Navajo Tribal Utility Authority (NTUA) Dilkon, AZ: Off-grid Demonstration Project

Sandia National Laboratories

URBAN ELECTRIC POWER




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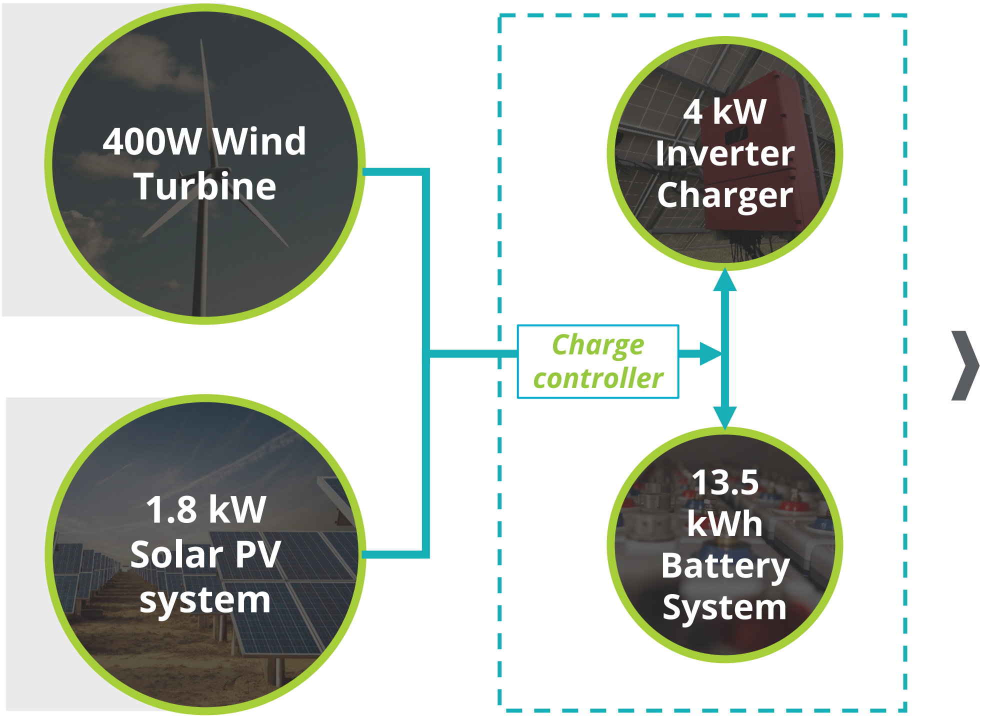
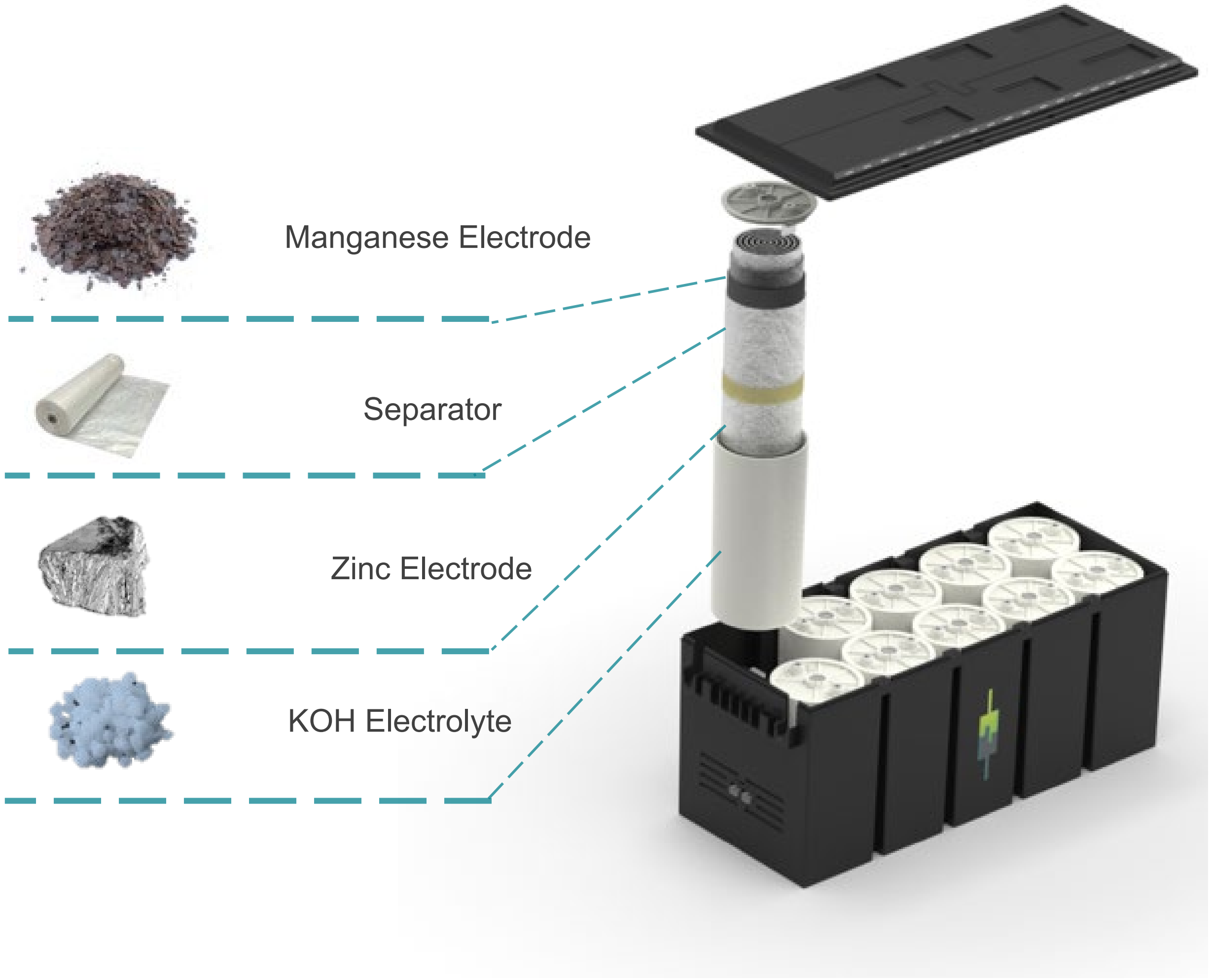
U.S. DEPARTMENT OF ENERGY NNSA National Nuclear Security Administration

Deployment Overview

- Deploy energy storage system using UEP Zn-MnO_2 batteries as a replacement for lead-acid batteries in a solar microgrid on the Navajo Nation, Dilkon, Arizona.
- Lead-acid and lithium-ion based systems have issues with performance, maintenance, cost, and safety
- Determine if rechargeable Zn-MnO_2 batteries can be used in fielded off-grid solar plus storage systems for remote communities.



Why Rechargeable Zn-MnO_2 Alkaline Batteries?



Zinc Manganese Dioxide

(Zn-MnO_2)

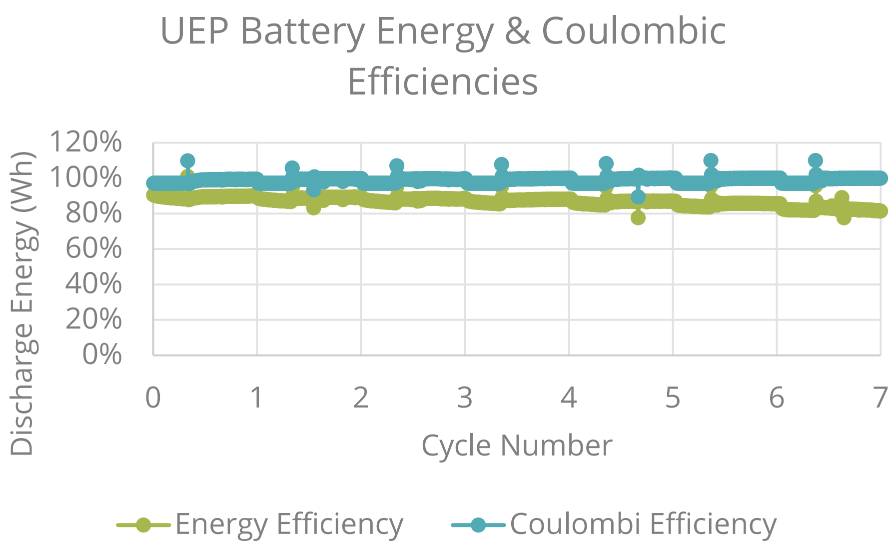
Recyclable and non-toxic, does not pose risk to users or environment.

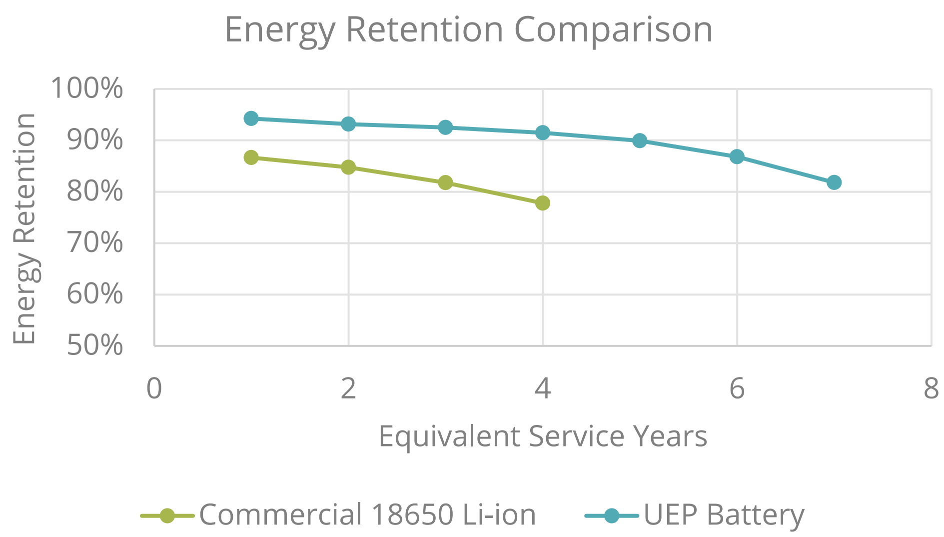
UL1973/9540A safety certification confirms no fire risk and safe handling.

Modular design to meet needs of customers both large and small.

Zn-MnO_2 battery under IEC standard protocol for solar microgrid

UEP Battery completed 7 years under IEC 61427-1 testing protocol, defined below, for solar microgrid use case.





IEC protocol (40 °C):
Phase A: 3h C/10 charge and 3h C/10 discharge cycling at low state of charge for 50 cycles.
Phase B: 6h charge and 2h C/8 discharge cycling at high state of charge for 100 cycles.
A 9-hour C/10 discharge is done between phases B and A at the end of each year. Each 150 accelerated testing cycles at 40 °C is equivalent to 1 year of service life in the field.

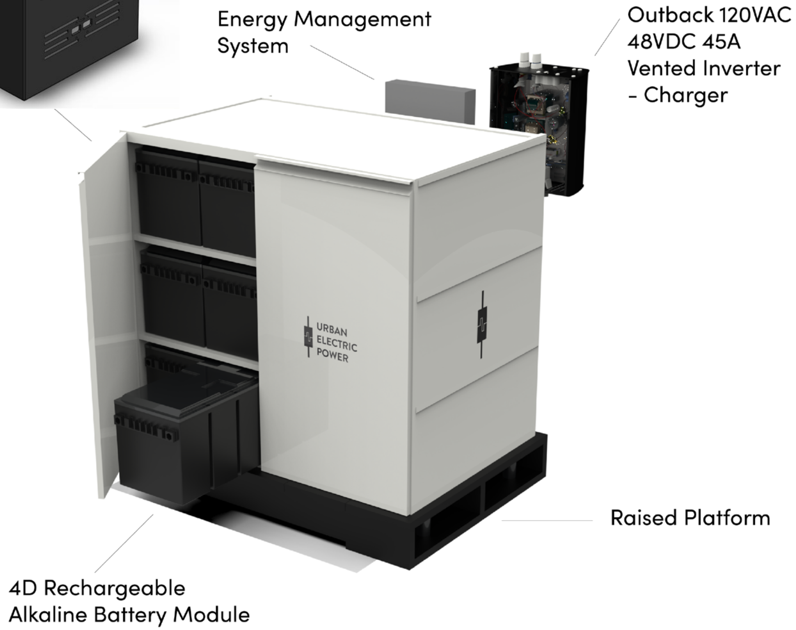
Under the same IEC 61427-1 solar protocol:

- The commercial 18650 Li-ion battery lost 20% of its nameplate energy after 4 years.
- UEP Battery shows an energy retention above 80% of its nameplate after 7 years of service life.

System design

Existing system

UEP system



Existing System: utilized Deka gel lead-acid batteries (8G8D), Outback power electronics array, and a palletized aluminum container.

Replacement System: UEP 4D $ZnMnO_2$ battery modules, Outback power electronics array, customized NEMA 3R container.

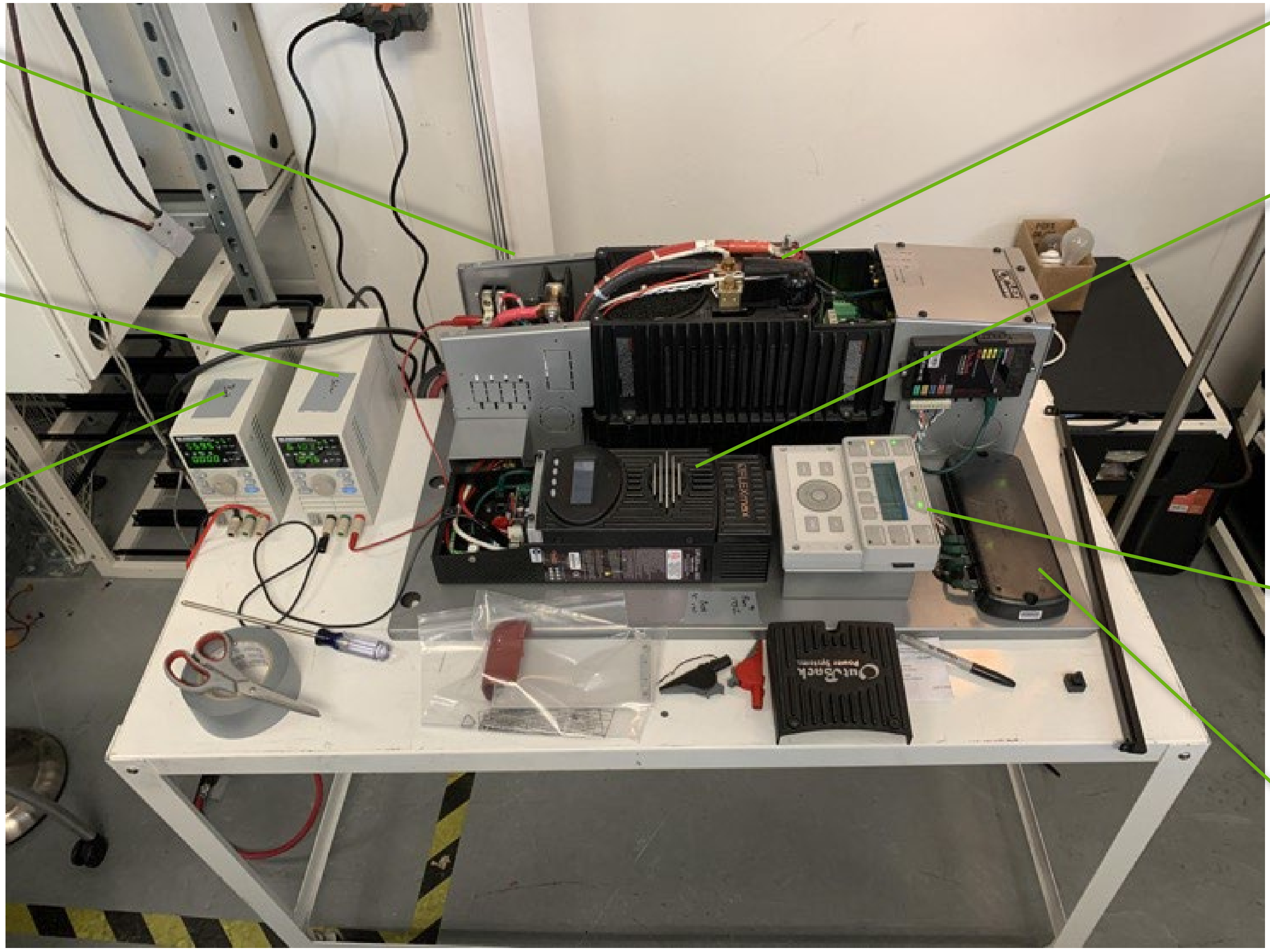
System concept

Power electronics array

FlexWare 250 wiring HUB

* Power Source to simulate SOLAR

* Power Source BAT simulator



VFXR 3648

FLEX 80 SOLAR Charge Controller

MATE3s System Display and Controller

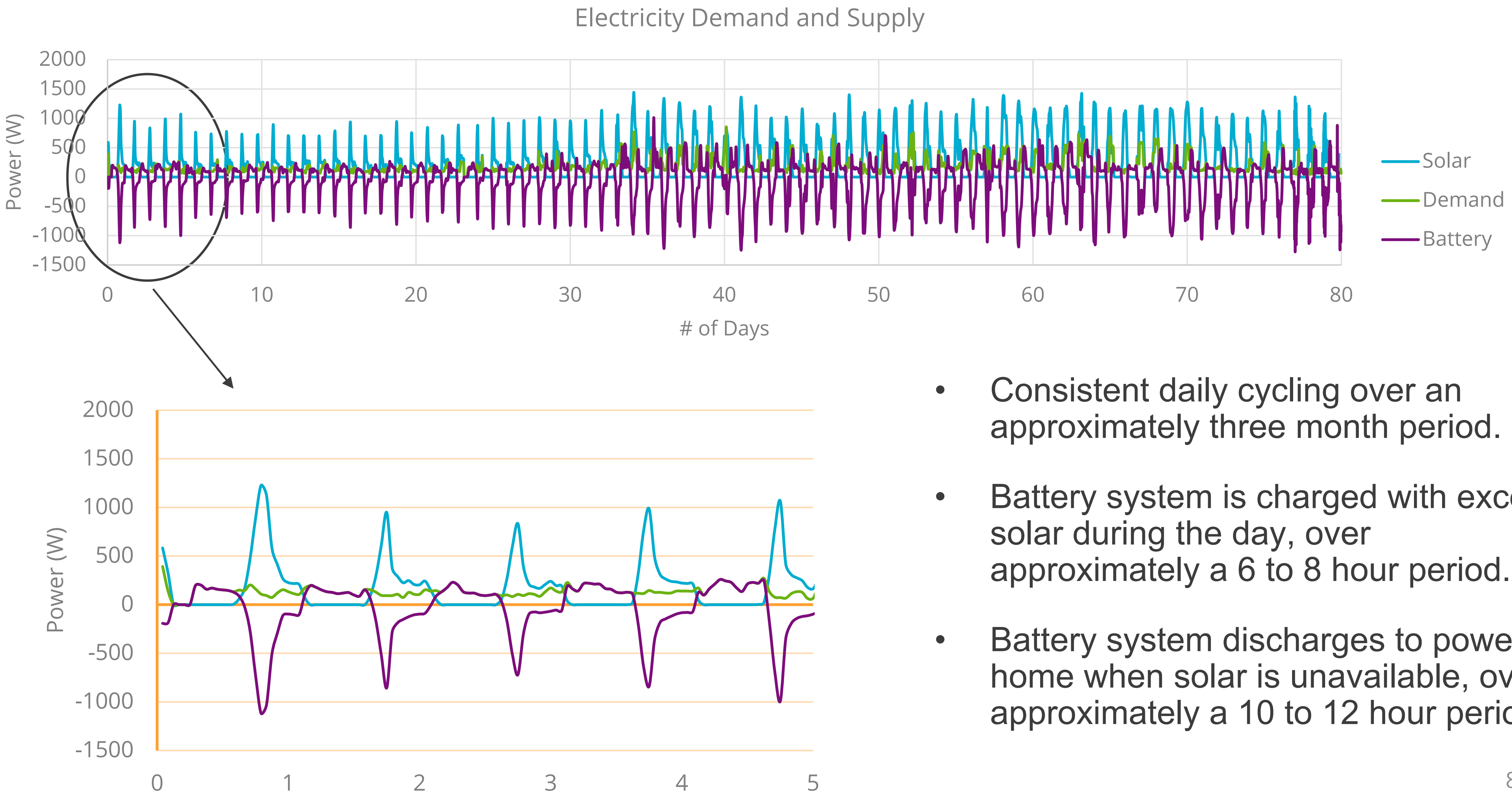
HUB4

* Used to simulate batteries and solar panel

Deployment

- Two-day installation in remote location over rough terrain.
- System installed with the assistance of UEP, Sandia, and NTUA teams.
- Remote location without accommodations or hardware stores nearby.
- Demonstrates the importance of having an easily deployable system with simple on-site installation processes.

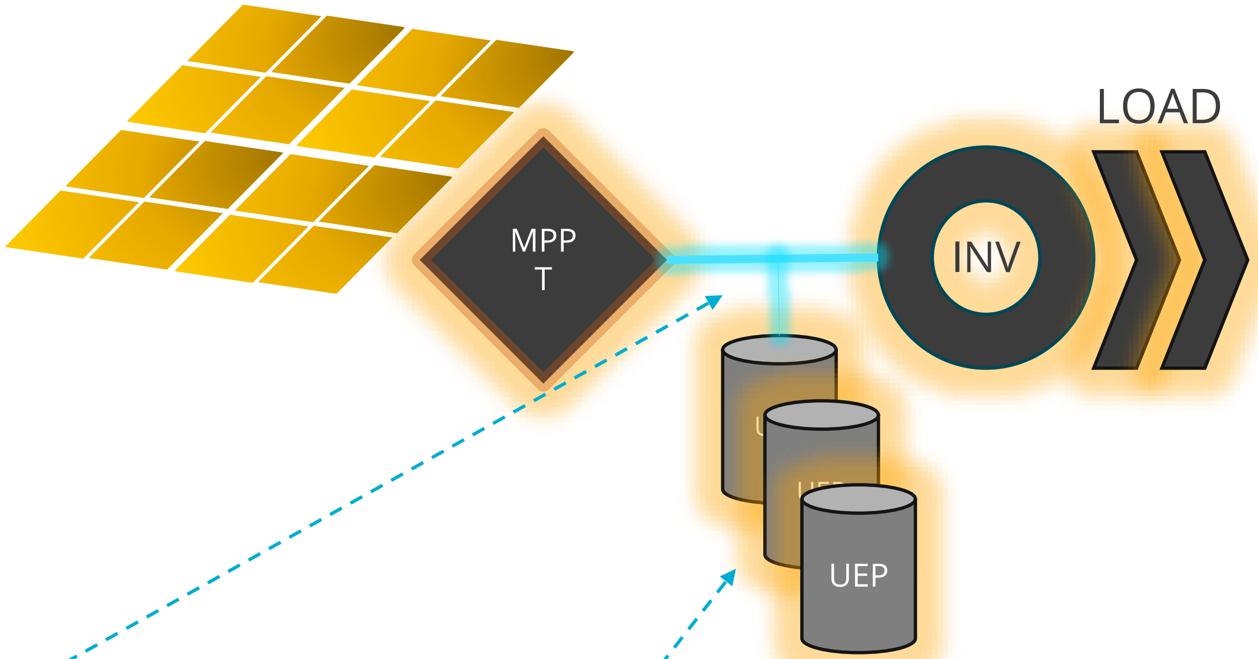
System Performance: Cycling data from May – July 2022

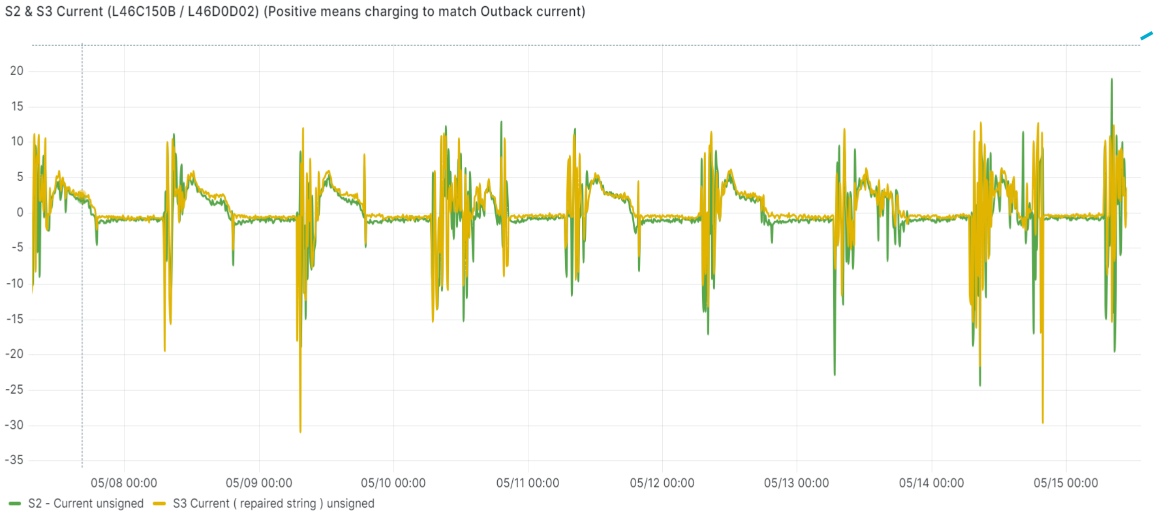


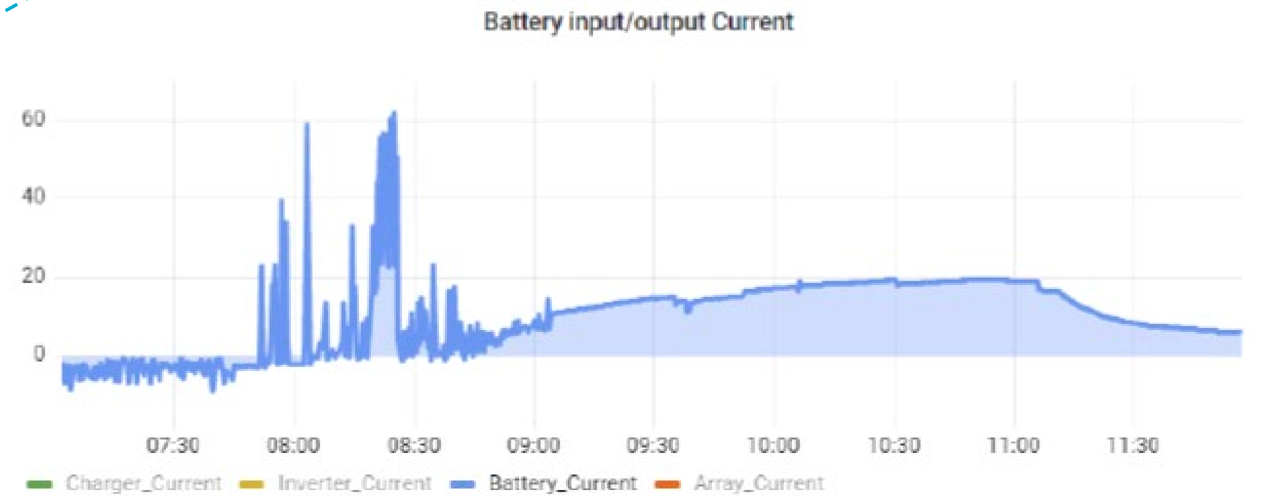
- Consistent daily cycling over an approximately three month period.
- Battery system is charged with excess solar during the day, over approximately a 6 to 8 hour period.
- Battery system discharges to power the home when solar is unavailable, over approximately a 10 to 12 hour period.

Observation 1: Degraded power signal quality from solar array

- Outback inverter on common DC bus with UEP battery strings and Maximum Power Point Tracking (MPPT) charge controller.
- Repeated degraded power signal quality and high current spikes observed typically during low solar irradiance time of the day due to MPPTs objective function to maximize energy harvesting.







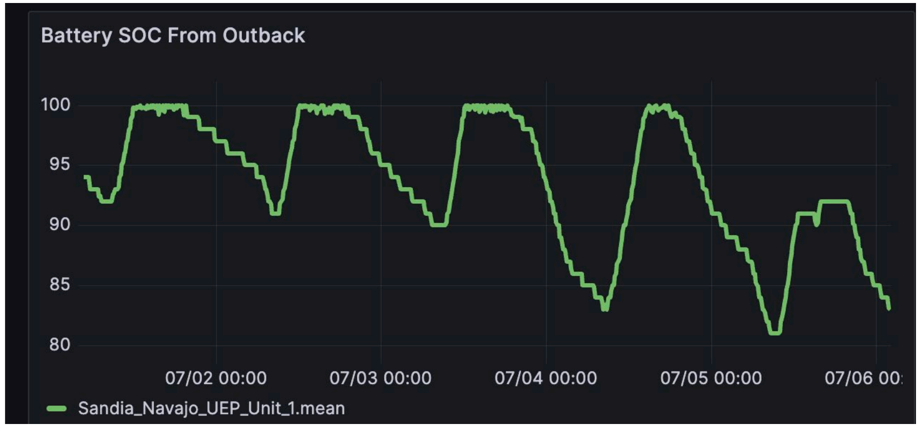
Solar and battery charge/discharge currents (left) and battery input current (right) as measured by UEP's data collection system.

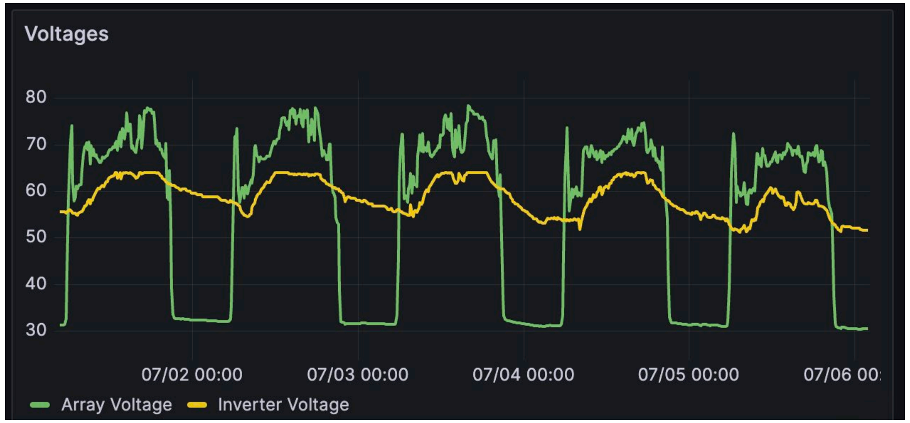
Observation 2: Inverter cutoffs insufficient to prevent over charge/discharge

- Outback inverter built-in voltage cutoff limits were utilized to regulate charging maximums and discharging minimums due to lack of available BMS/EMS controllers.

- Lack of dynamic cutoffs in place allowed the battery to be overcharged or overdischarged

- Problematic especially during periods when there is not sufficient solar charge available.

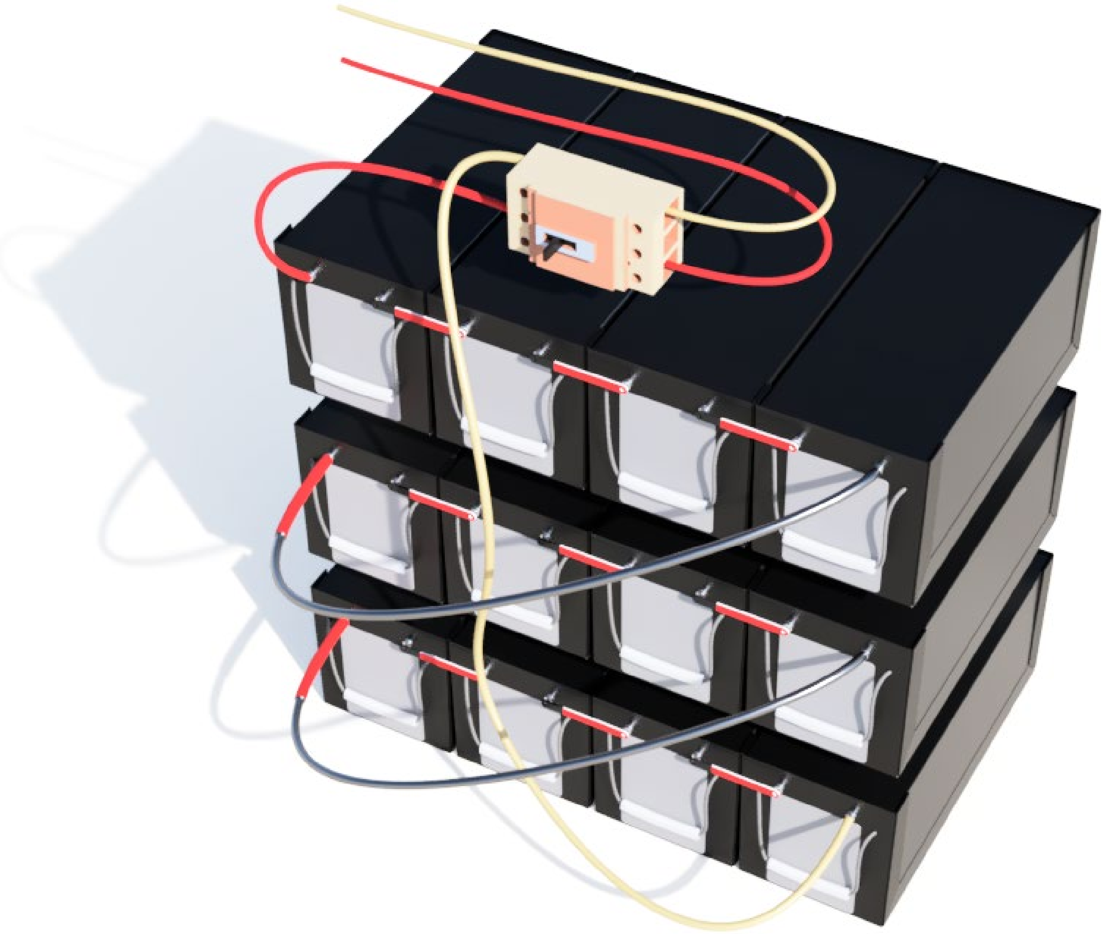




Battery system state of charge (SOC) alongside voltage of battery system and solar PV.

Observation 3: String setup not optimized for resilience

- The battery string setup consisted of 4 UEP modules (12V each) wired in series to create a 48V string, with 3 such strings operating in parallel.
- This provided an acceptable voltage range for the Outback inverter but did not emphasize resilience in the string array.
- In this configuration, individual battery cell degradation or failure can have greater impact on entire string.

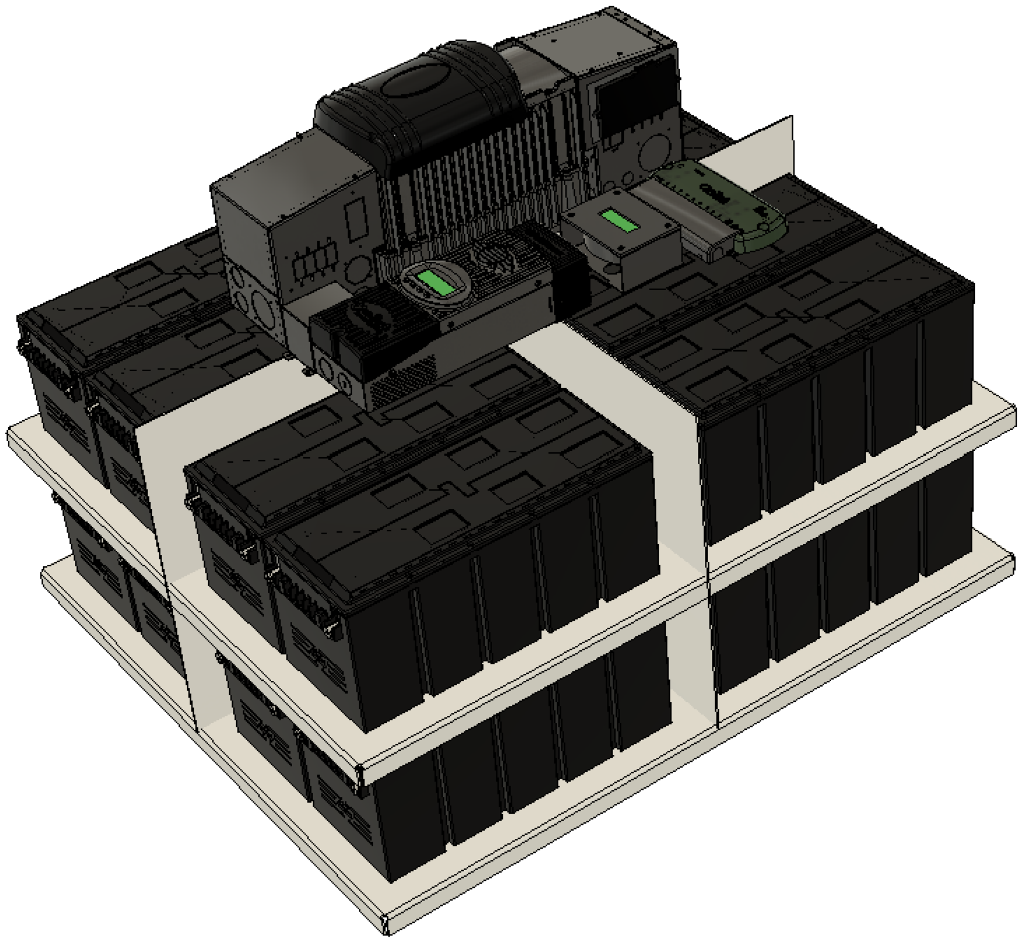


Wiring configuration of UEP battery container

Summary of observations and actions

Observations	Actions
DC bus shows significant low frequency noise during charging and operations.	Addition of optimized charge control system to smooth out signal.
No cutoffs in place to prevent overcharge or over discharge, off-the-shelf BMS not suitable.	Energy management and battery management systems developed for future deployments.
String setup of batteries not optimized for resilience, container not suitable for parallel wiring.	New container reconfigured to provide more optionality and easier installation.

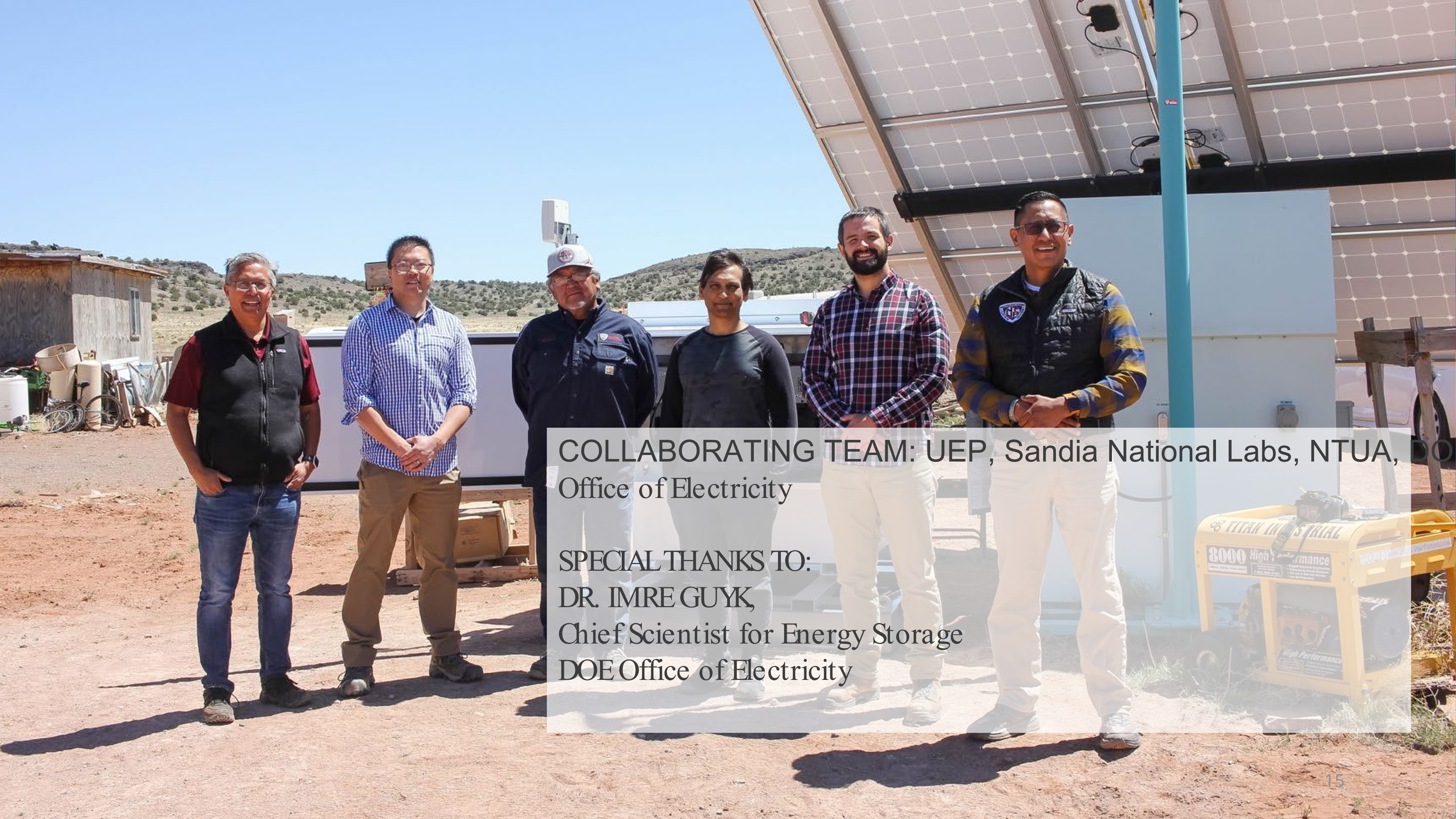
Updated system design



- Updated system design uses additional modules (16 in total) to enable series/parallel wiring.
- Power electronics and batteries in same housing to reduce cost, enable parallel wiring, and incorporate controlle

Looking Ahead

- UEP in process of developing and delivering second version of solar microgrid system for testing and deployment.
- Future opportunities for development of battery system controllers for solar microgrids.
- Optimized controls and architecture can benefit both new and existing battery chemistries.



COLLABORATING TEAM: UEP, Sandia National Labs, NTUA, DO
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