Department of Commerce

Center for Microgrid Research Grant

Project Report

Oct 1, 2023, to Dec 31, 2023

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This project was made possible in whole or in part by a grant from the Minnesota Department of Commerce through the Minnesota Renewable Development Account, which is financed by Xcel Energy ratepayers.

Continuing the design process from Q3, the team continued the effort to find a suitable location that can house all necessary power, testing, and research equipment for the microgrid expansion. Figure 1 (top left) shows the two locations (Options 4 and 5) that the team concentrated on throughout this quarter. Option 4 considered co-locating one or two of the new tier 4 diesel generators next to the existing emergency generator in the basement of OWS (Owens Hall). After thorough mechanical and civil engineering analysis, option 4 was ruled out due to multiple restrictions such as capacity of current fresh air intake, required height for silencer/exhaust pathways, height of attenuator, and limited space for Diesel Exhaust Fluid (DEF) and diesel storage. The design team then concentrated on option 5 as the most reasonable to locate the expansion equipment. Figure 1 (bottom left) shows a preliminary sketch that includes high-level space allocations for the switchgear, generators, energy storage system, power distribution systems, and testbays.

As stated in the 2023 Q3 report, UST interviewed architectural design firms to explore options 4 and 5. Mohagen Hansen (MH) won the contract and worked with the design team to narrow down the options. MH's preliminary concept is shown in Figure 2 (top). Through engagement with all stakeholders at UST, including the Biology department, the preliminary concept that was arrived at by end of Q4 is shown in Figure 2 (bottom). The concept includes locating the microgrid generators in the basement, the first floor would house the switchgear and testbays along with OWS's loading dock, while the Biology Department's Greenhouse gets relocated to the second floor. Costs associated with non-microgrid matters are not covered by this grant.

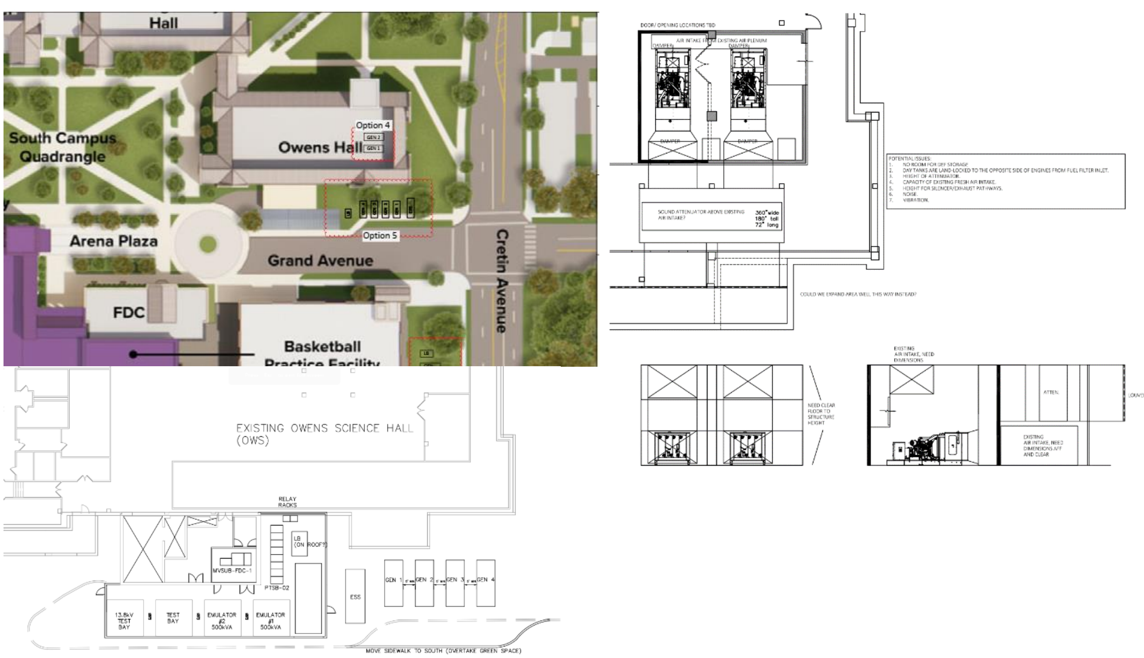

Figure 1: Design and engineering plans. Top left: proposed locations of new microgrid equipment, bottom left: preliminary layout of microgrid equipment and space. Right: air intake and exhaust designs for two tier-4 diesel generators.

Figure 2 Architect Preliminary designs: Top: Initial sketches for Option 5 space. Bottom: Preliminary drawings and space allocations of the proposed new space.

Hallberg Engineering, the Engineer of Record, continued working with CMR and UST Facilities Management on drafting the electrical and mechanical engineering plans for the expansion. CMR also completed an Investment Grade Audit for the microgrid control and protection systems with SEL Engineering Services, Inc. The plans included, but not limited to:

- a site plan shown in Figure 3 (top left) that includes the 5 buildings that the microgrid would connect to which are: Schoenecker Center (SCC), Owens Hall (OWS), O'Shaughnessy Science Hall (OSS), Facilities and Design Center (FDC), and Anderson Parking Facilities (APF) along with the utility tunnel connecting SCC to OWS/OSS and FDC.
- the diagrams for the building retrofits to enable the connection to the microgrid shown in Figure 3 (top right).
- current microgrid switchgear updates and retrofits to enable connection to FDC building switchgear and create a 480V loop for advanced research and testing (Figure 3 (bottom left)).
- plan for a new energy storage system (ESS) sized at 30kW/60 kWh shown in Figure 3 (bottom right)
- technical documentation for upcoming RFPs for the tier 4 diesel generators, paralleling switchgear, current microgrid refurbishments and updates, and new transformer.
- Xcel Energy interconnection application after the team was informed that there was miscommunication previously on its need.

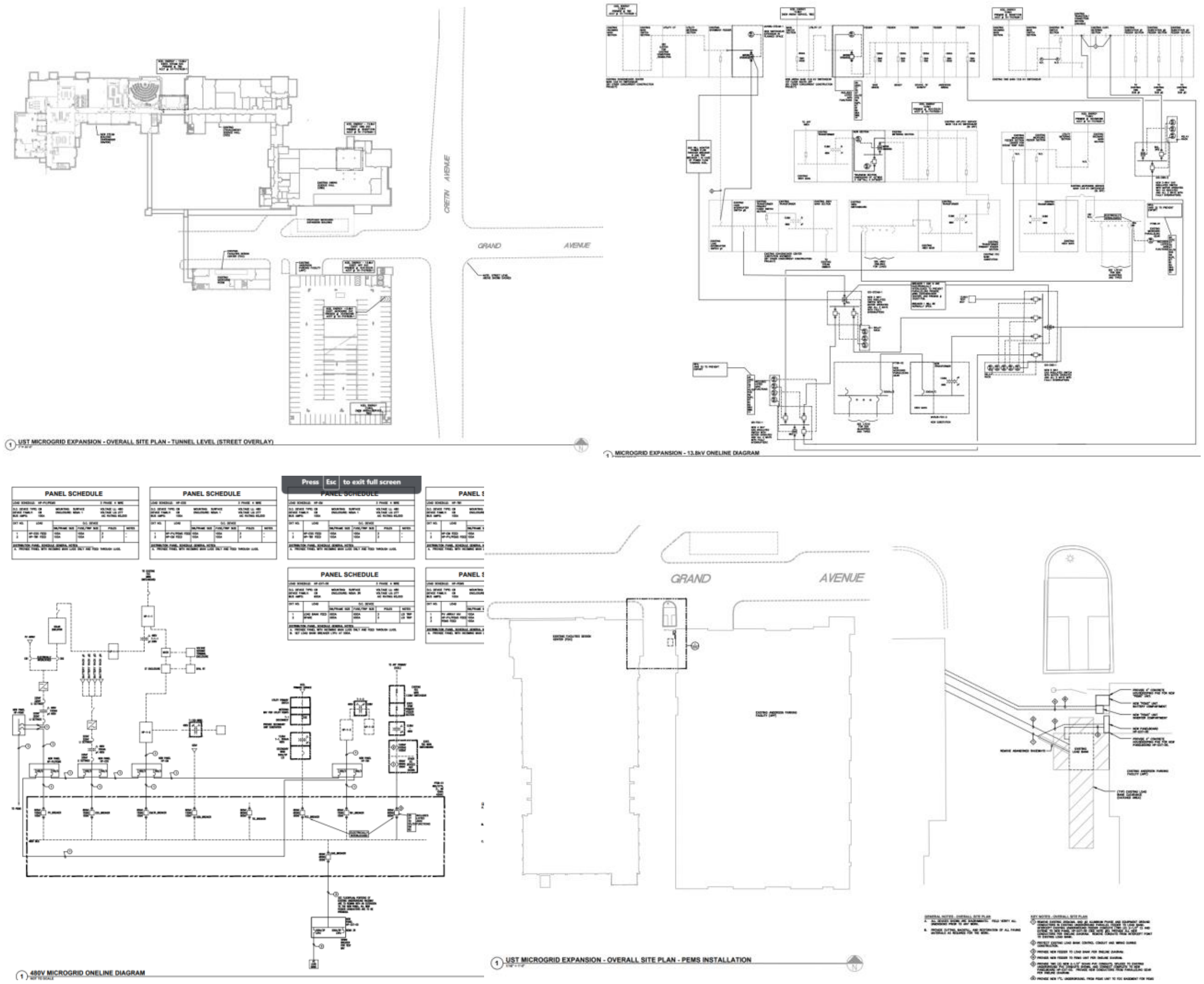

Figure 3: Top left: site plan showing the 5 main buildings and the utility tunnel. Top right: Building retrofits and high voltage loop. Bottom left: current switchgear retrofits. Bottom right: Installation of new energy storage system (PEMS 30kW/60kWh).

The computer simulation (steady-state power flow) model of the current microgrid and the expansion was updated in PowerWorld to reflect recent changes in the design. The planned location of the new gear was changed both geographically and electrically. Figure 4 shows the PowerWorld model reflecting the new switchgear being located south of OWS along with a new connection from the current microgrid switchgear to the 13.8kV loop via the current 13.8kV/480 transformer. This model helped the team understand how power would flow in the system to avoid overloading any current or proposed future equipment.

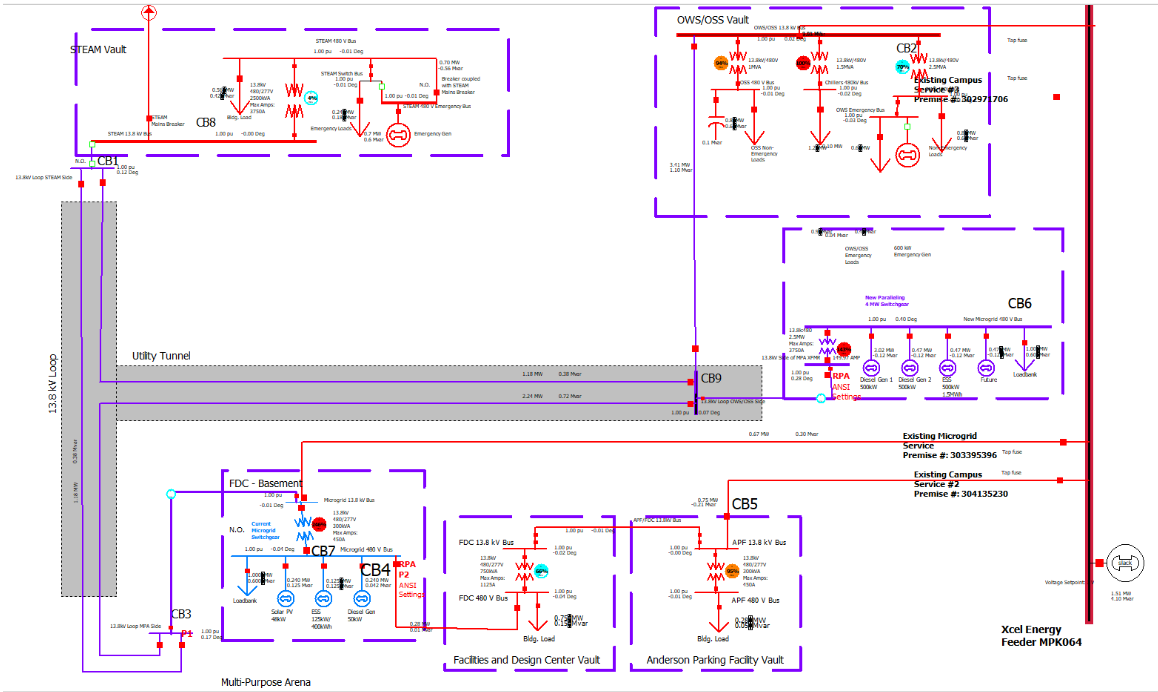

Figure 4 Updated PowerWorld Model.

Designing and validating advanced microgrid and distributed energy resources (DERs) controls includes multiple engineering levels and starts with mathematical and analytical methods and then proceeds through multiple iterations of testing and validation before implementation in the real world. These levels can be broadly categorized as mathematical tools, model-in-the-loop (MIL), software-in-the-loop (SIL), and hardware-in-the-loop (HIL) methods. HIL methods have two broad subcategories: Controller hardware-in-the-loop (CHIL) and Power hardware-in-the-loop (PHIL). CMR is now equipped to perform all these engineering levels for research, prototyping, and development on the MIL, SIL, and CHIL levels and work is ongoing to commission the new PHIL testbed. A few examples of these levels are discussed below.

An example microgrid MIL model, shown in Figure 5(a), was built by interconnecting different DERs and loads such as a battery energy storage system, solar inverter, and variable load in the virtual environment. Using this MIL model, tests such as variable load, variable solar power, transitioning to the islanding mode of operation from grid connected mode were performed. The data pertaining to the specific use cases and tests was captured and recorded. As an example, the real and reactive powers of the battery energy storage system and solar inverter are shown in Figure 5(b). In another virtual environment, an additional power system MIL example, shown in Figure 5(c), was studied. Different scenarios were simulated, and an example view of the voltages at a particular bus are shown in Figure 5(d). Such environments will allow CMR to support local, national, and international partners on projects spanning from real-world implementations to advanced and futuristic designs and algorithms.

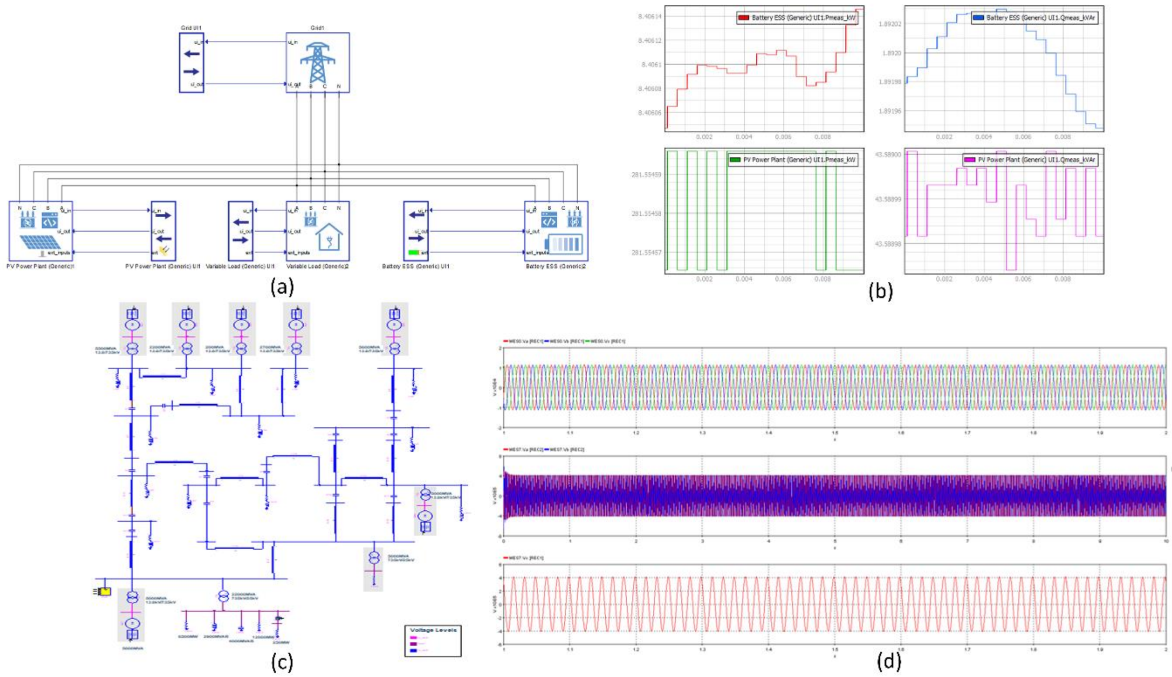

Figure 5 Model in the loop simulation(a) A virtual microgrid model (b) Monitoring the parameters of the microgrid (c) An example test power system (d) Monitoring the parameters of the test power system.

PHIL (Power-Hardware-in-the-loop) is a low-risk test environment where the performance of the device under test (DUT) can be safely tested at rated power by using a simulation model created in the HIL environment and a power amplifier. PHIL rack from Typhoon HIL was partially commissioned with successful communication to the power amplifier in the rack. A process was defined to accomplish the remaining commissioning steps which includes creating a model in the Typhoon HIL software to control the amplifier, configuring the Typhoon HIL user interface to display the current and voltage outputs from the amplifier, and testing the amplifier at different output levels to validate its performance across its operating range.

Educational opportunities for engineering students this quarter encompassed education on power systems concepts such as per-unit power, power factor, active and reactive power, leading and lagging current, line-to-line and line-to-neutral voltage, delta and wye configurations, and communication protocols like Modbus. Additionally, training sessions were conducted on the usage of PowerWorld software. This quarter, the hands-on experience included working with modeling in HIL equipment.

CMR’s training kits, equipped with real-world components such as relays, circuit breakers, power transformers, and current transformers, have been redesigned to allow for easier transport and to better facilitate educating students and working professionals. During this quarter, students worked on configuring the new training kits and were able to successfully configure an SEL-451 relay on the training kit to open and close a circuit breaker both manually and virtually.

To expand partnerships, disseminate knowledge, and grow industry collaborations, the Center hosted a tour that was open to the public on October 5, 2023, there were more than 15 attendees from industry and government such as Connexus Energy, Clean Energy Economy Minnesota, and HDR, Inc. The Center also hosted two high profile groups of guests for private CMR tours and conversations around the Center's current and future projects. Senator Nick Frentz and his team visited CMR on Dec 4th. Senator Frentz is the chair of the Energy, Utilities, Environment, and Climate Senate Committee. The second was the City of St. Paul resiliency team visit on Dec 11th (shown in Figure 6). During both visits, CMR shared updates on the project status and current challenges around costs and equipment lead times.

Figure 6 Tour with Senator Frentz and Team (left) Tour with the St. Paul Resiliency Team (right)

To disseminate knowledge, share project updates, and showcase CMR's capabilities, the following activities were completed in this quarter:

- CMR was one of the Exhibitors at the Minnesota Power Systems Conference (MIPSYCON) on Nov 7th. CMR's booth included the new Hardware-in-the-loop platforms to allow for fast engineering studies and prototyping and CMR's newly developed power system protection training kit (see Figure 7).
- CMR participated in events and meetings with partners such as Grid Catalyst (pitch sessions), Mortensen, 3M, MN Department of Commerce (Energy Outreach division), Connexus, and U.S. Army Research Laboratory
- CMR's Director gave a talk at the MnSEIA Gateway to Solar Conference Oct 10th titled "Case Study: The University of St. Thomas's Microgrid Research Center."
- CMR's Director participated in a panel at the Vision IREC Summit on Nov 9th titled "Keeping the Lights On: Grid Resilience Through Microgrids". The panel included national experts from IREC, McKnight Foundation, and Smart Electric Power Alliance (SEPA).

- CMR's Director gave a talk titled "Microgrid Systems and Development" at the Minnesota Municipal Utilities Association (MMUA) Technical and Operations Conference on Dec 6th.
- A CNET article on microgrids quoting CMR's Director.
- CMR team actively engaged with two start-ups to explore further collaborations and testing.
- CMR continues to collect and archive data from the CMR Microgrid and the FDC Building as part of the effort to create a public repository.

Figure 7: CMR at MIPSYCON Exhibitor Reception

CMR's webpage was updated to include awards and grants that were awarded by leveraging the current legislative appropriations, shown in Figure 8. The update this quarter included the $11M joint program with U.S. Army Engineer Research and Development Center (ERDC). The technical Kick Off Meeting (KOM) for that project was on October 2nd. Each panel has a "Learn more" link that sends the viewer to page with more details on the grant. UST had multiple conversations with State Reps on current and future RDA funding during this quarter.

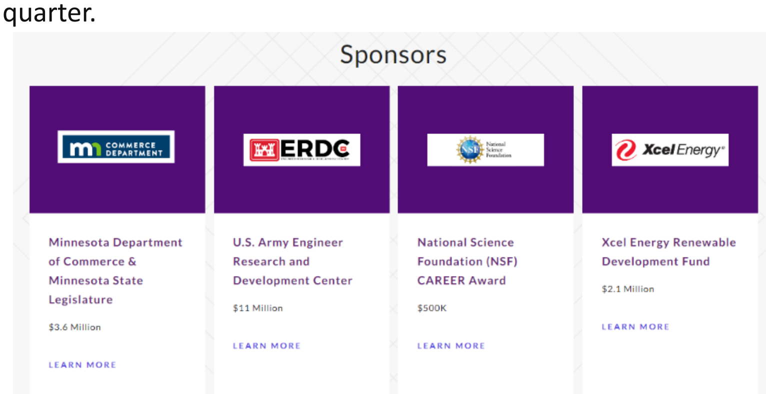

Figure 8 Sponsor Panels.