Multiport Multi-Directional Modular and Scalable Power Conversion Platform with AC/DC Source/Storage Integration

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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 lack of available financing and up-front capital requirements.

MOTIVATION OF RESEARCH

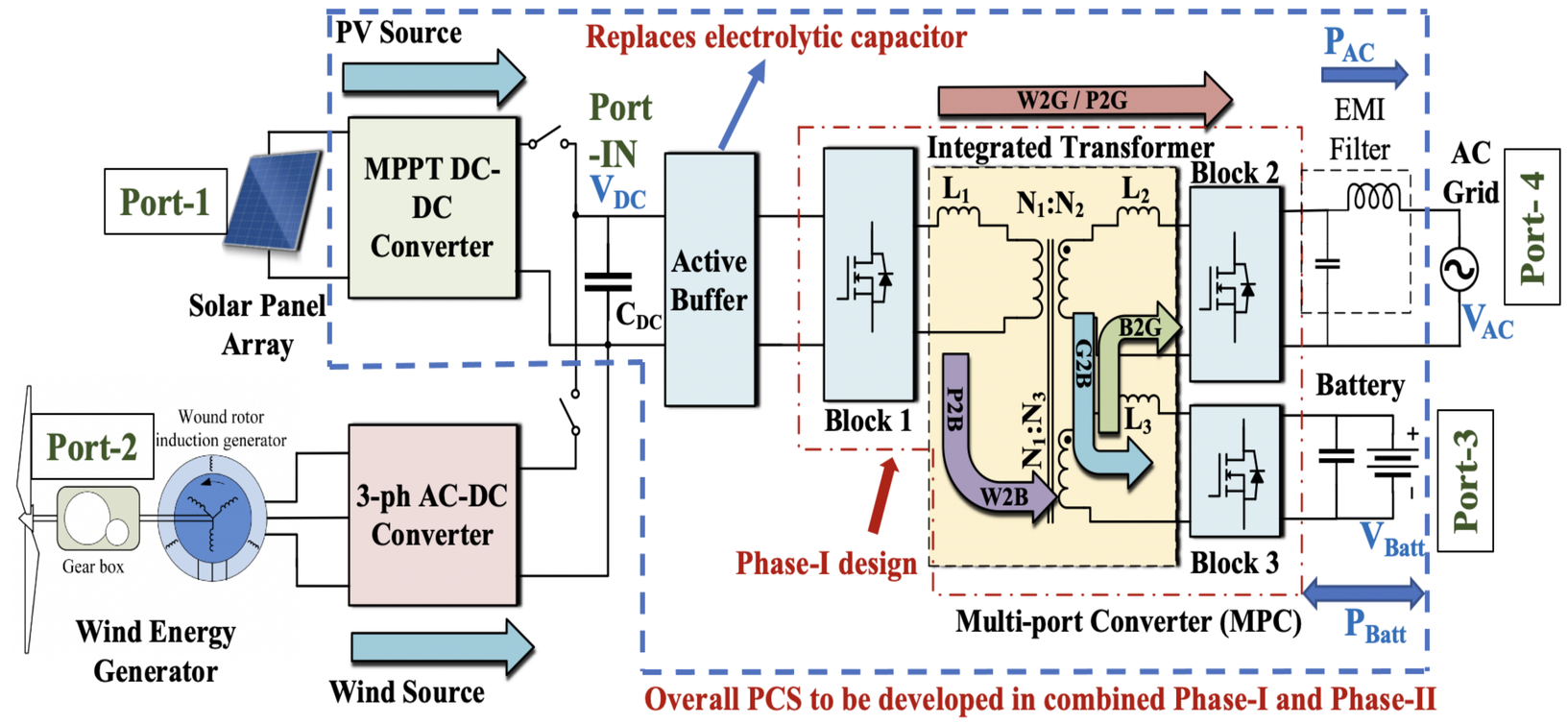
This research will develop a novel power conversion platform for interconnecting renewable energy with energy storage and the AC grid. The proposed solution will have greater than 95% efficiency, longer mean time to failure, a 40% reduction in cost and 30% reduction in volume compared to conventional 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 gallium-nitride-based power conversion system to target 95% efficiency and power density of 6.1 kW/L.
  - Seamless integration of multiple renewable energy resources 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.
- 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 incentivizing solar adoption by subsidizing the cost of system even $3,000 is 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 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.



PROJECT MILESTONES

Complete | In-Process | Future

Task-1: Design and Development of High-density Energy Storage System and PCM-based Thermal Management System

- **Subtask 1.1.** Energy storage system component identification and order
- **Subtask 1.2.** Energy storage system manufacture
- **Subtask 1.3.** Energy storage system lab testing

Task-2: Design, Control, Modulation Optimization and Hardware Development of Triple Active Bridge Converter

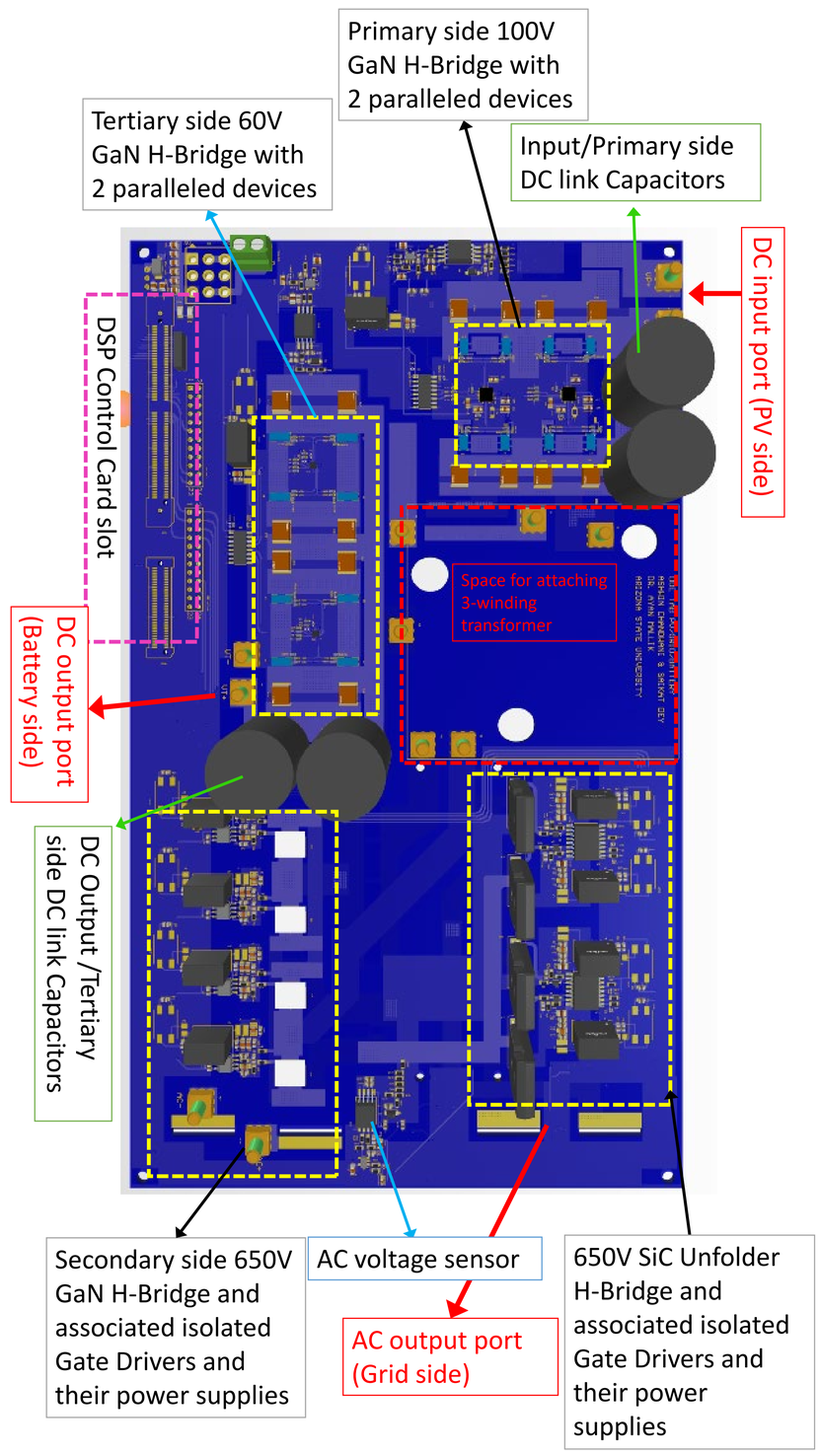
- **Subtask 2.1.** TAB converter modeling, component selection and loss analysis
- **Subtask 2.2.** Switching Modulation Optimization for Maximum Efficiency Tracking in TAB DC-DC Converter
- **Subtask 2.3.** PCB Layout Optimization and Thermal Management System Design

Task-3: Design and Validation of a Volume-Optimized Planar Integrated High-Frequency Transformer with Minimized Stray Effects

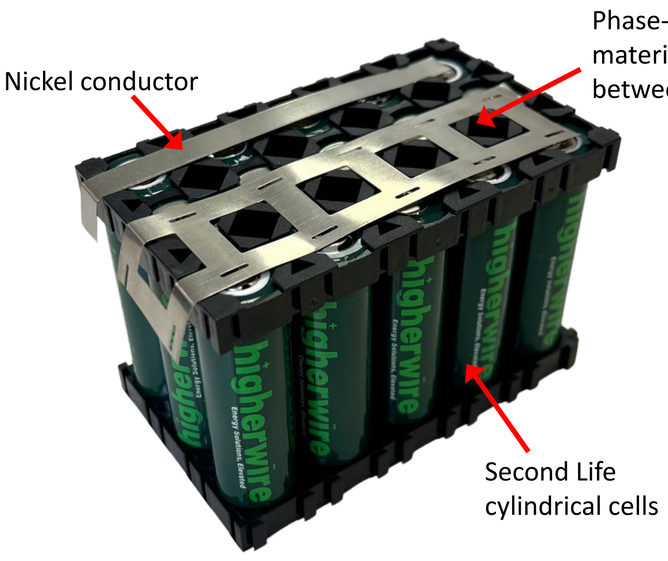
- **Subtask 3.1.** Development of inter/intra-winding capacities in the TAB converter
- **Subtask 3.2.** Circuit testing to validate the circuit design

Task-4: Simulation and Experimental based Verification of the DC-DC Stage and EMI Compliance

PCB DESIGN PROCESS



ENERGY STORAGE DESIGN



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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