of Events in this issue of ***Surge*** or visit **nps.edu/web/eag/seminars** for upcoming and archived seminars.

CASE STUDY

Multipurpose, Scalable, Modular Small Power Hybrid Systems Architecture Analysis and Real-World Applications

Josh Crosby
President/CTO, CatalystE, LLC

David Spilker
Director of Managed Power Products, Virideon

What is the ideal power system architecture? Large scale power systems are normally easy to define. There is the generation source (solar farm, generator farm, wind farm), distribution and metering, and optionally an energy storage component. The small power system (5W–500W) is a little different, mainly because size and weight are often the limiting factors in the design. This requires a more focused design intent to achieve the goal while maintaining the appropriate size, weight, and power. Typically, there are two models for small power systems.

The first model is normally defined as a single building block comprised of energy storage and built in bi-directional power conversion that can operate as an AC or DC source. This model allows for a single, multi-functional module that is scalable, allowing for the creation of configurations that meet multiple mission requirements.

The second model is defined as individual stand-alone modules comprised of power management, energy storage, and power conversion (i.e. 28VDC energy storage with solar charging for a DC load), or a modular stacked configuration to build a more capable system (i.e. 28VDC energy storage connected to a power manager and DC/AC inverter to provide silent capability for an AC load).

Either of these power architectures are valid and useful as long as the load and use period is taken into account first. To restate the initial question, "what is the ideal power system architecture?", the answer is dependent on the user, mission, environment and use case. The real thought challenge is defining the 80% architecture solution.

POWER SYSTEM ARCHITECTURE FACTORS

LEARN MORE
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STUDENT ENERGY RESEARCH SPOTLIGHT

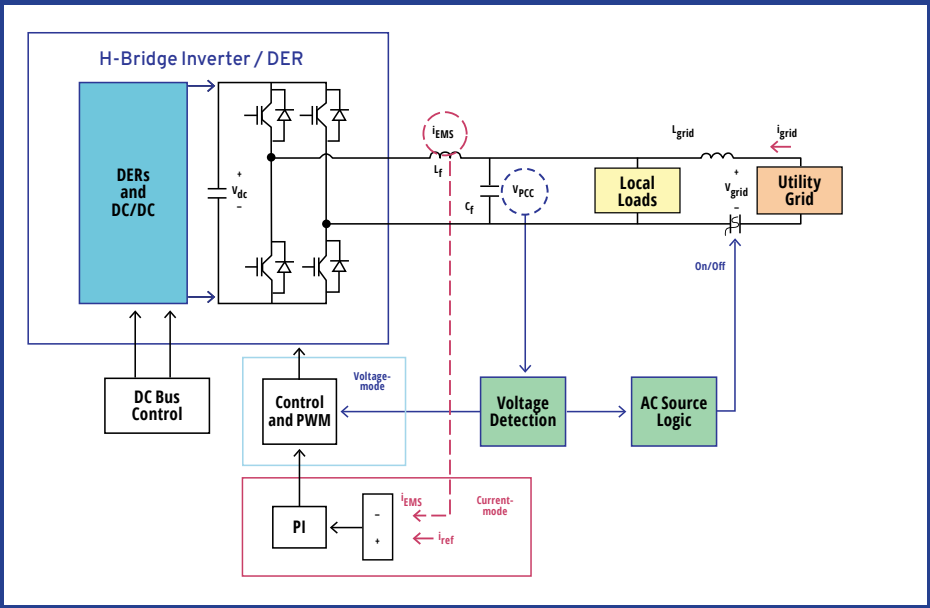
Evaluation of Unscheduled Intentional Islanding Methods for Single Phase Grid-Connected Inverters in Compliance with IEEE Standard 1547-2018

By LT Timothy Tencate, USN

A power electronics-based Energy Management System (EMS) is a key component of a microgrid; it manages loads, controls power flow to improve overall efficiency, and disconnects Distributed Energy Resources (DER) from the main grid in the event of a grid fault.

The latter is the focus of the research conducted for this project. Institute of Electronic Engineers (IEEE) Standard 1547 provides the requirements relevant to the connection of a microgrid to the main grid. The standard requires that the disconnection control method maintains connection for a specified time, known as voltage ride-through time, during voltage disturbances in the main grid voltage.

The research conducted for this project explored five different methods of EMS control and their respective algorithms for disconnection from the grid. The response times of disconnection from the grid were simulated using a physics-based model validated by experimental measurements on a laboratory prototype. The simulations were compared against the IEEE Standard 1547 voltage ride-through times to determine if the different controllers' dynamic responses could meet the requirements. Of the five methods tested, all were in compliance with IEEE Standard 1547 grid disconnection times, but only the two best performing methods, extended MSOGI (Multiple Second Order Generalized Integrator) and true RMS, were able to comply with the voltage ride-through requirements.



H-Bridge Inverter / Distributed Energy Resources

LT Timothy Tencate, USN

About the author

LT Timothy Tencate, USN, is a student of Electrical Engineering at the Naval Postgraduate School. Contact Dr. Giovanna Oriti at goriti@nps.edu for more information about this research.

OPERATIONAL ENERGY

Air Force Energy Supports Sustainable Microgrid Project

By Corrie Poland, Air Force Operational Energy (SAF/IEN)

F-22 Flight Simulator building at Joint Base Pearl Harbor Hickam, Hawaii, is part of the Pacific Energy Assurance and Renewables Laboratory, a renewable energy microgrid project demonstrating new ways for military facilities to address energy needs. Source: Burns & McDonnell

Article originally published January 22, 2020. Provided by the U.S. Air Force Air Combat Command and reprinted with permission.

The development of a sustainable microgrid power station is now underway for the Hawaii Air National Guard's 154th Wing at Joint Base Pearl Harbor-Hickam (JBPH-H) after a traditional Hawaiian blessing ceremony kicked off the project on December 17, 2019.

The microgrid, which is being developed as part of the Pacific Energy Assurance Renewables Laboratory (PEARL), is designed to provide energy to the Wing through on-site energy sources, including fuel and solar power.

In contrast to centralized power grids that make up a majority of energy distribution systems, microgrids allow power to be stored and distributed directly to the end-user, instead of going through a large interconnected network of energy systems. In turn, microgrids offer a more resilient energy source, resistant to weather and external attacks, both physical and cyber-related.

As part of its goal to improve base resilience and provide energy assurance to the warfighter, Air Force Energy, leveraging congressional appropriations for 'alternative energy' research and development, allocated funding and provided support to PEARL from the outset of the project. Former Senator Daniel Inouye (D-HI), along with Senators Brian Schatz (D-HI) and Dick Durbin (D-IL), were critical champions for these alternative energy efforts.

"Establishing resilient energy sources at our bases is fundamental to Air Force mission success. PEARL is just one of the ways we are executing our energy strategy and ensuring installations have the robust and stable power they need," said the Honorable John W. Henderson, Assistant Secretary of the Air Force for Energy, Installations, and the Environment.

The first phase of development, scheduled for completion later this year, will focus on constructing the microgrid system at JBPH-H by connecting the base's existing solar array and a battery storage system to the local network. Phase two will incorporate solar to hydrogen for energy generation, storage, and utilization, and then culminate in the final phase of potentially powering the network with 100 percent on-site generated energy.

"Initiatives like PEARL help the Air Force improve mission resilience and provide secure, reliable power to our installations and critical facilities, and ultimately our Airmen," said Mark Correll, Deputy Assistant Secretary of the Air Force for Environment, Safety, and Infrastructure.

The Office of the Assistant Secretary of the Air Force for Energy, Installations, and the Environment (SAF/IEN) enables Airmen to fly, fight, and win through ready installations, reliable environmental infrastructure, and resilient energy solutions.

LEARN MORE

For more information on energy optimization efforts in the Air Force, visit: **safie.hq.af.mil/OpEnergy**

Calendar of Events

Spring 2020 Defense Energy Seminar Series
Due to rapidly changing circumstances surrounding the COVID-19 virus, the Defense Energy Seminar Series will be offered exclusively online for the Spring Quarter. Please visit our website at https://nps.edu/web/eag/seminars for upcoming seminar dates and all EAG event details.

Interested in Energy-related Thesis Research?

Since 2013, NPS and the EAG supported a plethora of student thesis research in the area of energy. Publicly viewable student theses can be searched from the Resources page of the EAG website at **nps.edu/web/eag/resources**. The EAG's extensive resources, intellectual capital, and connections with multi-disciplinary faculty and energy professionals provide students enhanced support for energy-related research. If interested in energy research, please reach out to the EAG team!

ENERGY ACADEMIC GROUP
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Connect with the Energy Academic Group

The Energy Academic Group is located in Quarters D, Bldg 281 on the NPS campus in Monterey, California. A wide range of NPS faculty are affiliated with the energy program, actively participate in energy graduate education, energy executive education, and energy research. For questions, please contact one of the principal EAG faculty members:

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Contribute to an issue of *Surge*

If you would like to contribute an article or have your research/work published in the *Surge* newsletter, please contact Lois Hazard via email at lkhazard@nps.edu.

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