High-Efficiency Modular SiC-based Power-Converter for Flexible Combined Heat and Power Systems with Stability-Enhanced Grid-Support Functions

EE0008411

Virginia Tech, Siemens

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Overview

<u>Project Title</u>: High-Efficiency Modular SiC-based Power-Converter for Flexible Combined Heat and Power Systems with Stability-Enhanced Grid-Support Functions

<u>Timeline:</u>

Project Start Date: 01/01/2019
Budget Period 1 End Date: 12/31/2019
Budget Period 2 End Date: 12/31/2020
Project End Date: 12/31/2021

<u>Project Budget and Costs:</u>

Budget	DOE Share	Cost Share	Total	Cost Share %
Overall Budget	$1,500,000	$375,000	$1,875,00 0	20%
Approved Budget (BP-1)	$584,412	$145,972	$730384	19.99%
Costs as of 4/31/19	105,157	83,075	$188,231	79%

<u>AMO MYPP Connection:</u>

- 3.1.13 Combined Heat and Power Systems

<u>Barriers and Challenges:</u>

- Control system complexity
- Communication and integration with microgrid
- Online measurement of microgrid
- Availability and cost of SiC

<u>Project Team and Roles:</u>

- Virginia Tech
  - System design, integration, and test
  - Grid support functions development
- Siemens
  - Microgrid controller programming

Project Objectives

Problem and Relevance: To develop state of the art technologies that are intended to **enable small to mid-sized combined heat and power (CHP) system**s to **provide support to the grid** in the form of electricity supply, voltage and frequency regulation, resiliency, efficiency, and reduced emissions

Objectives: **To develop** an flexible-CHP power converter with **stability-enhanced grid-support functions** avoiding the onset of dynamic interactions with grid and other system components.

To enable the system for **both microgrid and standalone** applications.

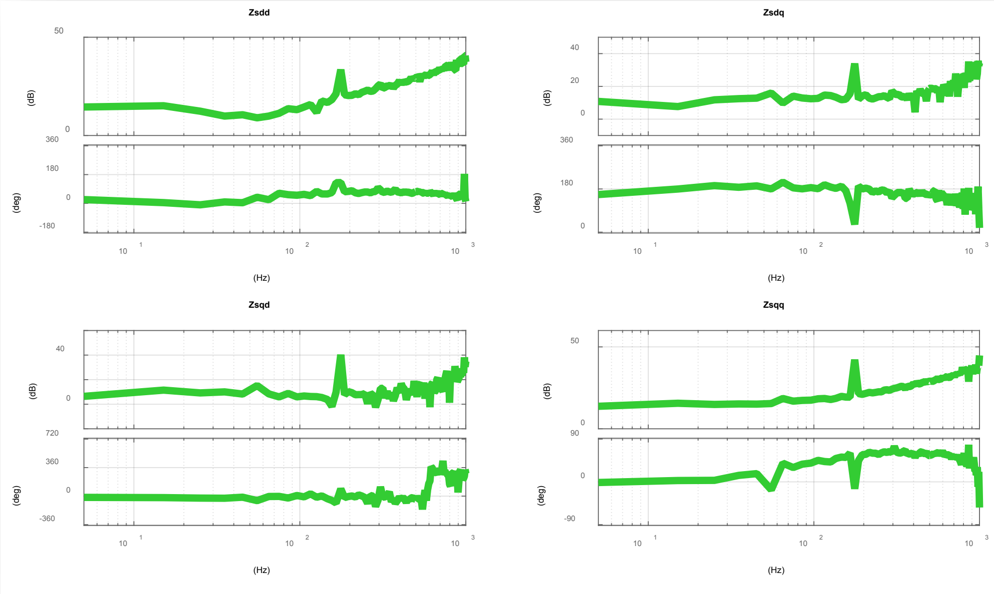
To develop a **modular, scalable** power converter **concept with** lab **demonstration** in a low-voltage power-hardware in the loop **system**.

Why it is difficult:

Complex control system to enable grid-support functions
Advanced algorithm to enable system stability monitoring
High power conversion **efficiency** requires **design iterations**

Technical Innovation

- **Present CHP systems** have been sized to match the facility's own energy needs, not to support the grid. **Very few cases of power converters** used between CHP systems and the grid
- **Grid-connected power converters** work as **grid-following** mode **without** participating in grid voltage and frequency regulation, i.e., **grid-forming mode**
- **This project is developing** a power converter with **stability-enhanced grid-support** functions, including:
  - Reactive power generation
  - Voltage regulation
  - Frequency regulation
  - Respond to abnormal conditions
  - Standalone operation
  - **Monitors the grid stability**
  - **Grid inertia emulation**
  - Phasor measurement unit

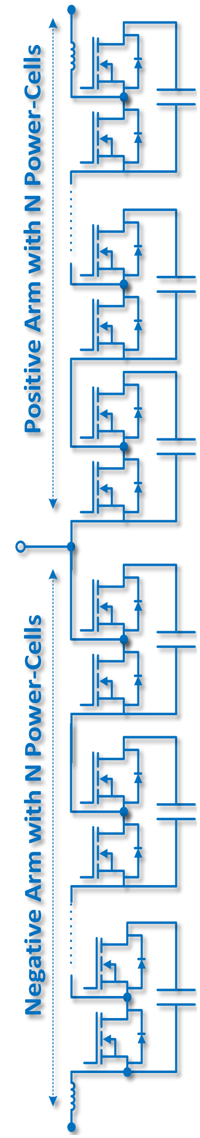


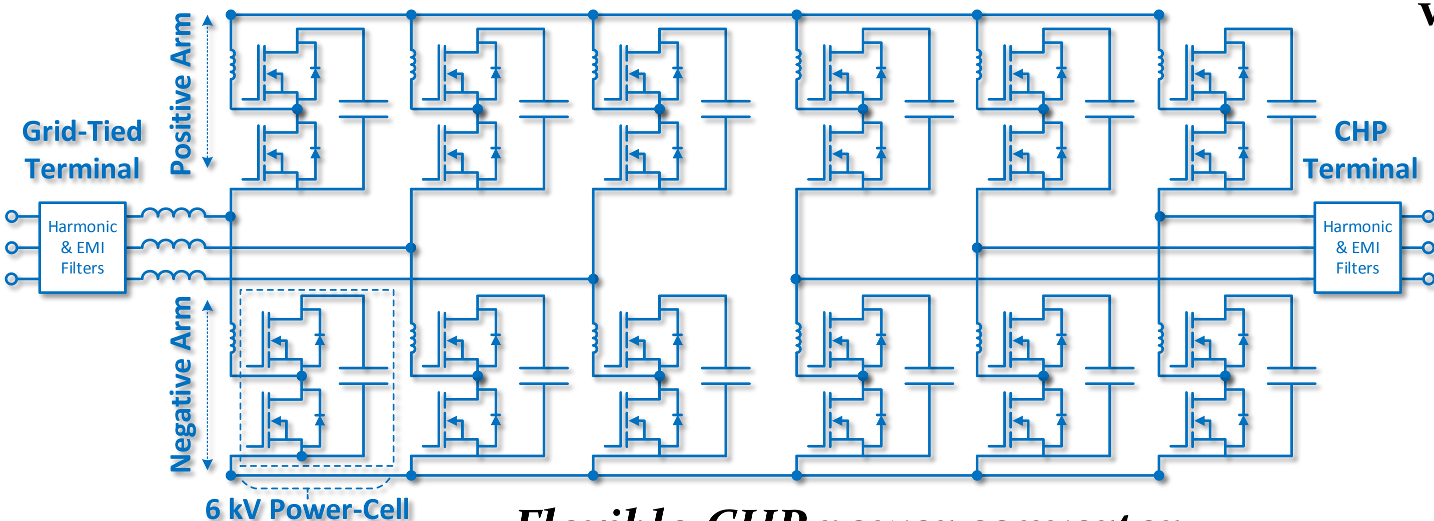
Synchronous D-Q Frame Impedance

Technical Approach

- Modular, scalable **power converter** topology used for High-Voltage Direct Current (HVDC) systems
  - Adapted for high switching frequency operation
  - Uses 10 kV SiC MOSFET devices
  - Can achieve 98 % ac-to-ac efficiency

Scalable structure to increase operating voltage





Flexible-CHP power converter

- Converter design and test will be done by Virginia Tech

Technical Approach

- **Virginia Tech** team designs control systems for **grid-support functions** with full compliance with the **IEEE Standard 1547**, category B, for operation in local areas **with high aggregated renewable resources**

- **Virginia Tech team** designs **on-line** grid impedance **measurement functions** to enable **grid stability monitoring** using the CHP power converter

- **Virginia Tech and Siemens** design **communication** system to enable connection between CHP power converter and microgrid controller fulfill the IEEE Standard 2030

Results and Accomplishments

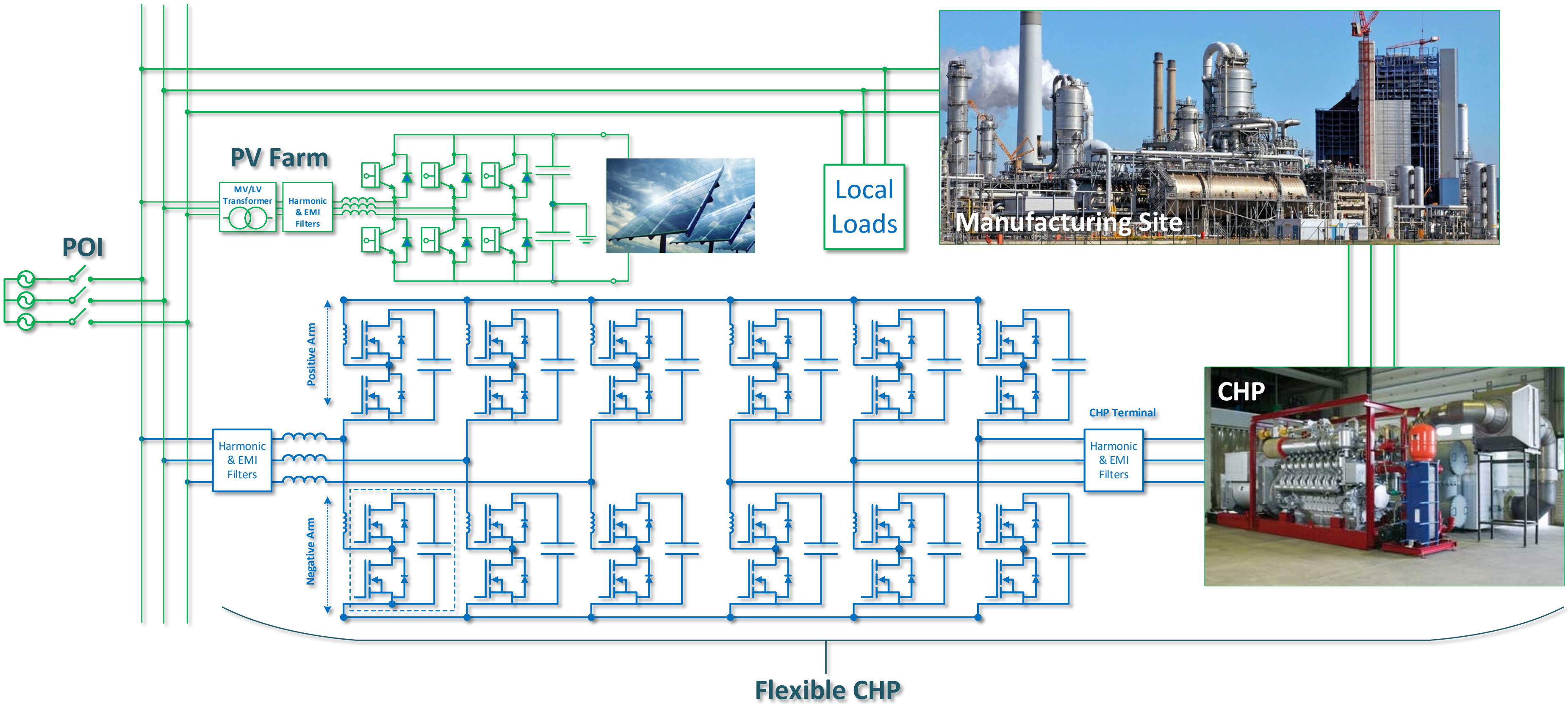
- **Milestone 1.1 was met**
  - Mathematical and simulation models of the converter were developed
  - Feedback control was designed to regulate the voltage and current of the converter
- **Control system hardware was designed and ordered for construction**
- **Training on the microgrid controller for Virginia Tech team was offered by Siemens**
- Power converter design, construction, and grid-support functions development will be finished in 2019
- Power converter commission, grid-support functions test, and communication will be finished in 2020
- System test in a power-hardware in the loop and grid-support functions evaluation will be finished in 2021

Transition

- Technology Readiness Level (TRL) -4 will be achieved by the end of the project.
  - Experimental prototype will be constructed in a laboratory environment and tested using a power hardware-in-the-loop approach

- The market transformation plan relies primarily on the DOE CHP Technical Assistance Partnerships, the collaboration with Siemens, as well as the Virginia Tech Center for Power Electronics System (CPES) industrial consortium and Power and Energy Center (PEC) collaborators
  - The CPES industry consortium has more than 80 members

Questions?



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