Task 2. Request for Proposals:
Hydrogen-based DERMS Grid-tied Technologies

Task sponsored by Diamond Sponsor El Paso Electric Company
and Gold Sponsor Las Cruces Utilities

Task:
Teams will design hydrogen-based technologies in combination with intermittent renewable energy technologies (photovoltaics) to demonstrate how intermittent renewable energies can be modified to become a firm dispatchable resource.

Background
As more renewable and emergent technologies, such as rooftop solar, Battery Energy Storage Systems (BESS), and Electric Vehicle (EV) adoption continue to grow in our region, we are looking for ways to integrate these Distributed Energy Resources (DER) into the electrical grid to support grid resilience and ensure the grid's ability to withstand and/or recover from disruptive events.

New technologies, such as hydrogen-based technologies, allow grid operators to provide more advanced levels of control and allow private operators to provide valuable services to the grid.

DER consists of two subsets: 1) Power generation sources (solar, wind, nuclear, fuel cells, generators powered by internal combustion engines) and 2) stored energy sources of power (Fuel cells, EVs, BESS). Renewable DER, such as solar and wind, are intermittent energy sources for which the energy production peaks do not always match energy demand. This increased variability can be costly and create potential disruptions to the modern grid's operations. To solve the issue, companies implement advanced digital solutions for leveling loads on the grid, such as Distributed Energy Resource Management Systems (DERMS).

<u>Grid Basics</u>
On the supply side, utility companies need to provide reliable energy. To do so, they predict the maximum demand required when loads are expected to reach a peak, such as during extreme weather events (very hot summer days or winter storms), and they design their power generation and Transmission and Distribution (T&D) systems to match the demand expected from peak loads. Their designs must strike a balance between supply and demand to ensure supply systems are not underbuilt, which may result in outages, and are not overbuilt, which would needlessly raise the cost of electricity for all rate payers.

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There are often times when supply and demand do not match. The primary events are:

Peak Load Events: During extreme events, customers use more energy than usual to heat/cool their buildings. This can exhaust the energy that the utility company is able to supply. Such peak load events place stress on the grid and may lead to brownouts or blackouts.

Excess-Energy Events: Conversely, during off-peak daytime hours, the amount of solar, wind, or other low-carbon distributed energy sources may far exceed demand. Sometimes referred to as a “low-carbon event,” this excess energy places a strain on the grid, often requiring a utility to pay neighboring utilities to take the excess energy off of their hands; such “negative pricing” raises costs for the utility company and its rate payers.

Supporting the Grid

A solution is needed that will level the generation profile (known as “firming”) by storing energy during excess-energy events and making it available during peak load events. As generation is firmed across a day, there is an added advantage of leveling market prices for electricity, helping reduce costs for consumers. In addition, efficiently storing renewable energy can reduce a community’s carbon footprint.

DERMS have the ability to shed, shift, modulate, or generate electricity [1]. Examples for each of these are: dimming lights during peak loads will *shed* the load, EV charging can be *shifted* to off-peak times, or stored energy in EVs can provide energy back (*shifting*) to a building or the grid, batteries *modulate* power to maintain the grid, and rooftop solar *generates* electricity.

Firming

Firming on the grid scale is a way to level generation by de-coupling energy production from energy consumption. It has been implemented using BESS to store excess energy by charging the batteries during excess-energy events and later utilizing that energy when energy demand is high. The goal of firming is to ensure a constant output from an intermittent energy source for a specified period of time. Firm energy output is equivalent to a flat electricity output curve.

A schematic for combining a photovoltaic plant (PV) with battery storage for a utility operation is shown in Figure 1. The goal is to store excess energy from renewables to achieve firm (reliable) energy output at a later time. The stored energy from PV output (the area under the green curve) can be used to provide firm energy output in the morning and evening (blue shaded rectangles). The goal is a perfectly level stored-energy curve. This would indicate a “firm dispatchable resource’” meaning that the energy available meets specified criteria and will be reliably available to be dispatched to the grid when needed.

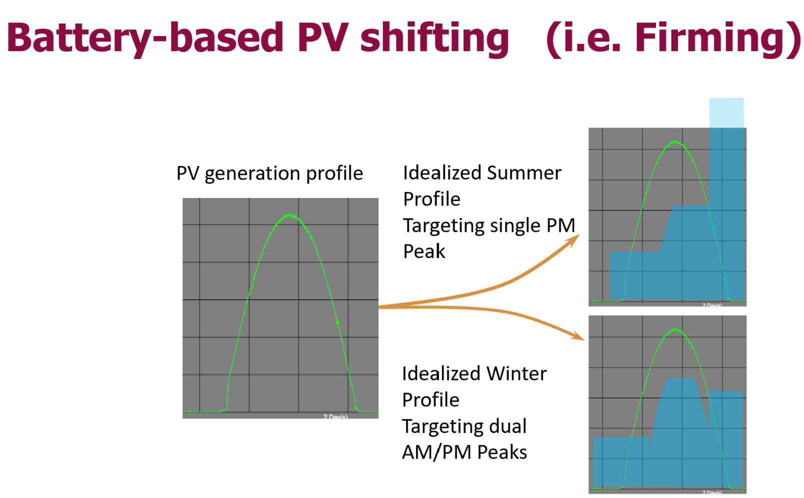

Figure 1. Combining PV plan with battery storage with idealized PV generation.

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Figure 2 shows the results of a real-life BESS implementation at a utility operation in New Mexico. As is seen in the figure, perfectly flat stored energy curves are rare in application. Therefore, the variability (or DC ripple) is measured to assess the firmness of the energy resource.

Some challenges with working with variable PV are the rapid changes in loads that create "ramps" in the curves. These require special algorithms for responding to this variability and efforts to create a firm resource that is as firm (i.e., as flat) as possible. The real-life curves in Figure 2 illustrate that this is a difficult and complex challenge.

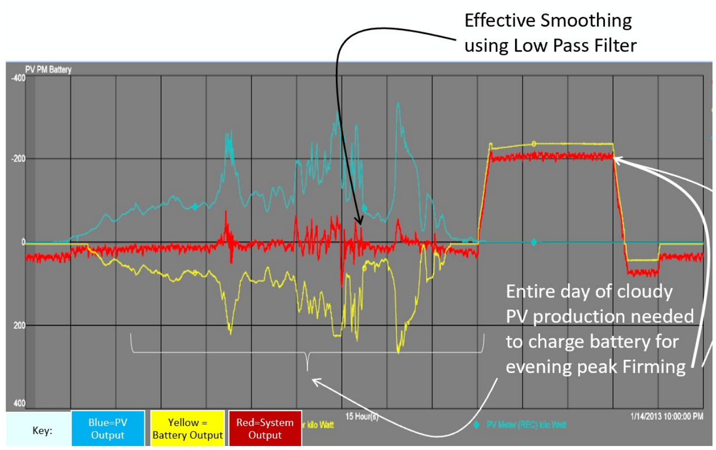

Figure 2. Real-life curves illustrating combining PV plant with battery storage for a utility operation in New Mexico.

Integrating Hydrogen

The innovation requested in this task is to utilize hydrogen-based technologies to modify intermittent renewable energies into firm dispatchable resources.

For this competition, teams will be challenged to use a Fuel Cell plus appropriate medium (water, hydrogen) INSTEAD of battery storage. Additionally, teams will be challenged to design and implement additional circuits and/or algorithms to make the energy output from a combination of PV+Fuel Cell as "flat" as possible, similar to Figures 1 and 2.

Problem statement

Design and develop a small-scale model of a grid-tied DERMS solution that integrates an intermittent renewable PV source with a hydrogen fuel cell to provide a firm dispatchable resource, and demonstrate that your solution can be scalable from small residential size up to large-scale utility size.

The design should implement an operational protocol for DER engagement that details how the utility will manage DER capacity and energy for dispatch, focusing on firm energy resources.

Algorithms for the overall system should respond to PV system variability ensuring that the firm resource is as consistent as possible with minimal DC ripple, and respond to DERMS signals from the utility. System performance will be measured by measuring the output characteristics of the firm dispatchable resource, specifically DC ripple or variability.

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Design requirements

Theoretical and Fundamental Design Requirements

- Design and Development of Hydrogen-based DERMS Solution:
  - Create a small-scale model of a grid-tied Distributed Energy Resource Management System (DERMS) integrating an intermittent renewable PV source with hydrogen fuel production and a hydrogen fuel cell.
  - Teams that are interested may propose innovative approaches to hydrogen fuel generation and storage, particularly if the overall grid-tied solution benefits from the technological advancements.
- Operational Protocol for DER Engagement:
  - Develop and present an operational protocol detailing how the utility will manage DER capacity and energy for dispatch, focusing on firm energy resources.
  - Describe the goals and objectives of the operational protocols, and the energy management/energy savings/cost savings they will produce for consumers or grid operators.
- Algorithm Development: Develop algorithms for the overall system:
  - To respond to PV system variability, ensuring the firm resource is as consistent as possible, with minimal DC ripple.
  - To respond to DERMS signals from the utility.

Bench-scale Demonstration Design Requirements:

- Bench-Scale Demonstration: Conduct a live bench-scale demonstration of the proposed solution at the contest, showing integration of the hydrogen fuel cell with renewable energy sources.
- Response to Utility Events: Demonstrate the ability of the system to respond to utility events such as peak load or excess-energy events, with the option to include additional functionalities.
  - Emulate a utility signal by generating your own internet-based control signal.
  - If additional functionalities are implemented, describe their contributions to system performance.
- Communication and Control Systems: Select and demonstrate the communication types and control infrastructure used to optimize energy management and interaction with the utility grid.
- Techno-Economic Assessment: Present a comprehensive Techno-Economic Assessment (TEA) analysis including capital costs (CAPEX), operational costs (OPEX), and potential revenue, with graphical representations of cost data.

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Bench-Scale Demonstration

The bench-scale demonstration will be conducted either at the contest location or at the New Mexico State University (NMSU) IDEAL Center, according to the power needs of your team's bench-scale demonstration. The IDEAL Center is a medium-to-high voltage test facility where NMSU researchers conduct experiments integrating renewables into the microgrid and smart grid infrastructures.

Conduct a live bench-scale demonstration of your team's proposed solution showing communication and control infrastructure to optimize energy management and interaction with the utility grid. The bench-scale prototype will be a small-scale system that integrates communication and control systems with PV power generation, hydrogen fuel generation, and fuel-cell storage and demonstrates the ability of the system to respond to utility events such as peak load or excess-energy events, with the option to include additional functionalities.

Your team is free to determine the equipment needed to accomplish the task, including selecting your own photovoltaics, hydrogen generation, fuel cells, small-scale storage and microcontrollers.

In addition to the bench-scale demonstration, teams may include video productions, computer simulations, tabletop displays, and scale or architectural models to assist in the presentation; these inclusions can be beneficial to your presentation but shall not be substitutes for the bench-scale demonstration.

DERMS Bench-scale Testing Form

If a team's solution will be greater than a table-top, teams will provide WERC with the number and type of devices that they intend to control and the voltage, current, and power ratings of each. This will help the IDEAL Center prepare for your team's demonstration (due February 17-26, 2025).

Pre-contest Bench-scale Testing

Perform pre-contest testing of the equipment at a home location or lab to ensure functionality and readiness for the competition.

Analytical Testing at the Contest

Conduct a live bench-scale demonstration of the proposed solution at the contest, showing integration of the hydrogen fuel cell with renewable energy sources.

At the contest, each team will be provided with testing infrastructure consisting of:

- Wi-Fi connection.
- 120V (preferably, although 240V may be possible at the IDEAL Center) electrical connections, as needed (up to five electrical connections will be provided to each team for the bench-scale demonstration. However, the team's software should not necessarily be restricted to five controllable connections).

Teams are expected to bring to the contest:

All necessary software and hardware control infrastructure needed for their demonstration including PV modules, and/or FC, and/or hydrogen generation processes/electrolyzers, and/or small-scale storage, and/or microcontrollers. This equipment may include components provided in small science kits or larger-scale units, according to equipment you are able to transport to the contest. List all devices and equipment in the ESP. If in doubt prior to the February deadline, feel free to email us in advance to confirm the appropriateness of your selected equipment.

Experimental Safety Plan (ESP)
Submit an Experimental Safety Plan (ESP) covering all safety aspects of the bench-scale demonstration, along with completion of mandatory safety courses.

Required On-Demand Safety Short Courses

- The course, "Preparing the Experimental Safety Plan" is required of all team members. You will be emailed a link to access the ESP short course after your team registers for the contest. Complete this training on or before February 20, 2025.
- The "Hydrogen Safety Awareness" course is required of all team members participating in Task 2 prior to submitting the ESP. You will be emailed a link to access the ESP short course after your team registers for the contest. Complete this training on or before February 20, 2025.

Evaluation Criteria
Each team is advised to read "Evaluation Criteria" and "Contest Scoring" in the 2025 Team Manual for a comprehensive understanding of the contest evaluation criteria. For a copy of the Team Manual, Public Involvement Plan, and other important resources, visit the WERC website: Guidelines | werc.nmsu.edu

In addition to evaluation criteria that applies to every task, judges will evaluate your team's response to the problem statement, with consideration of the Design Considerations listed above.

Dates, Deadlines, FAQs (*dates subject to change—watch website FAQs*)

- Today: Email us to let us know you are interested in this task. We will enable you to register for the contest, and we will put you on our list to contact you with breaking news.
- October 15, 2024 - December 31, 2024 – Early Bird Registration (discount applies).
- December 1, 2024 - February 20, 2025: Mandatory On-demand Course: Preparing the Experimental Safety Plan. See website and Team Manual for information.
- February 17 - 26, 2025: Experimental Safety Plan (ESP) and Bench-scale Testing Plan due. Include requests for volume of brine concentrate and ancillary equipment needed at the contest.
- March 7, 2025: Final date to register a team.
- March 31, 2025: Technical Report due
- Weekly: Check FAQs weekly for updates:
  - Task-specific FAQs: 2025 Tasks/Task FAQs
  - General FAQs: 2025 General FAQs
- All dates or task requirements are subject to change. Check FAQs for updates online.

Reference
[1] Lavrova, O. and D. Zigich. July 6, 2021: Non-Wires Grid Alternatives: Behind-The-Meter. Whitepaper submitted to New Mexico Energy Manufacturing. (Available upon request; email: werc@nmsu.edu)

Glossary of Abbreviations
BESS – Battery Energy Storage System
DER – Distributed Energy Resources
DERMS – Distributed Energy Resource Management Systems
EV – Electric Vehicle