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

higherwire
Energy Solutions, Elevated
@higherwireinc higherwire.com

Trevor Warren
Dr. Ayan Mallik

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Arizona State University
The Team

Trevor Warren
Founder, President and CEO

Dr. Ayan Mallik
Professor of Engineering, ASU

Jack Landry
Engineering Lead

HIGHERWIRE MISSION: To create innovative technologies that make renewable energy storage and generation more sustainable and accessible.
The Project

Motivation
• To develop a novel power conversion platform for interconnecting renewable energy with energy storage and the AC grid.
• Easily scalable to maximize potential applications and greatly drive down the costs of renewable energy
• Seamless integration of multiple renewable energy resources with existing loads and local storage systems
• Facilitate multi-directional power flow with reduced power conversion stages

Proposed four-port power conversion architecture

\[ V_{DC} \in [40, 100]V; \]
\[ V_{ac} = 120V \text{ RMS}; \]
\[ P_{ac} = 1kW \text{ (max)}; \]
\[ V_{batt} = 28V \text{ nominal}; \]
\[ P_{batt} = \pm 1kW \text{ (max)} \]
Impact

• According to NREL, subsidizing residential PV system cost by $3,000 would
  • Increase solar adoption among LMI households by 50% over the next 10 years
  • Increase all residential installations by 25%
  • Generate $69 billion in first-year utility bill savings

• Our solution will significantly drive down the cost and improve the reliability of a typical solar install

• This will spur increased demand in similar fashion to the NREL model without requiring additional government spending.

LMI communities constitute 43% of all US households but only 15% of solar adopters. [NREL]
Objectives

• Greater than 95% efficiency
• 6.1kW/L power density
• As compared to existing technologies
  • Longer mean time to failure
  • 40% reduction in cost
  • 30% reduction in volume
  • Up to 20°C operating temperature
• Develop a passive thermal management system using phase-change material (PCM) for high-density energy storage

Proposed Project Features

- Triple-active bridge converter with three ports integrating renewable source, battery and grid.
- Adjustable Modes of Operation to Minimize the Conduction and Switching Losses
- Soft Switching at Nominal Condition Facilitated by multivariable control technique
- Power Split optimization among multiple energy sources or sinks
- Controllable Leakage Integrated three winding Planar Transformer
PCB Design

- DC input port (PV side)
- DSP Control Card slot
- DC output port (Battery side)
- DC Output /Tertiary side DC link Capacitors
- AC output port (Grid side)
- AC voltage sensor
- 650V SiC Unfolder H-Bridge and associated isolated Gate Drivers and their power supplies
- Primary side 100V GaN H-Bridge with 2 paralleled devices
- Secondary side 650V GaN H-Bridge and associated isolated Gate Drivers and their power supplies
- Tertiary side 60V GaN H-Bridge with 2 paralleled devices
- Input/Primary side DC link Capacitors
- Space for attaching 3-winding transformer
- DC input port (PV side)
- DC Output /Tertiary side DC link Capacitors
- 650V SiC Unfolder H-Bridge and associated isolated Gate Drivers and their power supplies
Simulation Results

Input source @40V supplying to 120Vac Grid @1kW and 28V LV Battery @1kW

\[ V_{in} = 40V \]
\[ V_{bat, avg} = 28V \]
\[ P_{bat, avg} = 1kW \]
\[ V_{grid} = 120Vac \]
\[ P_{grid, avg} = 1kW \ (active power) \]
**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
Next Steps

• Commercialization Plan
  • We have engaged numerous potential stakeholders, including multiple inverter manufacturers and solar integrators

• Phase II submission
  • Manufacture development hardware
  • Team with industry partners to develop a turn-key nanogrid system with 24v battery
  • Field testing in applications in the Southwest

• Pairing with our existing Second Life battery products to further reduce barriers to adoption
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