High Speed Medium Voltage CHP System with Advanced Grid Support

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Clemson University and TECO Westinghouse Motor Company

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J. Curtiss Fox, PhD – Clemson University

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Overview Slide

Timeline

- Award issued: October 2018
- Scheduled end date: June 2021
- Projected end date: June 2021
- Project Progress: 15%

Budget

	FY 19 Costs	FY 20 Costs	FY 21 Costs	Total Planned Funding
DOE Funded	$627,264	$422,240	$449,864	$1,499,368
Project Cost Share	$391,329	$399,751	$18,779	$809,859

AMO MYPP Connection

- Combined Heat and Power Systems
- Wide Bandgap Semiconductors for Power Electronics
- Advanced Manufacturing to Enable Modernization of Electric Power Systems

Partners

Clemson University

TECO Westinghouse

Barriers

- Acceptance of wide bandgap semiconductors in medium-voltage utility class power electronics
- Demonstration of megawatt scale medium voltage, power electronics coupled CHP system
- Development of a control system able to meet grid connected and islanded operational standards
- Achieving cost projections and market penetration

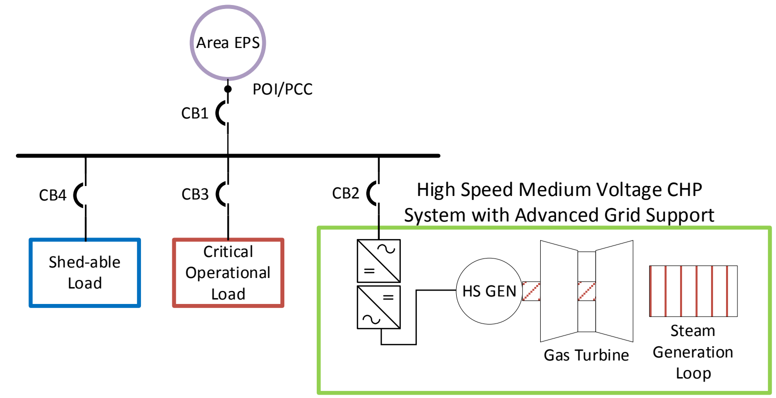
Project Objective(s)

- Part of a portfolio of projects aimed at enabling CHP systems to provide advanced grid support functions
- The primary goal of this project is to be in a position to develop a medium voltage commercial grid-tied system with advanced grid support functions validated against UL 1741 SA
- Enable a TRL 5 demonstration of the 1MW, 500Hz, 15,000RPM high frequency generator and electric machine system for advanced CHP grid integration
- The demonstration system developed during this project will:
  - Validate the grid-tied SiC enabled high frequency CHP generator converter.
  - Implement and validate the system replicating the gas turbine dynamics and high speed generator-tied converter.
  - Demonstrate island mode transitions and resynchronization for reconnection with the power grid with the fully coupled system prototype setup.

Demonstration System Specifications	
Generator Voltage	4.16 kV
Power Rating	1 MW
Operating Speed Range	11,000 – 15,000 RPM
Grid Voltage	480 V – 13.8 kV
Enabling Technology	WBG SiC MOSFET
Microgrid Controller	Compliant with IEEE Std. 2030.7
Interconnection and Interoperability	Compliant with IEEE Std. 1547
Installed Cost Target	< $1,800/KW rated power

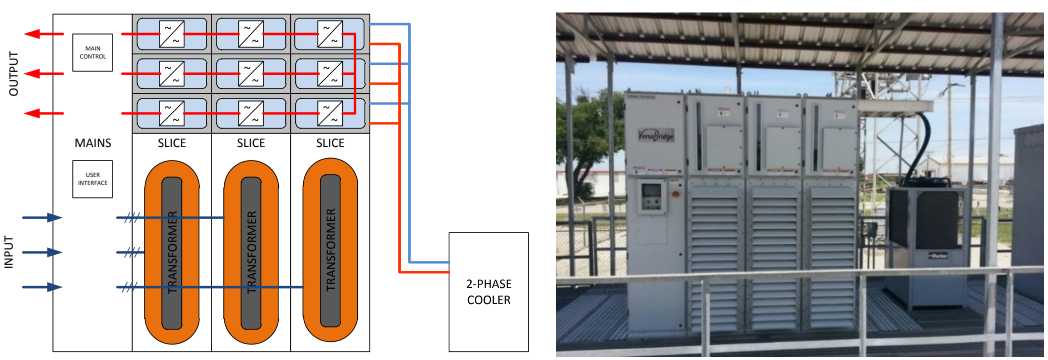
Technical Innovation

- Manufacturing plant microgrid solution for increased resiliency
  - Scalable architecture for applications in the power range of 1 – 20 MW
  - IEC 61850 GOOSE messaging for real-time communication in the plant
  - Medium voltage, multi-megawatt power electronic converter certified for DER
  - High speed dynamic control for medium voltage induction generators in direct gas turbine shaft coupled systems



Simplified block diagram of the manufacturing plant with the advanced CHP system

- Control function enabled through high frequency variable speed drive
  - The multi-level topology of the drive results in ultra-high effective power electronic switching frequencies
  - High effective switching frequencies enables bandwidth to respond to fast dynamic events on the grid and generator

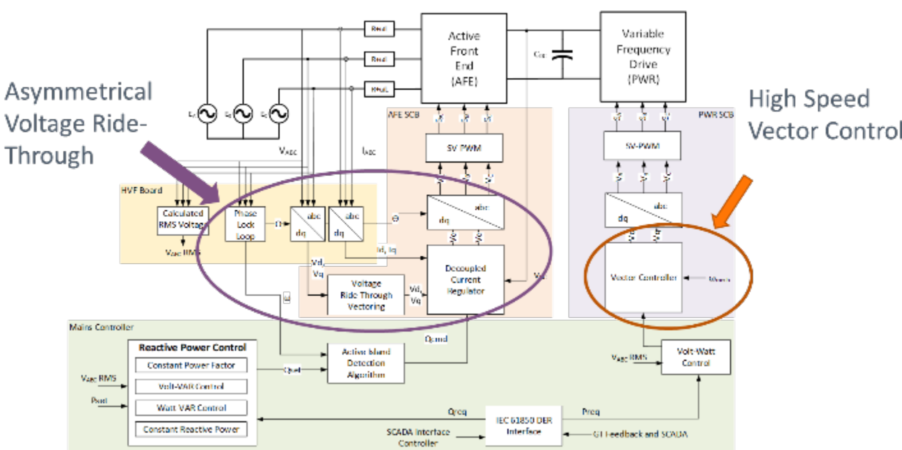


Schematic and actual system installation of a 1 – 2.5 MW SCHB architecture

Technical Approach

- SCADA Interface Controller – IEC 61850
  - Utility interface and Microgrid EMS
- System Grid Tied IEEE 1548 Classification
  - Implemented system will follow Local EPS 3 configuration
  - Classification of resource would be Category B with respect to clause 5 with abnormal operating voltage performance as per Category III
- Machine Side Controller Dynamics
  - High speed vector control to manage the safe operating area during load changes

Task	Description
1	Integration of Power Electronics Coupled CHP in Advanced Manufacturing Plants
2	Development of Advanced Grid Support Functions
3	Hardware Validation of Advanced Grid Support Functions
4	Development of Machine Controls for High Speed Gas Turbine Dynamics
5	Hardware Validation of the Coupled Gas Turbine and High Speed Generator Dynamics
6	Simulation and Controller Hardware-In-the-Loop Validation of the Fully Coupled System
7	Power Hardware-In-the-Loop Testing of the Fully Coupled System

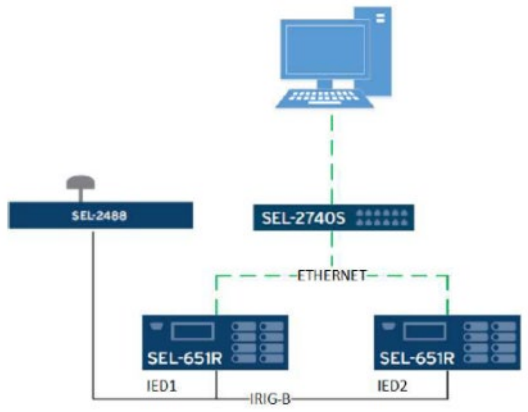


Block diagram illustrating functions and capabilities to meet IEEE Std. 1547 and UL 1741

- System Prototype Validation and Verification
  - Real-time modeling of the Area EPS, plant, grid-side converter, machine-side converter, induction generator, and gas turbine
  - Controller Hardware-In-the-Loop includes IEC 61850 IEDs, SCADA Interface Controller and representative grid-side control hardware
  - Power Hardware-In-the-Loop includes full scale demonstration at the Clemson eGRID Center

Results and Accomplishments

- Results to date
  - IEC 61850 demonstration
    - Successfully completed GOOSE messaging benchmarking
    - Deployed GOOSE enabled control elements on a software defined network in a DERMs controller Hardware-In-the-Loop setup
  - Development of Advanced Grid Support Functions
    - Created the functional requirements document for IEEE 1547 and UL 1741
    - Completed development of library based full system model for controller development
  - Development of Machine Controls for High Speed Gas Turbine
    - Researched gas turbine dynamic loading models for islanded operations
    - Implemented high speed communication paths for Speedgoat CHIL applications



GOOSE messaging benchmark diagram

Real-Time Distributed Control system used for initial controller demonstration

Transition (beyond DOE assistance)

- In discussions with stakeholders and potential customers
  - Stakeholders include both end users and turbine OEMs
  - Additional system designs are being developed for specific location and plant specifications
  - Larger range of applications than initially anticipated
  - Expanding microgrid controller capabilities to incorporate existing and future DER
- Certification of the system
  - Leverage present UL certification of the motor drive to extend for grid support requirements in distributed generation applications
  - Leveraging Clemson's eGRID in development of a pre-certification test plan that will meet the requirements of UL 1741 and IEEE 1547