

## Extreme Solar: Towards 24-7 Renewable Energy

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### What

Take distributed solar to the next level by integrating the UEP's Zn-MnO<sub>2</sub> batteries with solar panels and microinverters.

### Why

Increase grid resilience and reliability by deploying distributed energy generation and storage.

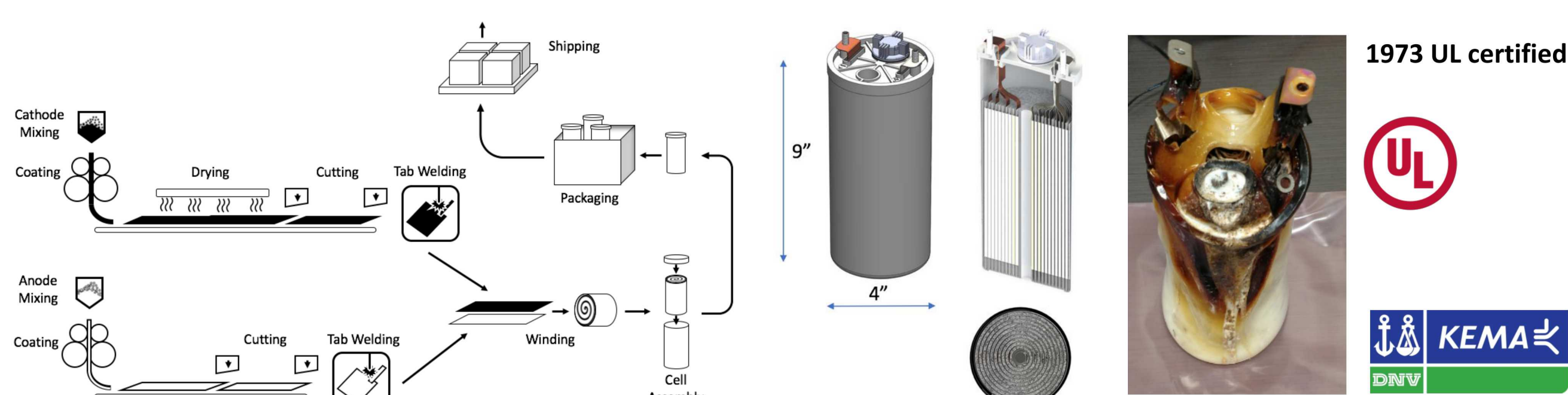
### Metrics

Energy in, Energy out  
Energy efficiency  
Cost  
Durability

### Tasks

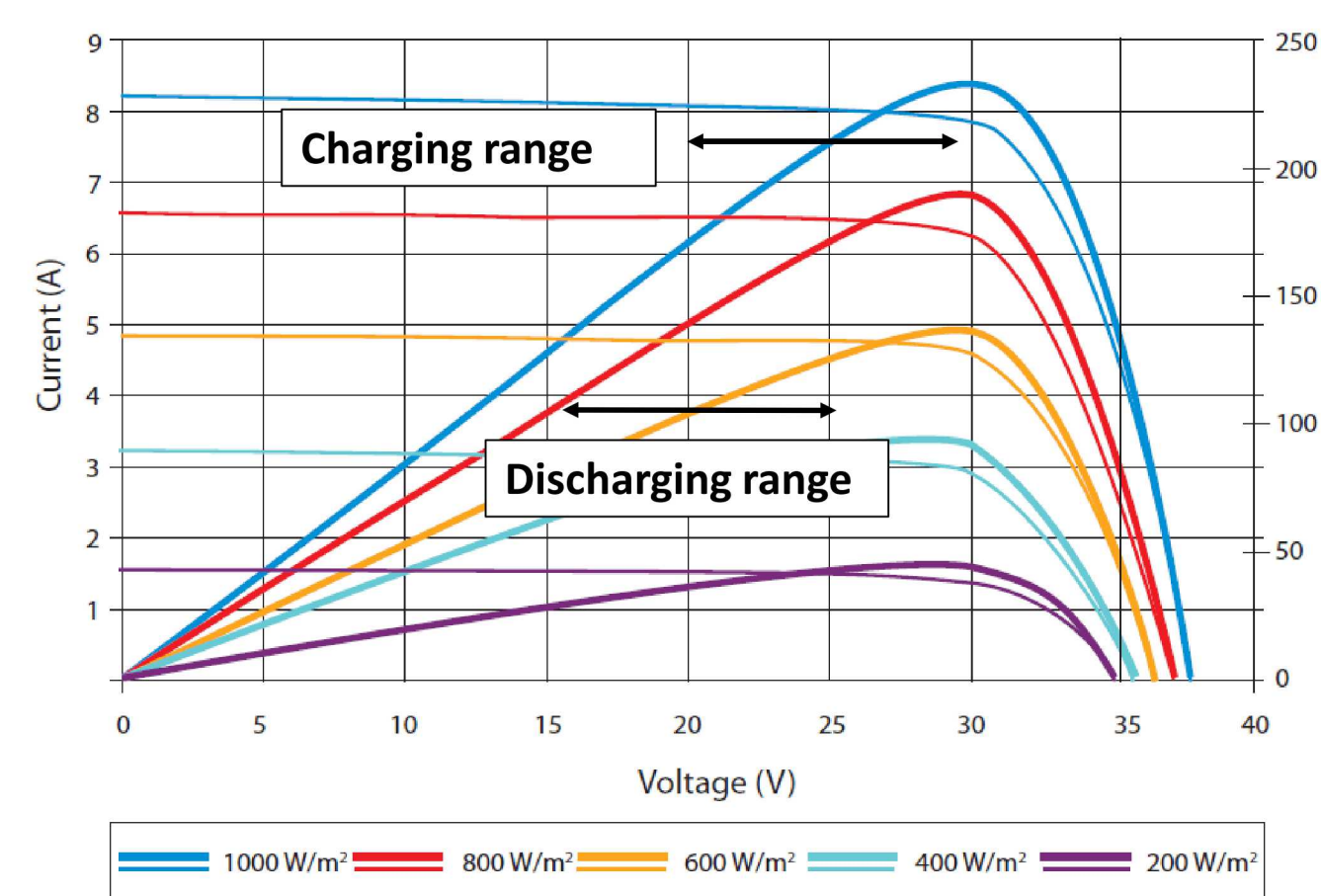
Year 1 (FY19): Proof of concept, installation, monitoring, and operation (completed)  
Year 2 (FY20): Dedicated DC/DC converter and batteries mounted directly under the panels  
Year 3 (FY21): Cost reduction and commercial production

Safe, Low-cost, wide window of power charging conditions, safe to operate up to 60°C



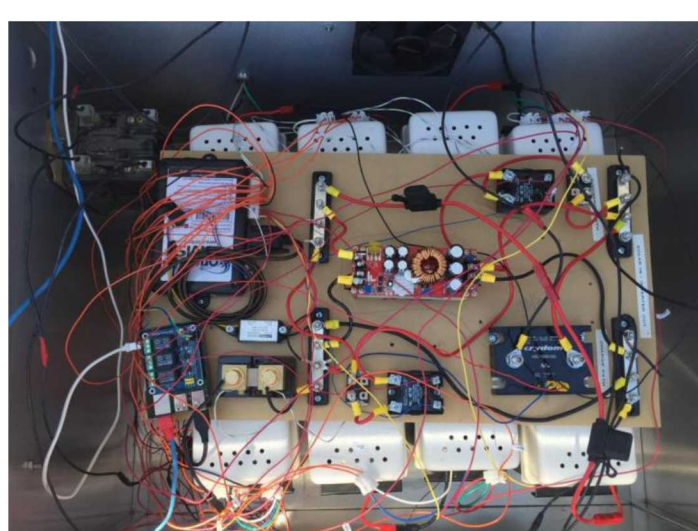
Installation in New Mexico State University  
16 UEP cells connected to solar panels and Enphase inverters

Current-Voltage & Power-Voltage Curve(230-20)



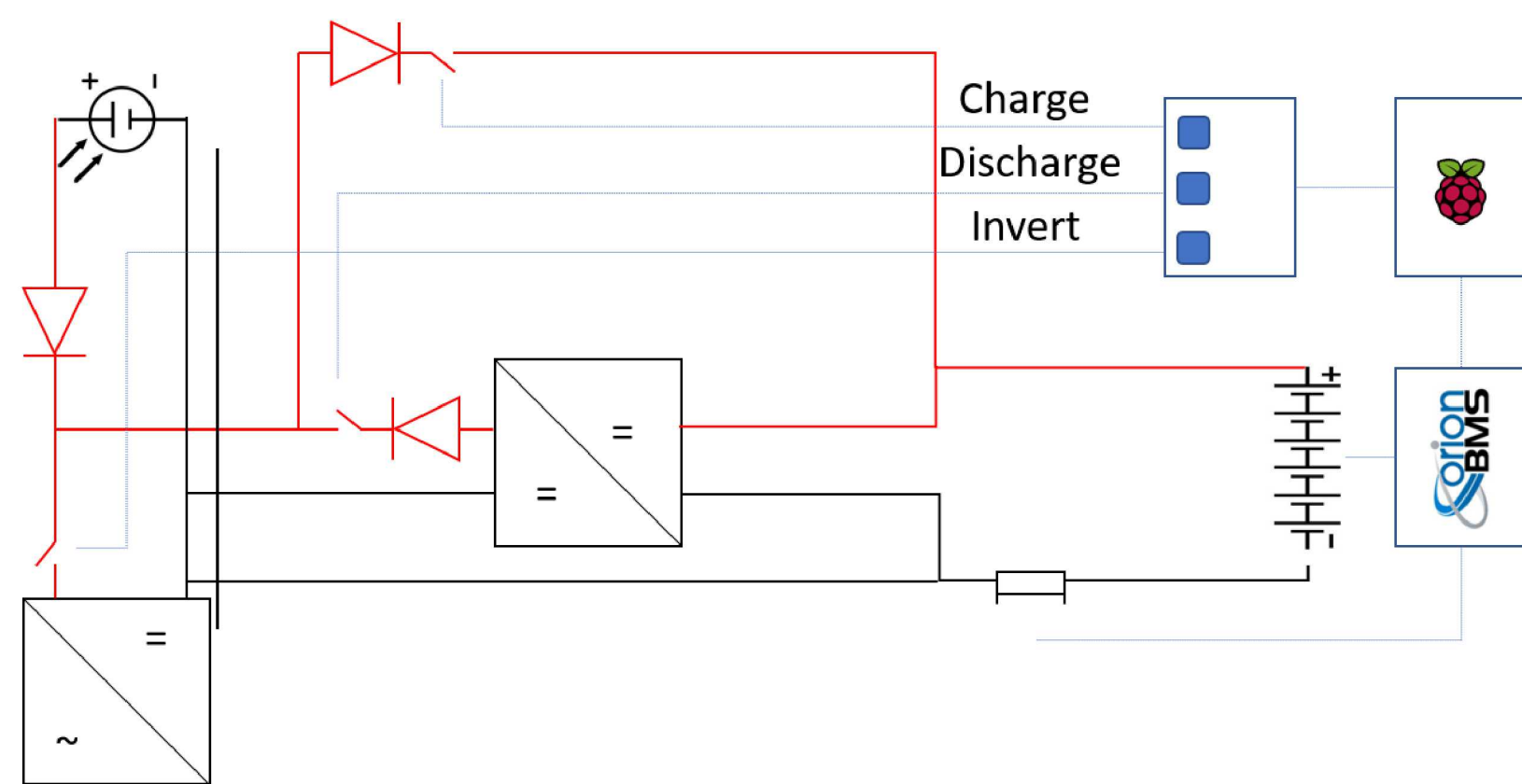
**Charging characteristics**  
Solar MPPT voltage 30V  
Cell charging range 1.25V to 1.81V  
Battery charging range: 20V to 29V

**Discharging characteristics**  
Inverter operation range: 16V to 60V  
Cell discharge range 1.5V to 1V  
Battery discharge range: 24V to 16V

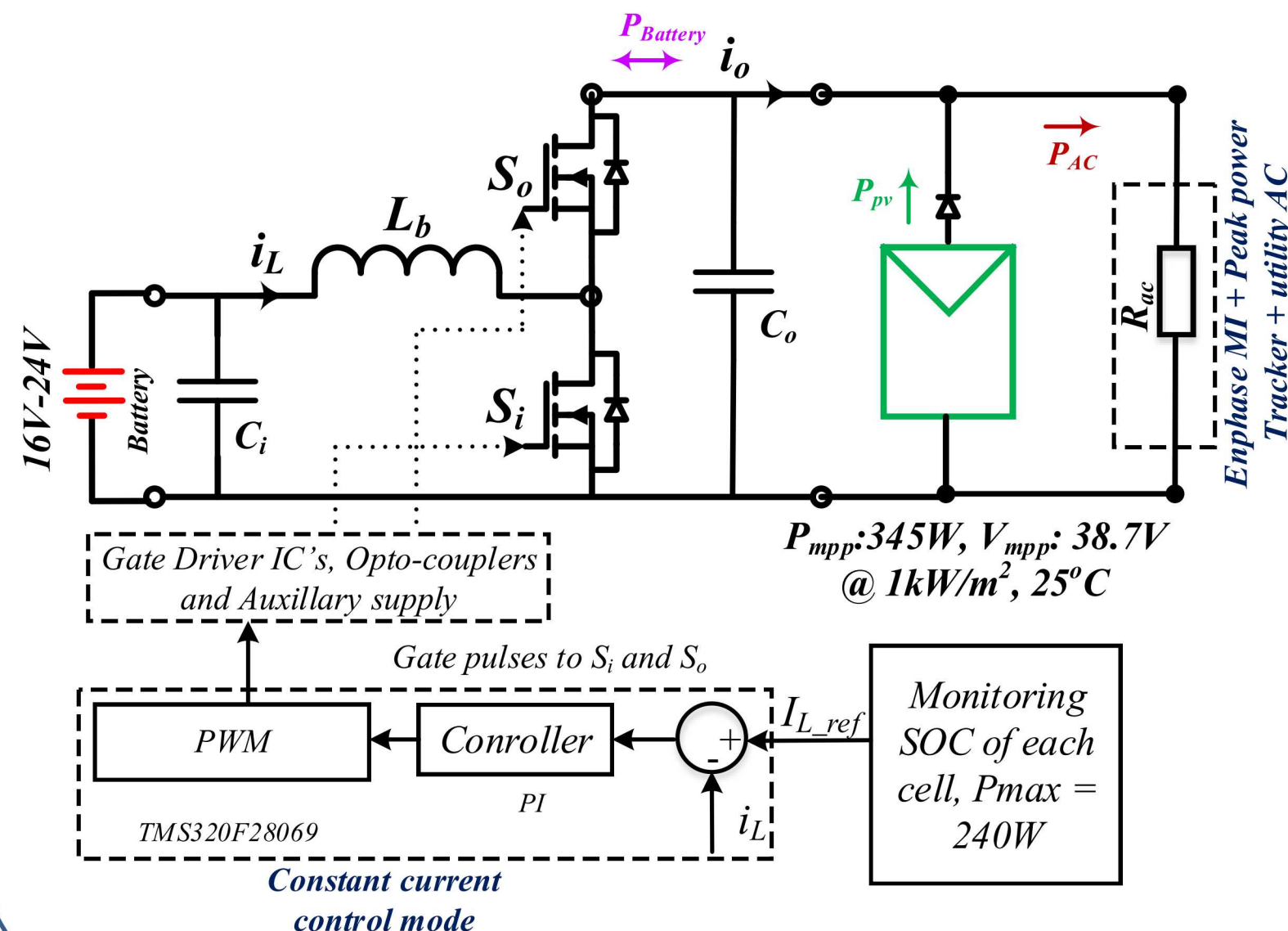


**FY 19: Electrochemical charge solution: direct connection between the solar panels and the battery**

**Mode of operations**  
0 to 12 PM: Invert relay closed  
12 PM to 3 PM: Charge relay closed  
3 PM to 12 AM: Inverter relay closed  
7 PM to 8:30 PM: Discharge relay closed



**FY 20: Bi-directional DC/DC converter**

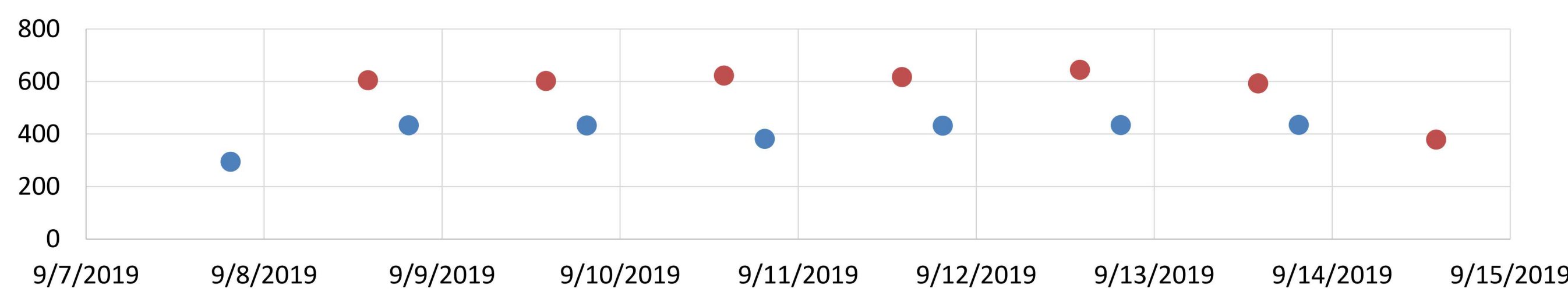


**System:** Bi-directional dc/dc converter interfaced between battery (16V-30V) and solar PV ( $P_{mpp}$ : 345W,  $V_{mpp}$ : 38.7V@1kW/m<sup>2</sup>, 25°C) terminals, and then Enphase Micro-Inverter is connected between the solar PV terminals to the utility ac grid.

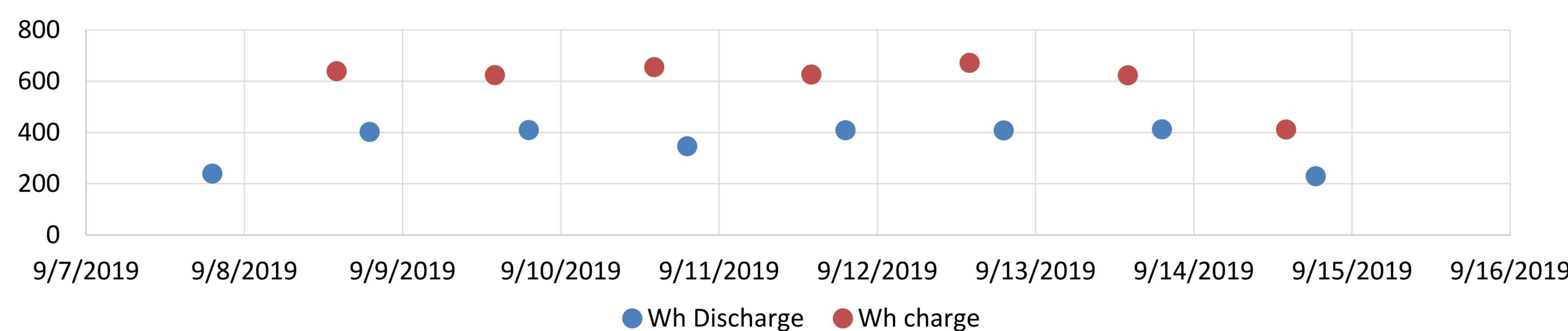
**Control system:** Enphase Micro-Inverter operates in peak power tracker mode, i.e., to operate the Solar PV at maximum power point. Battery converter is operated in bidirectional power mode (and constant current control mode), i.e., charging the battery from solar PV and discharging the battery to ac utility through inverter.

### Battery Charge and Discharge Energy

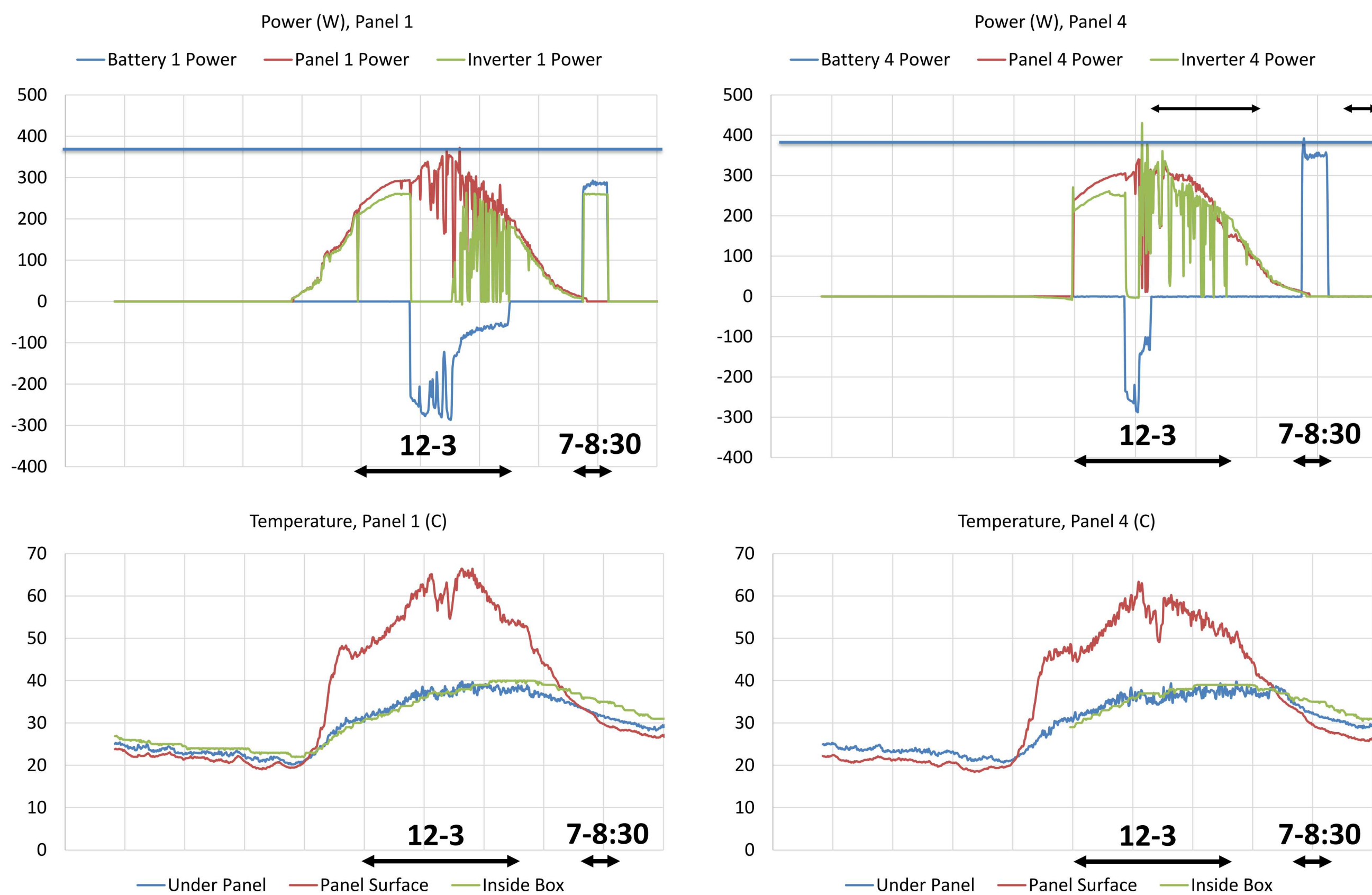
Panel 1 (Wh)



Panel 4 (Wh)



Data for September 6<sup>th</sup>, 2019



### Web-based monitoring interface



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