SiC Based Modular Transformer-less MW-Scale Power Conditioning System and Control for Flexible CHP System

DE-EE0008410

The University of Tennessee/Chattanooga Electric Power Board/
North Carolina State University/General Electric/Oak Ridge National Laboratory

Budget Period 1

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Overview

Project Title: SiC Based Modular Transformer-less MW-Scale Power Conditioning System and Control for Flexible CHP System

Timeline:

Project Start Date: 10/30/2018

Budget Period End Date: 12/31/2019

Project End Date: 12/31/2021

Barriers and Challenges:

- Support different combined heat and power (CHP) sources to flexibly connect with MV grid to provide a range of grid services, as well as meet grid requirements.
- Save cost for overall CHP system.

AMO MYPP Connection:

- AMO MYPP 3.1.13: Combined Heat and Power (CHP) system.

Project Budget and Costs:

Budget	DOE Share	Cost Share	Total	Cost Share %
Overall Budget	$1,075,701	$268,927	$1,344,628	20%
Approved Budget (BP)	$307,548	$106,367	$413,915	25.7%
Costs as of 3/31/19	$14,597	$12,901	$27,498	46.9%

Project Team and Roles:

- Project lead: The University of Tennessee (overall lead and project management).
- Team members:
  - Chattanooga Electric Power Board (utility partner)
  - North Carolina State University (CHP expert)
  - General Electric (power electronics manufacturer partner)
  - Oak Ridge National Laboratory (control system partner)

Project Objective(s)

- Existing combined heat and power (CHP) systems mainly serve site loads with very limited grid services. It highly limits the installation of small to mid-size CHP systems (1-20 MWe).
- Our work will enable grid-support functions for CHP systems , thus increase the market acceptance of cost-effective, highly efficient MW-scale CHP.
- <u>Objective:</u> develop 1) a Silicon Carbide based, modular, transformer-less, MW-scale, four-wire DC/AC power conditioning system (PCS), and 2) a corresponding control system for flexible CHP using general-purpose controller hardware:
  - Potential benefits include: bring additional revenue for CHP users through providing grid services, and lower cost hardware of overall system.
  - Target: Compliance with related grid standards (i.e. IEEE 1547 and IEEE 2030.7), <$1,800/kWe cost.
- How to achieve grid functions and Silicon Carbide PCS technology for CHP systems are still unknown and difficulties in this project.

Technical Innovation

- State-of–the-art CHP systems:
  - Power conditioning system (PCS): CHP sources interact with grid w/o PCS or w/ Silicon based PCS.
  - CHP Controller: dedicated proprietary controller specifically for one type of CHP source.

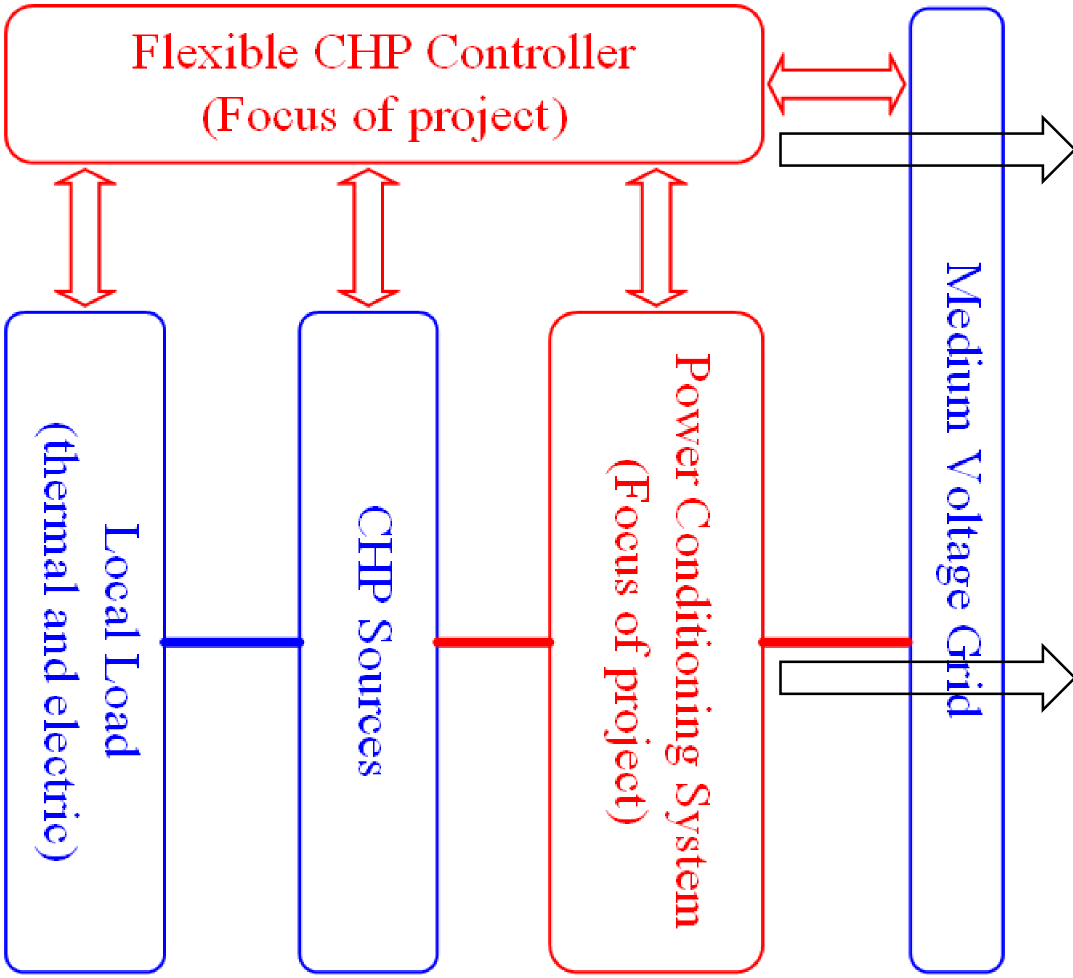
- Limitations:
  - Very limited grid functions, w/o PCS and w/ existing controller.
  - Inflexible and no coordination with other possible sources on site.
  - High cost hardware for Silicon based PCS and dedicated controller.

Technical Innovation

- Innovations of proposed approach: Silicon Carbide based PCS and general-purpose controller
  - Silicon carbide PCS, with a higher control bandwidth, enables more grid functions and meets all grid requirements;
  - The general-purpose controller can comprehensively consider different CHP sources, local load, grid interactions, as well as other possible sources on site;
  - Cost-effective: Silicon Carbide based PCS can save bulky transformer and passives compared to Silicon. The general-purpose controller is also cheaper than previous dedicated controller.
- Impact on manufacturing:
  - The developed PCS will use U.S. based Silicon Carbide devices. The conventional Silicon based PCS will be replaced by Silicon Carbide PCS in future manufacturing.
  - The dedicated CHP controller will be replaced by the general-purpose CHP controller.

Technical Approach

- <u>Scientific/technological aspects</u>:



Concept of overall CHP system

- **Flexible CHP (F-CHP) controller:**
  - Functionality and architecture
  - Operation in different modes
  - Transition between operating modes
  - Controller design considering protection
  - Modelling and test

- **Power conditioning system (PCS):**
  - Grid requirement identification
  - PCS design considering grid requirements
  - Multiple grid support functions
  - Topology, control and modulation
  - Silicon carbide device application issues
  - PCS function test

Technical Approach

- Participant roles:
  - The University of Tennessee (overall lead and project management): F-CHP controller algorithm development, PCS design and development;
  - Chattanooga Electric Power Board (Utility): Provide guidance on grid requirements on PCS and controller, provide data and model for CHP systems;
  - North Carolina State University (CHP expert): Provide expertise on CHP system, data and model;
  - General Electric (Power electronics manufacturer): Help on PCS design considering future manufacturing and commercialization;
  - Oak Ridge National Lab (Control system expert): Assist with control algorithm development.
- Risks:
  - PCS design using Silicon Carbide and fully considering grid requirements;
  - Controller integration with existing grid infrastructure.
- Risks mitigation:
  - Team experience on 10 kV Silicon Carbide based medium voltage grid interface converters, as well as microgrid controller.

Results and Accomplishments

- Planned accomplishments:
  - Specification and grid requirements determination for PCS: due date is 03/31/2019 and completed in 03/31/2019;
  - Flexible CHP controller functionality and performance requirement identification: due date is 03/31/2019 and completed in 03/31/2019.
- Accomplishment details:
  - Specification and grid requirement is determined including power rating, voltage rating, mechanical requirement, control bandwidth, grid functions and faults, etc.;
  - The controller functions, including central, local load, source and PCS controllers, are identified.
- The expected outcome by end of budget period 1 (12/31):
  - PCS converter design completed;
  - Flexible CHP controller designed and implemented.

Transition

- Technology readiness (TR) level of 4~5 anticipated by end of the project.

- The Silicon Carbide based power conditioning system (PCS) technology used in this project may be introduced in GE's power electronics product.
  - GE helps on PCS design considering future manufacturing and commercialization in this project.

- The flexible CHP controller will be published as open source software that can be easily adopted by manufacturers.

Questions?

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