Autonomous PV Monitoring System

Digital Twin–Assisted Autonomous PV System for Remotely-Deployed Monitoring Stations

ELECOMP Capstone Design Project 2026-2027

Sponsoring Company:

University of Rhode Island Power Electronics Laboratory (URI PEL)

URI-Fascitelli Center for Advanced Engineering, Room 430
2 East Alumni Ave.,
Kingston, RI 02881
https://web.uri.edu/power-electronics/

Company Overview:

The University of Rhode Island Power Electronics Laboratory (URI-PEL) is conducting cutting-edge research in the field of power electronics. Our vision is to develop highly reliable and intelligent power conversion systems (PCSs) and to accelerate the design process for power electronics in various applications. Based on our strong foundation in power electronics, we have advanced various multidisciplinary research projects.

Our work has been published in distinguished journals and conference papers and is supported by various federal and state agencies, including the Office of Naval Research (ONR), the United States Geological Survey (USGS), etc., and various industries.

Technical Director(s):

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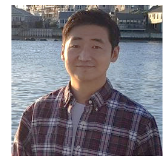

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Project Motivation:

Water resource information is essential for maintaining state, regional, and national economic health, protection of life and property, and ensuring effective management of water resources. Water monitoring stations are limited power budget systems that rely on battery and photovoltaic (PV) panels and often are in remote and harsh environments. With the development of multi-component data-collection systems, the power demands of water monitoring stations are also growing. However, data collection at monitoring stations can be inhibited because of insufficient energy production by solar panels, especially during seasonal periods when sunlight is limited by tree canopy cover or winter periods with fewer hours of sunlight and frozen precipitation covering the PV panels.

To address these challenges, this project proposes a digital twin (DT)–assisted autonomous PV-powered water monitoring station, integrating a long-distance maximum power point tracking (MPPT) control architecture with a motorized PV frame. The project will investigate advanced sensing techniques, power management and control (PMC) strategies, and optimize energy harvesting under varying environmental conditions to improve energy availability during poor operating conditions. The ultimate goal is to enhance the reliability, energy autonomy, and operational lifetime of remote water monitoring stations.

Anticipated Best Outcome:

The expected best outcome of this project is the development and experimental validation of a prototype PV-powered remote water monitoring station with embedded DT–enabled autonomous control.

The anticipated outcome includes a functional PV-powered water monitoring prototype integrating the PV array, motorized tilting frame, MPPT converter, energy storage system, environmental and water-quality sensors, and communication devices.

The completed project will be showcased not only at the URI Capstone Design Summit but also at the student project demonstrations during the 2028 IEEE Applied Power Electronics Conference and Exposition (APEC), one of the premier international conferences in the field of power electronics. For reference, information about the 2027 IEEE APEC student demos can be found here: https://apec-conf.org/students/student-demonstration-competition/.

Composition of Team:

Two Electrical Engineers

Skills Required:

Electrical Engineering Skills Required:

- Analog and power electronics circuit design (ELE 212, ELE 446).
- Proficiency in MatLab, Simulink, and circuit simulation (PowerSIM, LTSpice).
- Knowledge of using lab equipment, including oscilloscope, power supplies, e-load, etc.
- Wireless communication, such as LoRa, Wi-Fi, or cellular communication.
- Soldering skills and experience working with various electronics circuits.

Anticipated Best Outcome’s Impact on Company’s Business, and Economic Impact

The anticipated best outcome is a field-validated, DT–enabled power conversion and management platform that enables PV-powered water monitoring stations to operate reliably for extended periods with minimal maintenance. By coordinating long-distance MPPT, motorized PV-panel tilting, battery operation, sensor scheduling, and wireless communication, the proposed system is expected to increase harvested solar energy and improve energy availability during unfavorable weather.

Broader Implications of the Best Outcome on the Company’s Industry:

The project will provide an intelligent power management platform for remote monitoring applications in water utilities, agriculture, aquaculture, environmental monitoring, and other remote infrastructure, maximizing energy harvesting, energy management, and system reliability. Improved energy harvesting, predictive maintenance, and reduced system oversizing can lower costs and extend operational life. The project will also prepare undergraduate students for careers in power electronics, renewable energy, embedded control, and digital-twin technologies while supporting future industry partnerships and commercialization.

Appendix A: AI Use Policy – Autonomous PV Monitoring System

Allowed

- Students may use AI tools for
  - ☒ brainstorming support
  - ☒ concept development
  - ☒ literature and publicly available documentation review
  - ☒ software development
  - ☒ debugging
  - ☒ data analysis
  - ☒ test development
  - ☒ non-proprietary paragraph editing
  - ☐ non-proprietary single-slide formatting
  - ☒ preparation of project deliverables
  - ☐ note taking or transcription of meetings
  - ☐ Others: ______________________________

Not Allowed

- Using AI in violation of university policies, applicable laws, or course-specific rules identified by capstone instruction team and project-specific rules identified by the technical directors.
- Entering proprietary, confidential, personally identifiable, security-sensitive, or otherwise restricted information into an AI system without authorization.
- Submitting AI-assisted work without understanding, reviewing, verifying, and appropriately disclosing its use.
- Submitting entire documents or presentations to an AI system for editing or formatting.
- Any unchecked items from the allowed list above

Requirements

- If any use is allowed, AI tools may only be used to enhance, but not replace, students' technical reasoning, engineering judgment, and understanding. Students must be able to explain, justify, and defend all submitted designs, code, analyses, test results, documentation, and conclusions.
- During the first two weeks of the project, the student team shall work with the Technical Directors to:
  - Identify any proprietary or confidential information that may be involved in the project.
  - Determine what information may or may not be shared with AI systems;
  - Identify the AI tools, models, accounts, and configurations approved for project use; and
  - Document any project-specific restrictions or approval requirements.
- Students shall transparently document the uses of AI using the URI CYPHER AI Usage Marking guidelines (https://web.uri.edu/cypher/ai-marking/). A workshop is planned for September to familiarize students with these guidelines.
- Students retain full professional responsibility for all design decisions, analyses, implementations, testing, documentation, presentations, and final deliverables, regardless of whether AI tools contributed to the work.