Hawai'i Natural Energy Institute Research Highlights

Grid Integration

Advanced Conservation Voltage Reduction Development and Demonstration

OBJECTIVE AND SIGNIFICANCE: HNEI Grid***START*** is demonstrating advanced conservation voltage reduction (CVR) as an energy efficiency strategy on the 13.8 kV distribution circuit serving the Plaza Housing complex at U.S. Marine Corps (USMC) Camp Butler in Okinawa, Japan. The project showcases innovative voltage control through a field demonstration that utilizes real-time data to reduce overall energy consumption and improve distribution efficiency for a range of military base loads.

BACKGROUND: CVR reduces energy usage by optimizing customer service voltage. For every 1% voltage reduction, energy use was reduced by approximately 0.7% to 0.9% (CVR factor). HNEI, in close collaboration with USMC facilities personnel, focused on a feeder section with seven distribution service transformers to demonstrate these benefits.

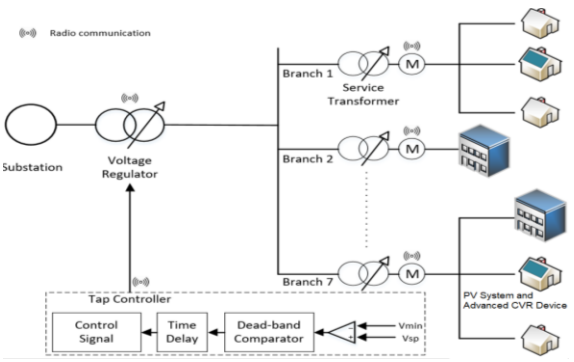

Figure 1. System architecture of CVR demonstration.

PROJECT STATUS/RESULTS: A pad-mounted voltage regulator (VR) was installed to manage voltages on the test section, simulating substation load tap changer operation on a localized scale. To address variable voltage points along the feeder, a patented advanced CVR device was developed and deployed at a critical low-voltage location (TH-415), enabling autonomous local voltage control via reactive power dispatch and inverter management. The project integrated new and existing grid technologies, including a VR with custom control, metering systems, mesh network communications and a 5 kW photovoltaic (PV) system at TH-415. Initial development included algorithm validation using hardware-in-the-loop testing and the creation of a control dashboard. Construction work encompassed circuit reconfiguration and installation of electrical components. System commissioning involved technical troubleshooting and field validation of the CVR system and devices.

Various operational improvements were made, including upgrades to system control and data protocols, enhancement of metering communications, implementation of a local NTP for data synchronization, and continuous system maintenance. The CVR system runs in scheduled alternating on/off cycles, producing observed monthly energy savings with CVR factors between 0.75% to 0.93% for the seven transformers, equating to 1.82 to 2.26 MWh per month.

In response to evolving cybersecurity requirements, communications were migrated off the Camp's AMI network in mid-2024. Following Typhoon Khanun in 2023, which led to a temporary VR shutdown, comprehensive testing and analysis confirmed equipment integrity, and the VR was re-energized in April 2024. The controller for the patented advanced CVR device was subsequently relocated and upgraded, and persistent communication issues were resolved through laboratory simulation and code revision in early 2025, restoring proper control and reactive power dispatch.

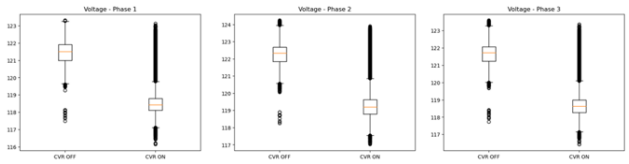

Figure 2. The impact of advanced CVR on voltage statistics at the VR secondary side.

The project's initial findings successfully validated advanced CVR strategies for military base distribution systems, achieving measurable and sustained energy savings. With the support of USMC personnel, the system continues to operate and generate data that will be used to validate advanced CVR's long-term savings. Final field testing and validation will be conducted once applicable funding is secured. The demonstrated infrastructure and operational insights contribute to best practices for distribution voltage optimization, localized control, and resilient grid operation in similar environments.

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Contact: Leon Roose, lroose@hawaii.edu

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