Program Final Report
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Summary of Accomplishments – In Support of Appalachian Regional Commission: Volunteer Energy Cooperative IoT Innovation Ecosystem Project

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LEXINGTON, MASSACHUSETTS

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1. EXECUTIVE SUMMARY

The U.S. electric power grid is undergoing a rapid change due to the expansion of Distributed Energy Resources (DER) (e.g. photovoltaic systems and rooftop solar plus batteries), widespread use of Electric Vehicles (EV) and charging stations, as well as changes in the magnitude and timing of electrical demand (due to controllable customer loads and the electrification of transportation). This transformation creates both challenges and opportunities to advance the resilience of the system. Electric utilities like Volunteer Energy Cooperative (VEC) are currently engaged in grid modernization efforts, such as "smart grid" adoption, to prepare today's electric grid for emerging changes in infrastructure and business models.

Modernization upgrades can benefit from prototyping and testing platforms, such as Hardware-in-the-Loop Laboratory Testbed and Open Platform (HILLTOP), to de-risk projects by providing a tangible proof–of–concept to new project stakeholders, ability to evaluate the performance of commercial products and new technologies, and means to evaluate potential investments and test edge-conditions prior to roll–out of new infrastructure. Under strategic support from the Appalachian Regional Commission (ARC), and in collaboration with VEC and Tennessee Tech University (TTU), the progression of support from Massachusetts Institute of Technology Lincoln Laboratory (MIT LL) to this program has been subdivided into stages outlined below.

- The **first** stage of this program (FY2020, completed) focused on MIT LL developing a Real-Time Hardware-in-the-Loop (HIL) Microgrid Prototyping and Technology Testing Platform. This HIL platform was showcased emulating a portion of the VEC power system providing electric service to the Pleasant Hill community.
- The **second** stage of this program (FY2021, completed) focused on the transfer of technology from MIT LL to TTU, and the training of TTU Center for Energy Systems Research (CESR) selected staff to utilize the HIL platform.
- The **third** stage of this program (FY2022, completed) was dedicated to sharing expertise and lessons learned in HIL testing and power system analysis to increase TTU CESR proficiency in employing the HIL platform while addressing practical problems presented by an electric utility, in this case, VEC.

2. ACCOMPLISHMENTS

Massachusetts Institute of Technology Lincoln Laboratory (MIT LL) is a Federally Funded Research and Development Center (FFRDC) administered by Massachusetts Institute of Technology under Air Force Prime Contract FA8702-15-D-0001. MIT LL researches and develops a broad array of advanced technologies to meet critical national security needs. MIT LL developed the Hardware-in-the-Loop Laboratory Testbed and Open Platform (HILLTOP) as a microgrid simulation and prototyping platform to help reduce project development risks by providing a tangible proof–of–concept to new project stakeholders, ability to evaluate the performance of commercial products and new technologies, and means to evaluate potential investments and test of edge conditions prior to expensive new infrastructure roll–outs.

Volunteer Energy Cooperative (VEC) provides electric service to a 17 county region in East Tennessee, stretching from the Georgia state line to the Kentucky state line. The VEC service area is comprised primarily of the rural parts of the counties served. Crossville, TN, is the largest and most densely populated area served by VEC. Crossville provides the cooperative an opportunity unique among all of the areas within VEC service territory. Most rural areas are supplied by a single electric feed. In order to take advantage of intelligent systems control, redundant supplies are often a prerequisite. One of the options of interest is to explore the use of utility-scale battery storage and renewable energy generation in combination with demand response participation to offset electrical demand and alleviate the cost of energy.

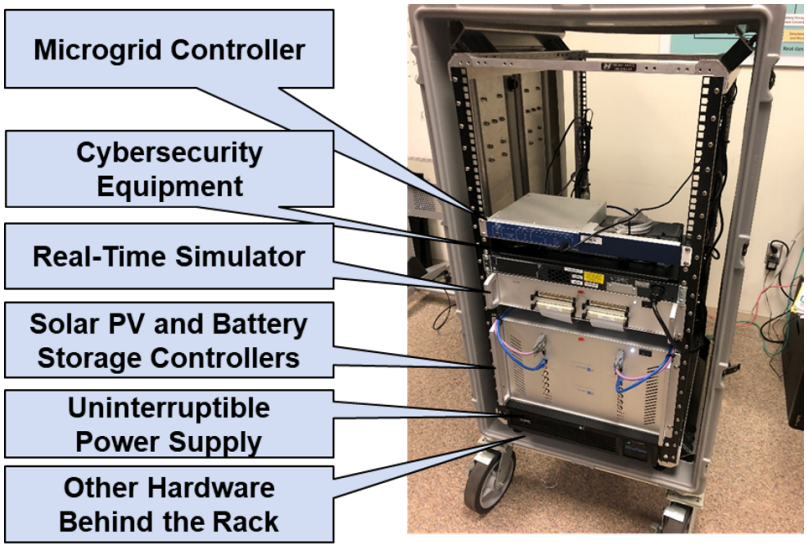

Figure 1. Real-time microgrid prototyping and technology testing platform as transitioned to TTU in FY2021.

Under strategic support from the Appalachian Regional Commission (ARC), and in collaboration with VEC and Tennessee Tech University (TTU), the progression of support from MIT LL to this program has been subdivided into stages, described below.

The **first** stage of this program (FY2020, completed) focused on MIT LL developing a Real-Time HIL Microgrid Prototyping and Technology Testing Platform (see figure 1). This HIL platform was showcased emulating a portion of the VEC power system providing electric service to the Pleasant Hill community (see figure 2). The simulation platform integrates a digital twin of the power system with commercially available solar array and battery energy storage controllers to evaluate operations and technology solutions before field deployment. Thus, reducing engineering concerns for marketing vaporware as well as a perceived risk by project developers and financial investors. Test scripts and scenarios were developed to demonstrate typical operations and edge conditions; simulation results addressed questions from VEC engineers. The architecture of the platform, models, and device communication details were documented to expedite technology transfer to TTU (assigned recipient) as well as to familiarize them with the platform.

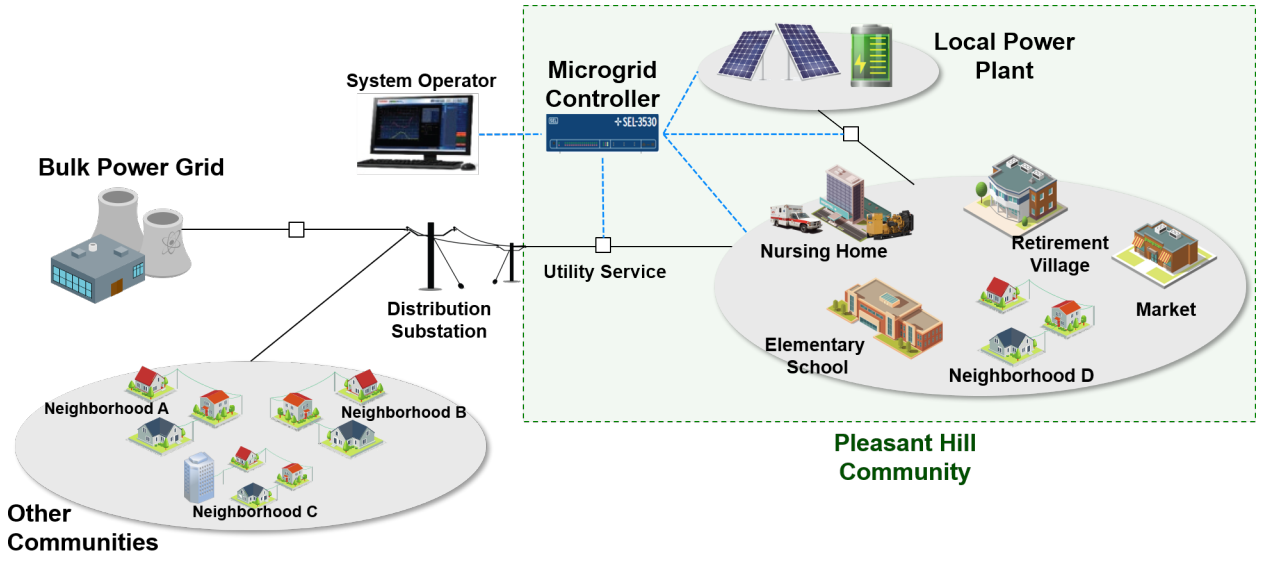

Figure 2. High level representation of a potential microgrid configuration for the Pleasant Hill Community.

The **second** stage of this program (FY2021, completed) focused on the transfer of technology from MIT LL to TTU and the training of TTU Center for Energy Systems Research (CESR) selected staff to utilize the HIL platform. The training was conducted via tutorial sessions and teleconferences to help address any issues experienced by TTU in coming up the learning curve.

The **third** stage of this program (FY2022, completed) was dedicated to help increase TTU CESR proficiency in employing the HIL platform while addressing practical problems presented by an electric utility, in this case, VEC. In collaboration with ARC, MIT LL shared expertise and lessons learned in HIL testing and power system analysis with TTU CESR as associated with their ARC funded research that implements the HIL platform and other power systems analysis tools, as co-simulation capabilities, to study the effects of combined solar Photovoltaic (PV), battery energy storage, and demand response in distribution circuits, which were selected and provided by VEC. Additionally, MIT LL provided support to this program in the form of feedback to brainstorm sessions, technical progress reports, and whitepapers produced by TTU CESR as related to this effort.