Business & Technology Surveillance

3-Phase Grid Energy Router for Use in MicroGrids and Distributed Generation

By Deborah Fish, PE, President Utility Resources, Inc.

AUGUST 2019

NRECA
America's Electric Cooperatives

Business & Technology Surveillance

3-Phase Grid Energy Router for Use in MicroGrids and Distributed Generation

By Deborah Fish, PE, President Utility Resources, Inc.

AUGUST 2019

SUBJECT MATTER EXPERT ON THIS TOPIC

Brian Sloboda,
NRECA Consumer Solutions Director:
Brian.Sloboda@nreca.coop

This article is a product of the **Distributed Energy Resources Work Group**

ARTICLE SNAPSHOT

WHAT HAS CHANGED IN THE INDUSTRY?

Deployment of the first 3-phase grid energy router (GER) by Sandhills Utility Services, LLC (Sandhills) promises to improve energy resiliency at North Carolina's largest military base, Fort Bragg, NC. Sandhills integrated the GER with an existing 3-phase 150 kVA transformer. The GER was installed to enhance power quality at a commercial load. The initial results of the 3-phase unit show voltage improvement, phase balancing, and reduced energy and demand. The GER is also expected to extend the motor life of the end-user equipment.

Sandhills deployed this "next generation" GER capable of real-time adjustments for voltage and VAR control at a three-phase customer site. This specific location was ideal because communication to SCADA was at the customer's meter and historical data had already been collected and analyzed for phase imbalance. Jeff Brown, CEO of Sandhills, made the decision to purchase the first three-phase unit because "Sandhills strives to bring solutions to the government, not problems."

This report is a follow-on report to early reporting of field demonstrations of the GridBridge-ERMCO grid energy router. Previous reports can be found here:

- **Field Demonstration: Grid Energy Router**—featuring Brunswick Electric Membership Corporation
- **Grid Edge Device Comparison**
- **Grid Energy Router Project Proves a Success for Farmers**, *T&D World* article—features efforts by Central Electric Power Cooperative (CEPCI) and NRECA. Results from this voltage optimization field demonstration will be available later in 2019.

NRECA
America's Electric Cooperatives

WHAT IS THE IMPACT ON COOPERATIVES?

The changing nature of the grid and changing consumer member needs may require the deployment of advanced technology on distribution feeders. Technologies such as the grid energy router have been successfully tested and deployed in a variety of uses at several co-ops. This article expands the understanding of the many use cases for the technology.

WHAT DO COOPERATIVES NEED TO KNOW OR DO ABOUT THIS?

The second-generation grid energy router, referred to as GER, leverages years of field work with the single-phase grid energy router. Installations of these distributed devices within microgrids have the potential to modernize the distribution grid while decreasing demand and energy and achieving near perfect power quality.

History of GridBridge and Grid Energy Router

GridBridge, located in Raleigh, North Carolina, developed this new technology. ERMCO purchased the company in 2017 to manufacture the GER with distribution transformers, to buck and boost voltage, regulate power factor, and demonstrate real-time monitoring and control. NRECA and several electric co-ops began collaboration with Gridbridge in 2014, to help shape products and standards, and provide first access to this new technology for electric co-ops.

Sandhills decided to purchase the first three-phase GER because of their partnership with Fort Bragg, NC, through their 50-year utility privatization contract where the cooperative owns, operates, and maintains the distribution system on the base.[1] Jeff Brown, Sandhills' CEO, read about the first GER in a NRECA report and started discussions about a three-phase padmount unit with ERMCO. Mr. Brown elaborates, "once we learned ERMCO produced the first three-phase padmount GER, we wanted to purchase and study the units to bring solutions to critical loads for the government. The GER is a good fit for Fort Bragg's underground three-phase electrical distribution loads." (See **Figure 1**.)

Sandhills' "Hopes" for the GER

Sandhills agreed to purchase and deploy the 3-phase grid energy router at Fort Bragg, North Carolina in November 2018. The unit was installed and monitoring is still underway, as testing is being performed in multiple stages. The GER has been integrated into Sandhills' closed communications' network, the control software has been installed, and the unit is fully commissioned.

David Keith, Manager of Engineering and MicroGrids, when asked why Sandhills bought the GER, stated "The grid energy router can help mitigate voltage and power factor issues and can help co-ops expand their potential for Conservation Voltage Reduction at the customer's level."

Sandhills identified a commercial location where voltage varies by leg to the customer, along with current imbalance causing high neutral currents. The cause for the imbalance at this location is unknown, except that it is common to see varied voltage drop and imbalance across the phases on long feeders, causing problems for three-phase customers' connected equipment. Sandhills' goal is to test the capabilities at the 3-phase distribution transformer level with real-time monitoring and control.

Sandhills purchased the GER to eliminate the issues outlined above, to verify that the GER works as advertised, and to consider wider deployment. Traditional ways to fix this problem are expensive, including reconductoring, line-regulation, engineering studies, and other equipment.

Wider application conversations are already taking place with Sandhills. Mr. Keith "hopes to capture the effect of solar on a feeder network, using traditional-looking equipment, like the TIGERpad." In addition to the three-phase GER installed at Fort Bragg, ERMCO now offers the TIGERpad, which is a single-phase padmount transformer, fully integrated with the GER. If all goes well with this initial testing of the GER, and as ERMCO produces more units, Mr. Keith "would like nothing more than to standardize on the fully integrated TIGERpad, especially for distributed generation additions to the grid."

Dennis Andress, Manager of Technical Services at Sandhills, "hopes to use the GER downline to immediately report back to the substation how far the taps on regulated feeders can be changed and correct for any resultant overage."

Installation of the 3-Phase GER at Customer Site at Fort Bragg

According to Sandhills, the installation was well-organized and straightforward (see **Figure 1**). GridBridge provided training onsite prior to the installation, so the software was loaded in the SCADA room prior to the field

[1] To learn more about the cooperative engagement with the military, visit: **https://www.cooperative.com/programs-services/bts/cooperatives-and-the-military/Pages/default.aspx**

Reliable communication is necessary to monitor and capture the data necessary for evaluation and assessment.

install. Other than the special training for the device, no special skills or additional personnel was required to install the GER. Mr. Keith suggested "the only additional person that might be useful beyond a typical three-phase transformer crew is someone from IT, either during or after the installation." More people participated in the initial installation at Sandhills, mostly because of the excitement and interest for the new product.

The installation was smooth, but there were some delays in the original project scope. The delays were in collecting the data, which was related to establishing continuous reliable communication to the GER on Sandhills' closed network. Once the GER was connected, if the fiber link dropped, intervention from Sandhills' back office was required. After investigation, Sandhills fixed the problem related to handling a fixed IP. GridBridge worked with Sandhills to fix this within their network and have not had issues since. Reliable communication is necessary to monitor and capture the data necessary for evaluation and assessment.

FIGURE 1: Sandhills linemen installing the three-phase GER into an existing 150 kVA padmount transformer at Fort Bragg

Mr. Andress explains that "considering the security of Sandhills' closed fiber network, there was a lot of collaboration to get the GER on the network, feeding directly into our SCADA room." Since the initial installation, GridBridge updated the operating system in April 2019, which is typical for this unit to release quarterly updates as they make improvements to the GER.

Initial Results (3 Months of Data) of the 3-Phase GER at Fort Bragg, NC

This three-phase customer was chosen for the first GER, not only because of the access to the closed fiber network, but it is also a non-priority customer with predictable load for analyzing improvements. Prior to the installation, Sandhills sampled load data, and the pre-installation load study was consistent daily. After the testing phase, Sandhills plans to install the GER at customers with known load issues. David Keith explains, "since the GER provides real-time data, Sandhills can collect and monitor the customer's load and determine what is causing the problems and fix." After identifying the initial irregularities from the collected data, Sandhills set a few initial goals for the GER to improve power quality.

GOALS FOR FIRST INSTALLATION

Phase 1: Verifying the GER's operation and capability to solve Sandhills' Power Quality concerns

Timeframe: 3 Months—December 2018 – March 2019

Product: Sandhills provided an existing 150 kVA three-phase transformer and ERMCO supplied the GER

- **Goal 1:** Eliminate voltage variation per leg, through bucking or boosting voltage to a dynamically adjustable setpoint from the control center.
- **Goal 2:** Eliminate or reduce current imbalance that is resulting in high neutral currents. The result will be more balanced currents and an elimination of (or significant reduction in) neutral current.

Sandhills' five goals for the GER to improve power quality were all achieved during the first phase.

- **Goal 3:** Power Factor correction reflected on the source-side of the distribution transformer (grid).
- **Goal 4:** Document connectivity and control from a centralized back office.
- **Goal 5:** Receive and interpret 30-day intervals of data, ideally along with an event capture utilizing the GER's 24-hour, 1 second database.

All 5 goals were achieved during this first phase. Goal 4 was to document connectivity and control to the GER from the centralized office. This was achieved within the first month after the installation. Goal 5 was also achieved, with the resulting data captured and interpreted in the next few figures and graphics below.

Goal 1: Controlling voltage volatility by regulating the voltage to a desired setpoint

Figure 2 is a 3-month plot from December 21, 2018 through March 26, 2019. The plot shows the voltage fluctuation between 118 Volts and 124 Volts from December 21st through January 25th when the GER was set to regulate voltage at 118 Volts per leg. From January 26th through February 26th, the GER was set to regulate voltage at 120 Volts per leg. The GER was then set to regulate voltage again at 118 Volts per leg from February 27th through March 26th.

Goal 2: Reducing or eliminating neutral currents caused by load imbalances

Figure 3 is an accurate illustration of the load current in Amps for this three-phase customer during a typical day. The graph is a plot of Amps per phase, starting from February 24th at approximately 23:00 HRS through February 25th at approximately 07:15 HRS. Phase A (Amps) is Red, Phase B (Amps) is Black, and Phase C (Amps) is Blue. The Neutral Current is shown in Green. At approximately 00:30 HRS (12:30 am), the GER phase balancing mode is turned on. Prior to turning on the balancing mode, the graph shows 20 to 30 Amps difference between A and B phases (Black and Red) and C phase (Blue). Once the phase balancing mode is turned on, the neutral current was reduced by over 20 Amps and all 3 phases are almost identical.

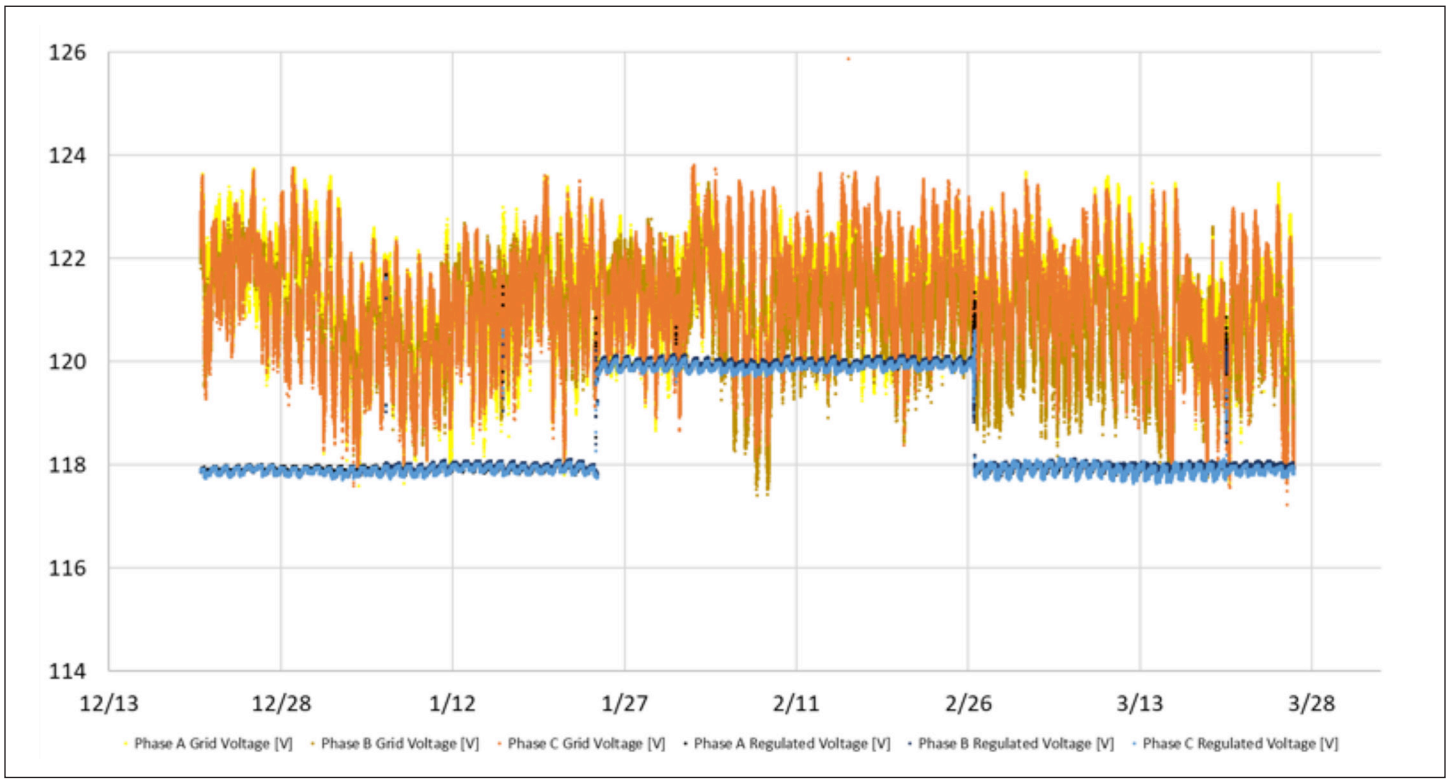

FIGURE 2: 3-Month Plot from the GER showing specific Voltage Set Points

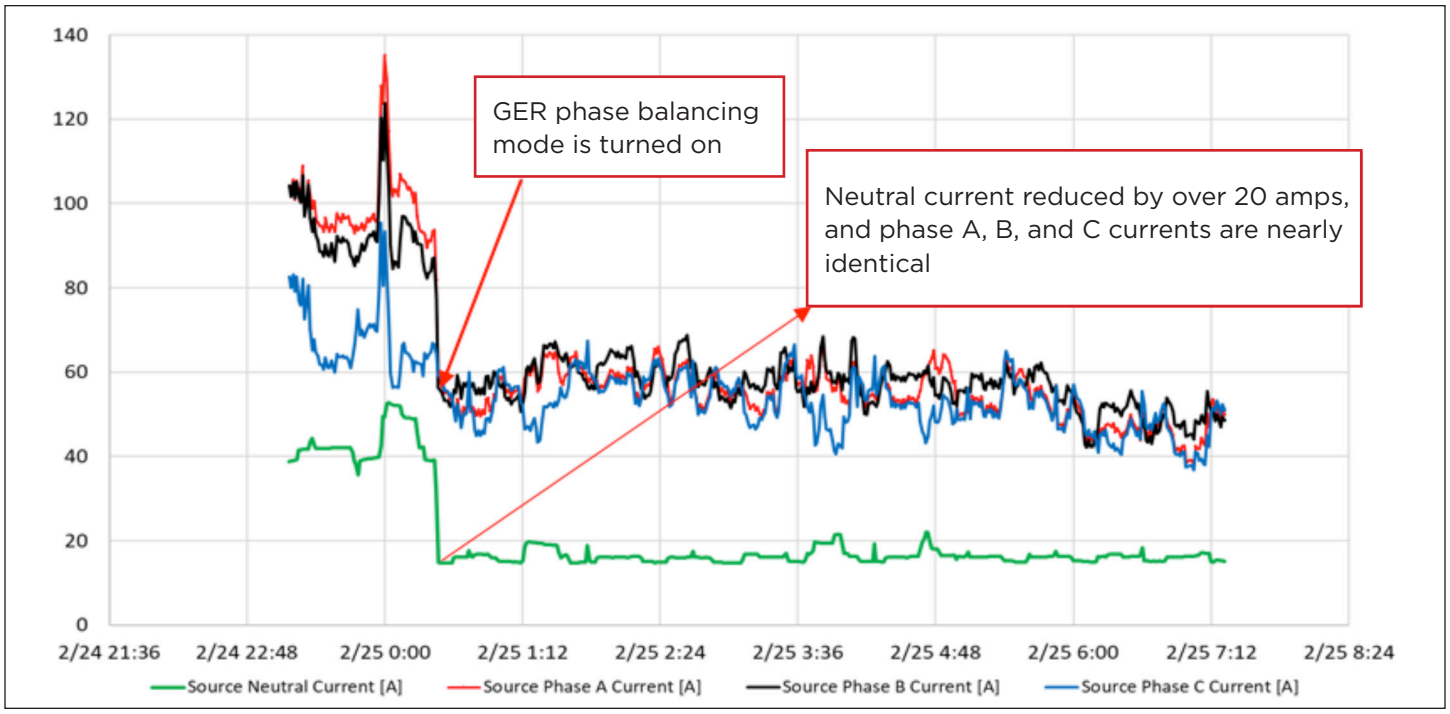

FIGURE 3: Phase Balance Mode Reduces Neutral Current

Goal 3: Reducing reactive power (VAR) per phase, therefore improving Power Factor reflected to the primary, through the transformer

Figure 4 is a graph of power factor from January 24th through February 26th, where 1.0 is equivalent to 100 percent, or unity power factor. The orange plot is measuring the power factor from the source-side of the transformer and the blue plot is a measure of the power factor of the load. With the power factor correction (PFC) mode turned on, the power factor measured from the source-side of the distribution transformer was near unity (1.0) power factor. When the PFC mode was turned back off, the source-side (grid) saw the fluctuation between 0.8 and 0.98, or 80 to 90 percent power factor.

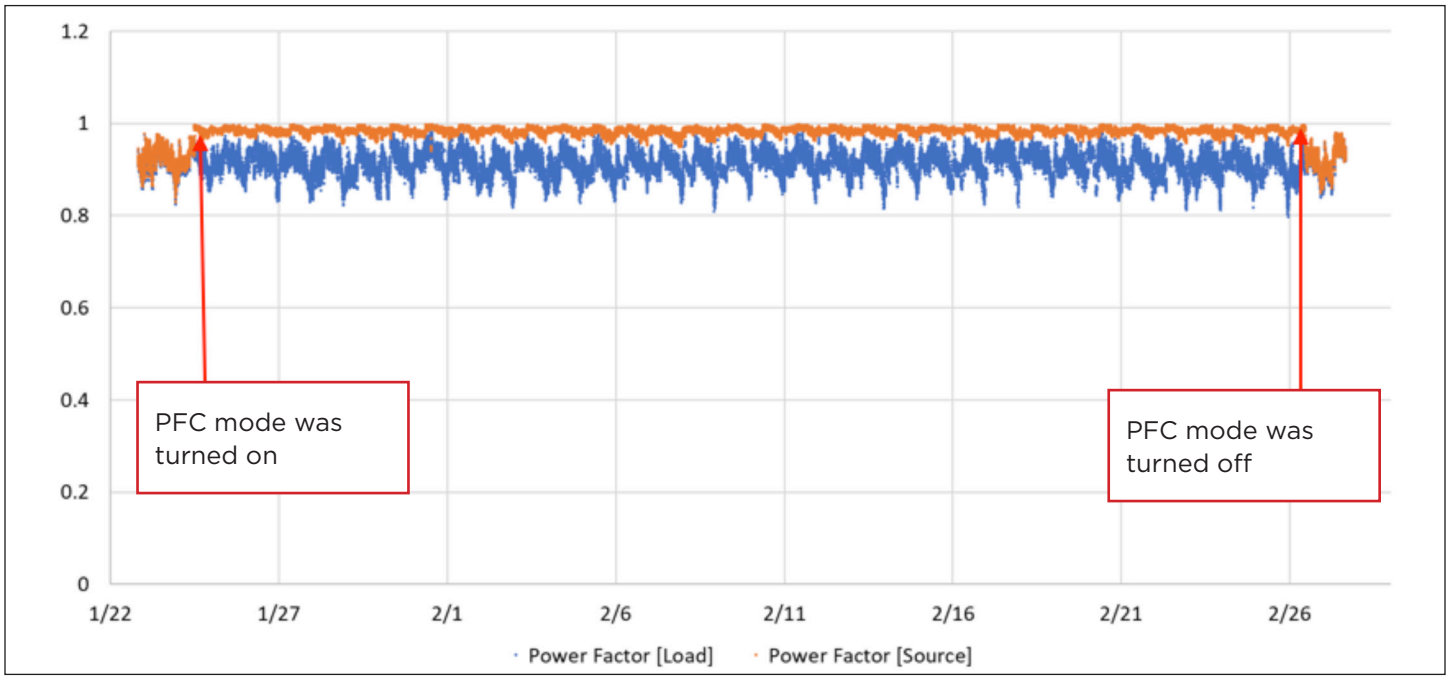

Figure 4: Results of Power Factor Correction Feature

Other Results from initial testing: Demand kW Reduction

Figure 5 shows the calculated demand reduction while the GER was tested in December 2018 and January 2019. This was not an original goal of the demonstration, but also not a surprising outcome from balancing the load and reducing the neutral current.

Another Result from initial testing: Energy kWh Reduction

Figure 6 shows the actual reduction in kWh with the GER and without the GER, during the same number of hours. For those skeptical of this result, Sandhills plans to compare historical kWh data with a longer time frame as the testing continues into phase 2.

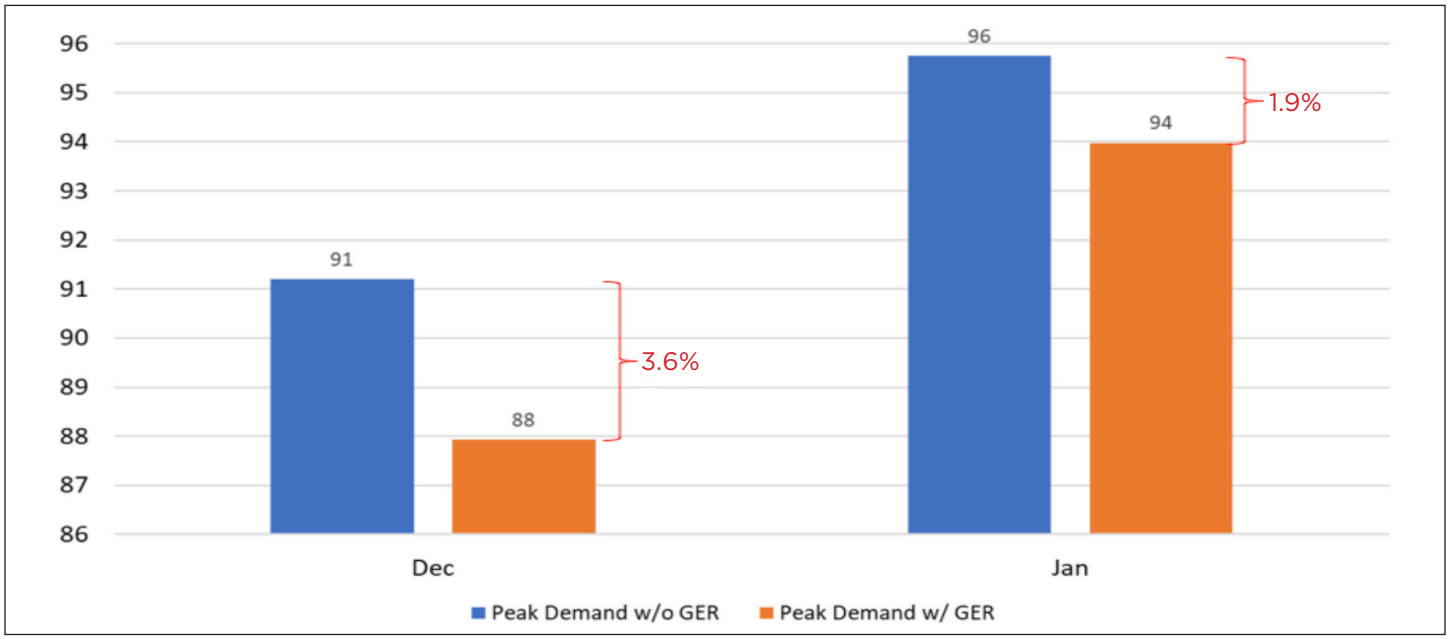

FIGURE 5: Calculated Demand Reduction at the GER location in December 2018 and January 2019

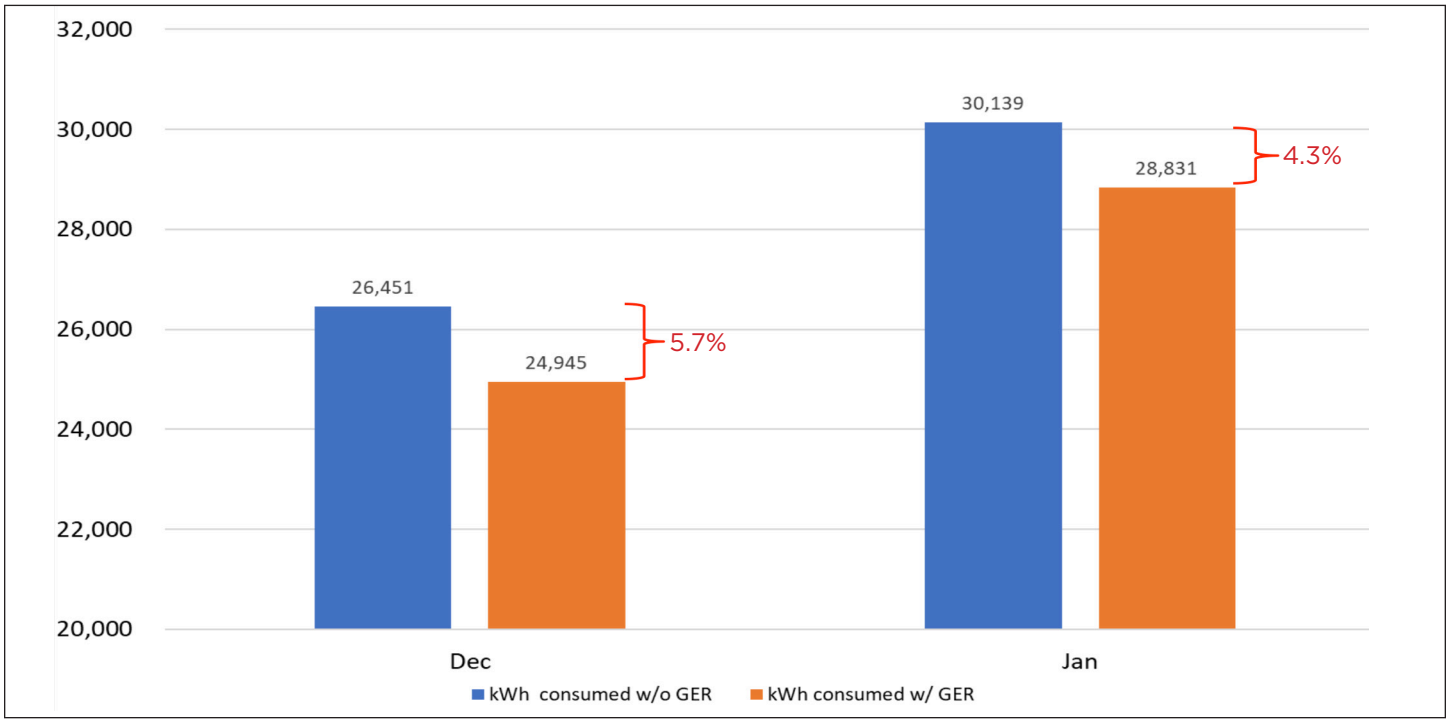

FIGURE 6: Another Result found during testing of the GER was a reduction in Energy kWh by 5.7% in December and 43% in January

Future applications of the GER at Sandhills

Based on the initial results, Sandhills is happy with the GER and would like to purchase more units. David Keith would like to install the GER at an existing transformer in a Micro-Grid test-bed for resiliency. Although not tested, based on these initial results, Sandhills hopes the GER will support distributed generation, reduce energy when islanded, and enable demand management tied to the upline substation. GridBridge is not promoting these capabilities, because there has not been enough testing at this point. There is also a size limitation on the three-phase padmount of 150 kVA, which automatically limits testing to small solar or distributed generation. With control at the distribution transformer, it seems reasonable that the results of future testing will prove these devices will benefit the distribution engineer's goals to manage the distribution system as distributed generation continues to saturate the grid.

Mr. Brown would like to take things slow, allowing the unit to be fully tested. Therefore, "a likely next step is for Sandhills to install the TIGERpad, which is the fully integrated GER (see Figure 7) with a transformer, to focus on power quality at key points for better grid infrastructure utilization." After a few installations, with multiple GERs, "Sandhills hopes to flatten feeder voltage profiles, which will also allow equipment to operate at higher efficiencies." Because of Sandhills' privatization contract at Fort Bragg, they would also like to install future TIGERpads to contribute to the U.S. Department of Energy (DOE) and Army's Net Zero initiatives by renewable generation integration.

This first generation GER was developed to be owned by the utility, downstream from the substation, with the ability to monetize benefits of voltage regulation, power flow control, and insert reactive power.

FIGURE 7: 1-Ph 50 kVA poletop GER and TIGERpad

What is the next generation for the GER?

ERMCO has plans for the next generation GER product. Chad Eckhardt, leading the Advanced Technology Center of ERMCO, explains "there is a natural evolution towards larger sizes. We are working on additional GER features that will open up even more applications and simultaneously enable utilities to manage the influx of distributed energy resources onto their grid." The three-phase 150 kVA GER is available to other co-ops and is being stocked by ERMCO today.

CAPABILITIES OF THE GRID ENERGY ROUTER

- Non-invasive load control
- Energy efficiency & power quality
- Phase balancing & neutral current reduction at transformer
- Voltage regulation per phase
- Power flow control upstream of meter
- Solar smoothing
- Historical reporting
- Programmable power parameter management
- Remote monitoring of generator systems ■

ABOUT THE AUTHOR

Deborah Fish, PE

Deborah is currently the President of Utility Resources, Inc., a consulting firm in North Carolina. She has worked with cooperatives across the country for 27 years. She also served as a Senior Program Manager for NRECA for the Distribution Operations Best Practices Member Advisory Group. Deborah has produced several reports for CRN on MultiSpeak and GIS along with various Business & Technology Surveillance studies. Contact Deborah at **deborah@utilityresources.net**.

QUESTIONS OR COMMENTS

- Brian Sloboda, NRECA Consumer Solutions Director: **Brian.Sloboda@nreca.coop**
- To find more resources on business and technology issues for cooperatives, visit our **website**.

DISTRIBUTED ENERGY RESOURCES WORK GROUP

The Distributed Energy Resources (DER) Work Group, part of NRECA's Business and Technology Strategies department, is focused on identifying the opportunities and challenges presented by the continued evolution of distributed generation, energy storage, energy efficiency and demand response resources. For more information, please visit **www.cooperative.com**, and for the current work by the Business and Technology Strategies department of NRECA, please see our **Portfolio**.