Multiport Multi-directional Modular and Scalable Power Conversion Platform with DC/AC Source/Storage Integration using Wide Bandgap Power Electronics

Co-PIs: Trevor Warren, Prof. Ayan Mallik; **Graduate student**: Payam Morsali

BACKGROUND

Falling prices, better quality and favorable government incentives have led to increased demand for alternative energy in recent years. However, renewables have not yet reached price parity with traditional sources of energy, and external factors such as price have disproportionately impacted low and moderate-income (LMI) homes. Such communities represent 43% of all US households, yet only 15% of solar adopters due in large part to a lack of available financing and up-front capital requirements.

MOTIVATION OF RESEARCH

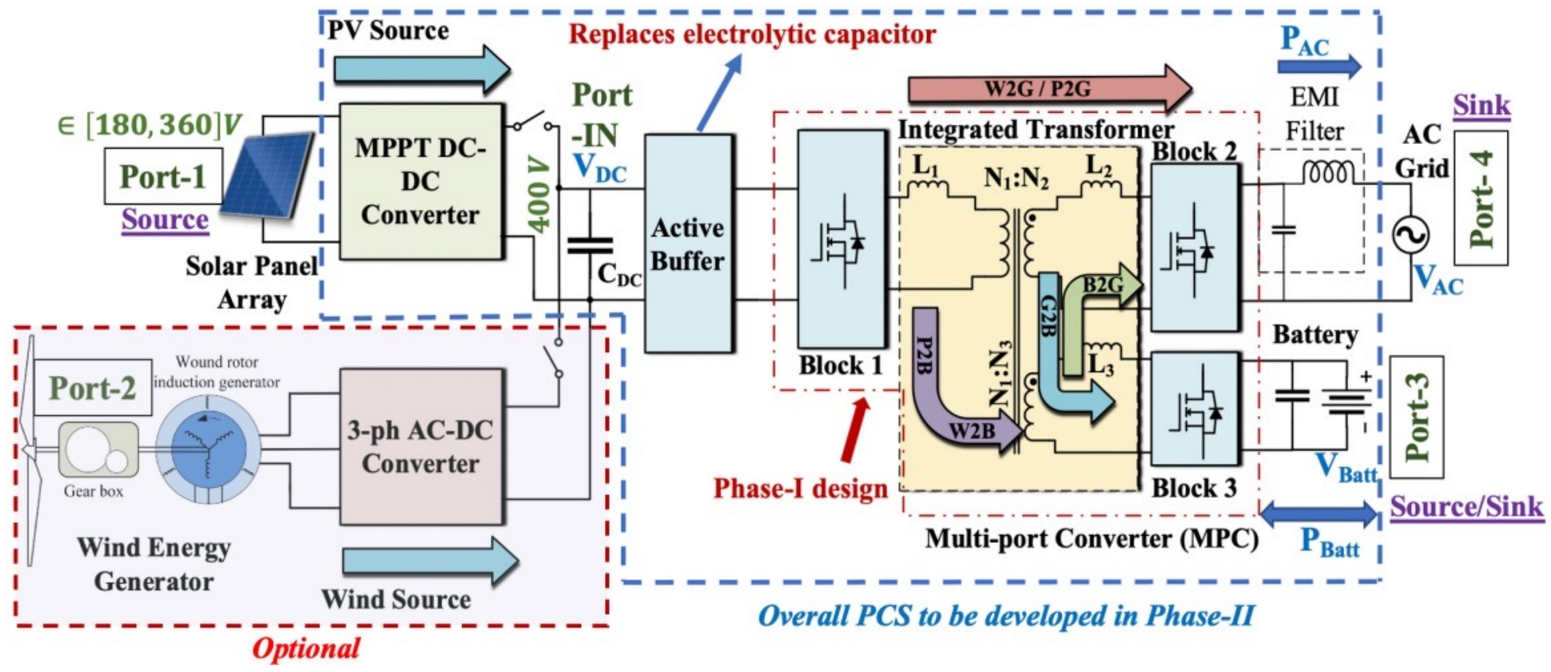
This research will develop a novel power conversion platform for interconnecting renewable energy with energy storage and the AC grid. The proposed solution will have greater than 97% efficiency, longer mean time to failure, a 40% reduction in cost, and a 30% increase in power density compared to conventional systems. It will be easily scalable to maximize potential applications and greatly drive down the costs of renewable energy adoption, which is especially critical for adoption among LMI communities.

RESEARCH OBJECTIVES

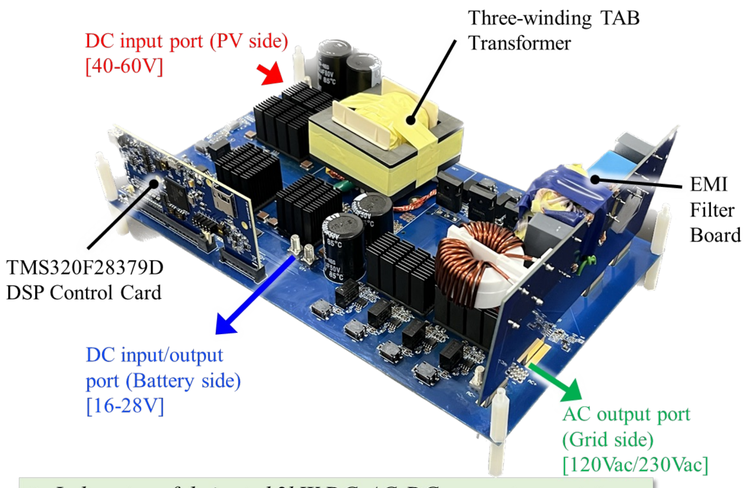
- Investigate components and fabrication of a fully Gallium Nitride (GaN)-based power conversion system to target 97% efficiency, a power density of 6.1 kW/L, and 4.1kW/kg specific power.
  - Seamless integration of multiple renewable energy resources (PV and/or Wind) with existing loads and local storage systems
  - Facilitate multi-directional power flow with reduced power conversion stages.
- Use computer software to simulate closed-loop control schemes for power flow regulation and output voltage control.
  - ➢ Statistical regression-enabled auto-tuning of TAB control parameters for maximum efficiency tracking with voltage regulation.
- Develop high-density energy storage system with phase-change material (PCM) passive thermal management.
- Build a proof-of-concept for testing and evaluation at low power.

POTENTIAL IMPACT

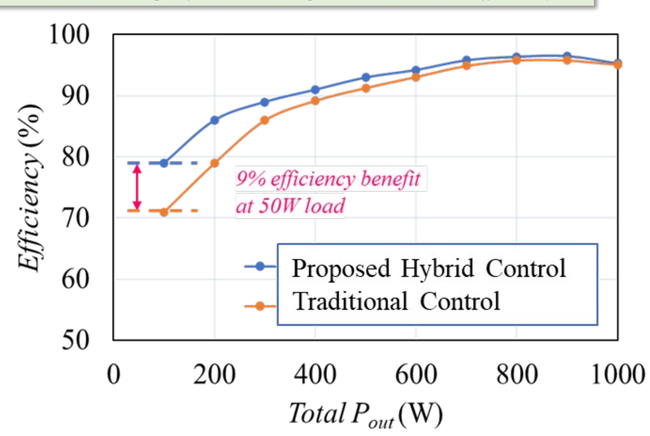
NREL projects that incentivize solar adoption by subsidizing the cost of the system even $3,000 would increase solar adoption among LMI households by 50% and all residential installations by 25% over the next 10 years [1]. It would also create $69 billion in first-year utility bill savings. Our solution aims to significantly drive down the cost and improve the reliability of a typical solar install, spurring increased demand in a similar fashion to the model without requiring additional government spending. It is essential to find innovative ways to drive down system lifecycle costs in a market such as for renewables that is still quite price elastic, and this project will help to achieve that goal.



PHASE-I HARDWARE PROTOTYPING



- *Laboratory fabricated 2kW DC-AC-DC converter prototype*
  - *All GaN design of HF switching networks, 96.2% Efficiency*



PROJECT MILESTONES

Complete | In-Process | Future

Task-1: Design, control, modulation optimization, and hardware development of the three-port dc-ac-dc PCS

- **Subtask 1.1.** TAB converter modeling, component selection, and loss analysis
- **Subtask 1.2.** Switching modulation optimization for maximum efficiency tracking in TAB DC-DC converter
- **Subtask 1.3.** PCB layout optimization and thermal management system design

Task-2: Thermal modeling and heat management system design and development for the three-port PCS prototype

- **Subtask 2.1.** Thermal modeling of the switching network
- **Subtask 2.2.** Thermal simulation of the converter to achieve a steady state temperature rise of <40 °C

Task-3: Enclosure fabrication and EMI+UL qualification tests for the three-port PCS prototype

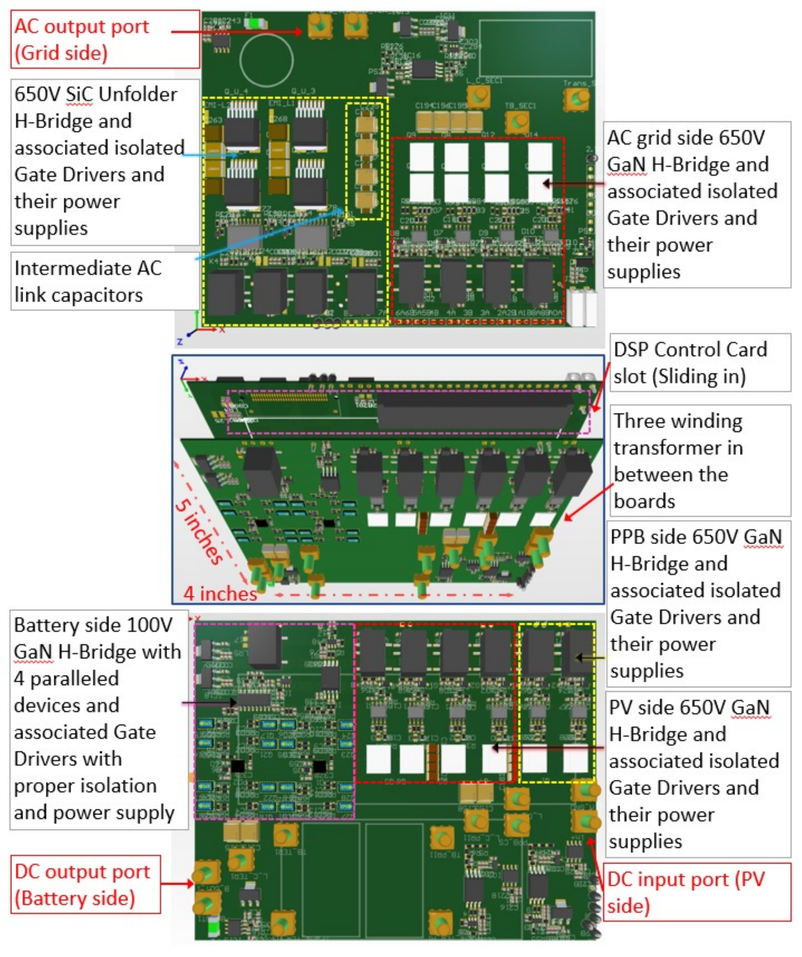
- **Subtask 3.1.** Development of the enclosure using SolidWorks for the three-port PCS hardware prototype
- **Subtask 3.2.** Fabrication and verification of the compliance of the unit with relevant EMI and UL standards.

Task-4: Experimental verification of the three-port PCS prototype testbed

- **Subtask 4.1.** PB2G mode
- **Subtask 4.2.** P2BG mode
- **Subtask 4.3.** P2G and B2G modes

PHASE-II PCB DESIGN PROCESS

Stacked PCB design to meet the 6.1 kW/L power density, consisting of two boards with ≈ 2cm spacing, with sliding in DSP control card configuration, and the three winding transformer installed in between the boards.



Award No. DE-SC0022600

SBIR · STTR America's Seed Fund

U.S. DEPARTMENT OF ENERGY

Find out more ways that Higherwire is reducing barriers to renewables.

1. Heeter, et al. "Affordable and Accessible Solar for All: Barriers, Solutions, and On-Site Adoption Potential" NREL, Sep. 2021; Online Accessible at: https://www.nrel.gov/docs/fy21osti/80532.pdf