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14. ABSTRACT

The Defense University Research Instrumentation Program (DURIP) is designed to improve the capabilities of U.S. Universities to conduct research and to educate scientists and engineers in selected technical areas of importance to national defense. DURIP funding provides for the acquisition of research equipment and instrumentation for this purpose.

This proposal is for the purchase of a Multipurpose Real Time Simulator (MRTS) system.

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microgrid modeling, real-time simulator, controls testing

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Report Title

Final Report: Enhancing Military Effectiveness through Real-Time Simulation of Forward-Operating Microgrids

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This proposal is for the purchase of a Multipurpose Real Time Simulator (MRTS) system.

This equipment will be used to augment and enhance research capabilities in the area of complex microgrid modeling and controls.

Enter List of papers submitted or published that acknowledge ARO support from the start of the project to the date of this printing. List the papers, including journal references, in the following categories:

(a) Papers published in peer-reviewed journals (N/A for none)

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TOTAL:

Number of Papers published in peer-reviewed journals:

(b) Papers published in non-peer-reviewed journals (N/A for none)

Received Paper

TOTAL:

Number of Papers published in non peer-reviewed journals:

(c) Presentations

Number of Presentations: 0.00

Non Peer-Reviewed Conference Proceeding publications (other than abstracts):

Received	Paper

TOTAL:

Number of Non Peer-Reviewed Conference Proceeding publications (other than abstracts):

Peer-Reviewed Conference Proceeding publications (other than abstracts):

Received	Paper

TOTAL:

Number of Peer-Reviewed Conference Proceeding publications (other than abstracts):

(d) Manuscripts

Received	Paper

TOTAL:

Number of Manuscripts:

Books

Received	Book

TOTAL:

Received Book Chapter

TOTAL:

Patents Submitted

Patents Awarded

Awards

Graduate Students

NAME	PERCENT_SUPPORTED
FTE Equivalent:	
Total Number:	

Names of Post Doctorates

NAME	PERCENT_SUPPORTED
FTE Equivalent:	
Total Number:	

Names of Faculty Supported

NAME	PERCENT_SUPPORTED
FTE Equivalent:	
Total Number:	

Names of Under Graduate students supported

NAME	PERCENT_SUPPORTED
FTE Equivalent:	
Total Number:	

Student Metrics

This section only applies to graduating undergraduates supported by this agreement in this reporting period

The number of undergraduates funded by this agreement who graduated during this period: 0.00

The number of undergraduates funded by this agreement who graduated during this period with a degree in science, mathematics, engineering, or technology fields:...... 0.00

The number of undergraduates funded by your agreement who graduated during this period and will continue to pursue a graduate or Ph.D. degree in science, mathematics, engineering, or technology fields:...... 0.00

Number of graduating undergraduates who achieved a 3.5 GPA to 4.0 (4.0 max scale):...... 0.00

Number of graduating undergraduates funded by a DoD funded Center of Excellence grant for Education, Research and Engineering:...... 0.00

The number of undergraduates funded by your agreement who graduated during this period and intend to work for the Department of Defense 0.00

The number of undergraduates funded by your agreement who graduated during this period and will receive scholarships or fellowships for further studies in science, mathematics, engineering or technology fields:...... 0.00

Names of Personnel receiving masters degrees

NAME

Total Number:

Names of personnel receiving PHDs

NAME

Total Number:

Names of other research staff

NAME	PERCENT_SUPPORTED

FTE Equivalent:

Total Number:

Sub Contractors (DD882)

Inventions (DD882)

Scientific Progress

Foreword: The Construction Engineering Research Laboratory (CERL) is in the process of developing a new tactical microgrid power system standard. Modern military operations are becoming ever more dependent on high quality reliable electrical power being available in a range of tactical environments. To meet this need a variety of diverse military power system equipment must be interconnected to form an ad hoc tactical microgrid. In the interest of minimizing the number of specialized support personnel that must be deployed, it is highly desirable that the assembly or reconfiguration of a tactical microgrid be able to be done by any warfighter. To make this goal feasible, the power grid equipment will need to be “plug and play”, which in turn requires that a new standard be developed to ensure this capability is incorporated in new equipment. To advance this development, stability and control studies rely heavily on extensive computer simulation, on experiments including when possible hardware-in-the-loop (HIL) testing, and on the development of suitable control systems to manage these tasks in real applications.

Problem Statement: To support research in advanced power systems, The University of Texas at Austin Center for Electromechanics established a flexible MW-scale microgrid laboratory to enable evaluation of navel power system topologies and controls. In order for the UT microgrid laboratory to more effectively emulate forward operating base power systems, UT-CEM proposed the purchase of a Multi-purpose Real-Time Simulation (MRTS) system for the UT-CEM Microgrid Laboratory under the Army Research Program DURIP Grant program. As proposed in March 2015, the total cost of the proposed Real-Time Simulation system for the UT-CEM Microgrid Laboratory was $81,269.13.

The MRTS proposal was based on a quotation from Opal-RT and consisted of Real-Time Simulation Hardware, Software, IO Package, Communication Protocol licensing, Installation, Commissioning and Training. After further review, very few vendors for Real-Time Simulation vendors and systems are available on the market and Opal-RT has developed a system optimized for power grid analysis, offering the best combination of performance and flexibility.

Summary of Key Results: The UT-CEM microgrid has already been used to perform experiments relevant to the CEED mission. A series of such experiments has been concerned with the sudden application or dropping off of a large load, and the sudden loss from or insertion into the system of a generating unit. The experimental study of the role of energy storage on the stabilization of the power bus has also begun.

Now that the MRTS has been delivered and commissioned, it will be used to support existing Army funded activities for tactical microgrid research into optimal electric distribution and machine design. Interconnection of advanced power generation, distribution and conversion equipment is, however, envisioned for future power system installation. The MRTS will be a key piece of processing and test equipment for the demonstration microgrid at UT-CEM and will enable research into critical power architecture issues as well as land based power systems, both from the theoretical simulation perspective and from the standpoint of experimental hardware testing and generation/de-risking of control strategies.

It will make possible the acceleration of computer simulations modeling power systems and would support the ongoing and projected tests of actual hardware and control methodologies in a realistic environment under the CEED program. In this manner, the DURIP equipment can lead to improved program research.

Technology Transfer

The University of Texas at Austin held multiple workshops for UT undergraduate electrical engineering students, first independently, and then in cooperation with National Instruments to teach the students the real-time simulators capabilities and value to microgrid design and controls development.

ENHANCING MILITARY EFFECTIVENESS THROUGH REAL-TIME SIMULATION OF FORWARD-OPERATING MICROGRIDS

Contract Number: W911NF-15-1-0383

Final Report
Submitted to:

ARMY RESEARCH OFFICE

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August 2016

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Foreword

The Construction Engineering Research Laboratory (CERL) is in the process of developing a new tactical microgrid power system standard. Modern military operations are becoming ever more dependent on high quality reliable electrical power being available in a range of tactical environments. To meet this need a variety of diverse military power system equipment must be interconnected to form an ad hoc tactical microgrid. In the interest of minimizing the number of specialized support personnel that must be deployed, it is highly desirable that the assembly or reconfiguration of a tactical microgrid be able to be done by any warfighter. To make this goal feasible, the power grid equipment will need to be "plug and play", which in turn requires that a new standard be developed to ensure this capability is incorporated in new equipment. To advance this development, stability and control studies rely heavily on extensive computer simulation, on experiments including when possible hardware-in-the-loop (HIL) testing, and on the development of suitable control systems to manage these tasks in real applications.

Problem Statement

To support research in advanced power systems, The University of Texas at Austin Center for Electromechanics established a flexible MW-scale microgrid laboratory to enable evaluation of novel power system topologies and controls. In order for the UT microgrid laboratory to more effectively emulate shipboard and forward operating base power systems, UT-CEM proposed the purchase of a Multi-purpose Real-Time Simulation (MRTS) system for the UT-CEM Microgrid Laboratory under the Army Research Program DURIP Grant program. As proposed in March 2015, the total cost of the proposed Real-Time Simulation system for the UT-CEM Microgrid Laboratory was $81,269.13.

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UT-CEM Microgrid Laboratory

UT-CEM has onsite a flexible, megawatt-scale microgrid that is available to assist in the validation of simulation models at relevant power levels and to conduct critical component and technology validation experiments. To reflect realistic installations, the various components of the microgrid are installed in two separate labs connected by an approximately 150 ft long primary distribution bus (Figure).

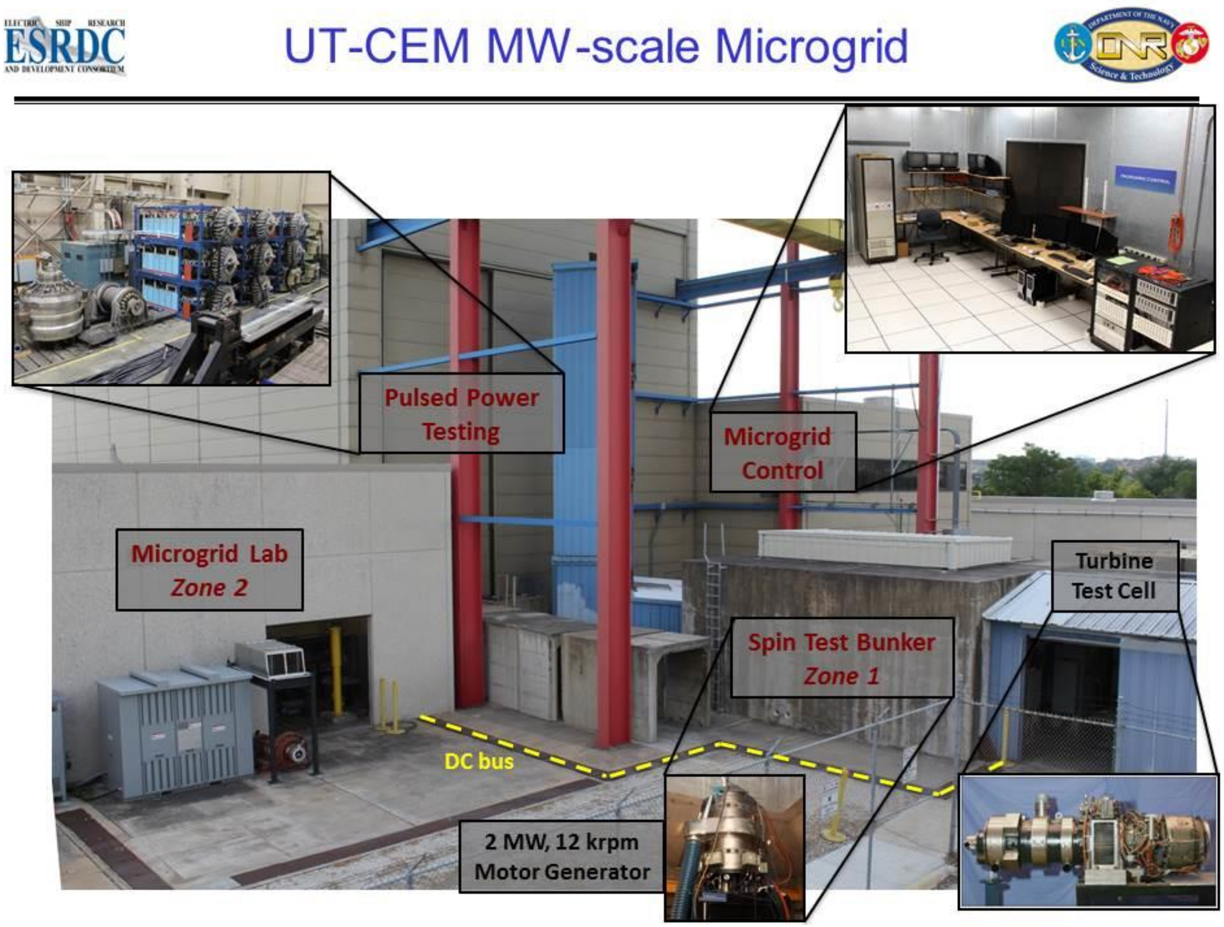

Figure 1: Distributed microgrid installation at UT-CEM.

The system is currently configured for dc distribution (Figure), but the microgrid can also be configured for 60 Hz or higher frequency ac distribution as well. As of this writing, additional power conversion stages are being installed onto the present microgrid. The acquisition of these additional power converters was also made possible thanks to a 2013 DURIP Grant from Office of Naval Research (ONR). These units, for a total of 7.5 MW of additional combined power, will add much more flexibility and reconfiguration options to the present architecture shown in Figure .

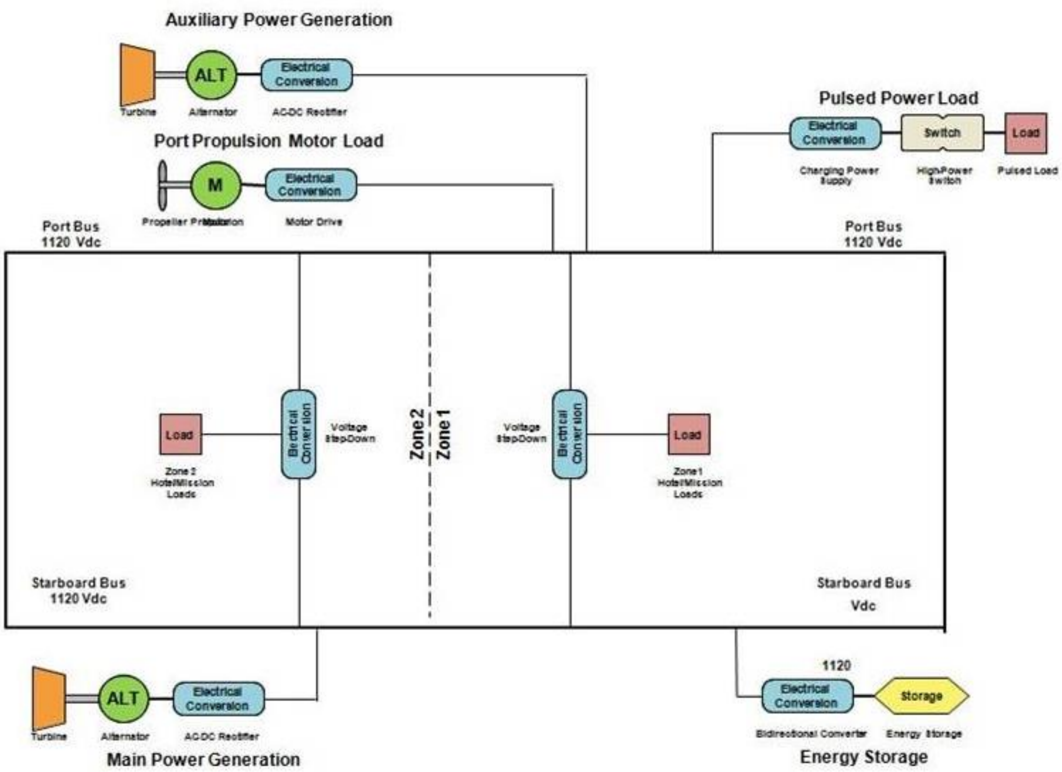

Figure 2: Schematic of present dc microgrid laboratory installation

The installation of these additional power converter units will enhance the UT-CEM microgrid capabilities as a flexible test-bed for HIL/PHIL testing of a variety of hardware at relevant power levels (see for example Figure). The addition of an MRTS would extend the capabilities of the test bed and make it more adaptable as a HIL/PHIL or hybrid validation tool.

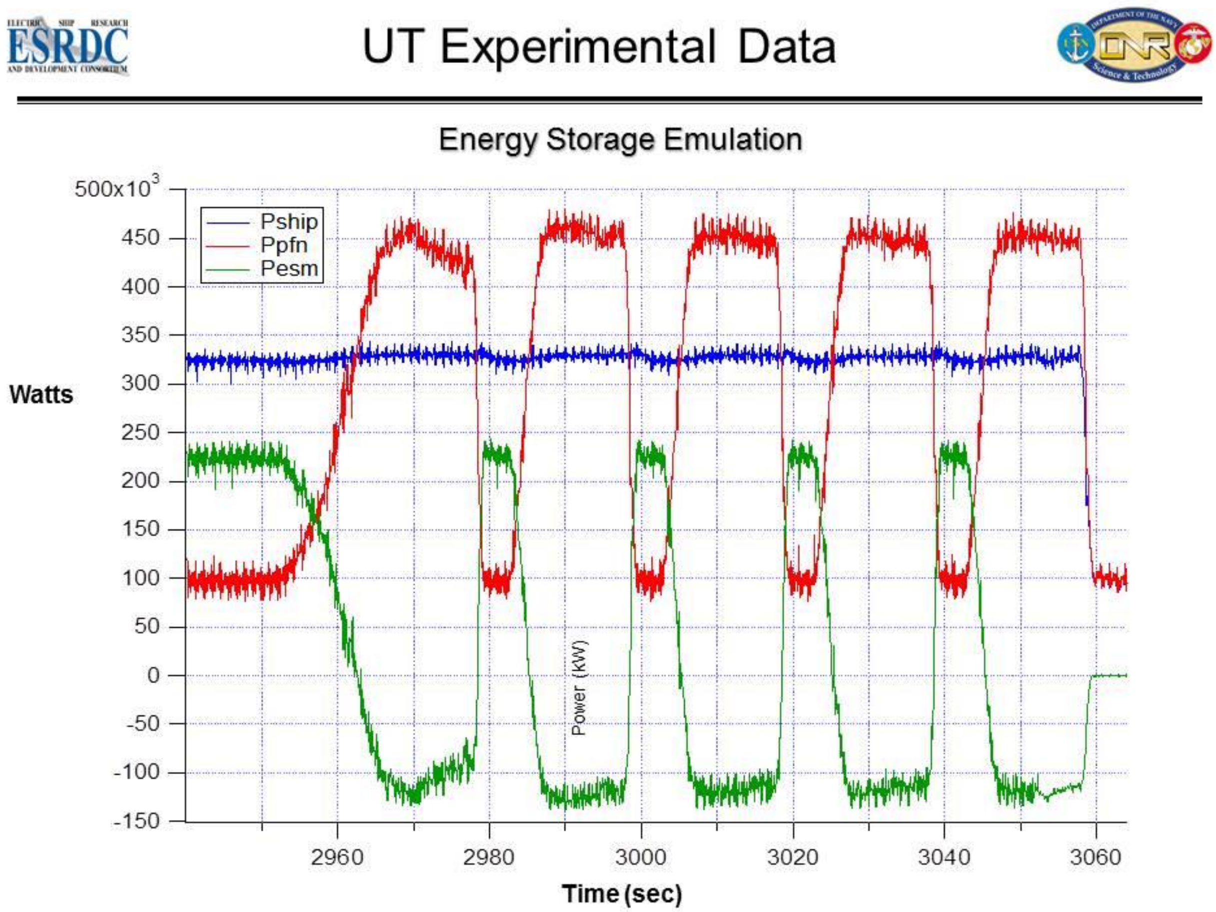

Figure 3: Example of HIL testing at UT-CEM: energy storage emulation on the microgrid

Multi-Purpose Real-Time Simulation System Description

A schematic diagram illustrating the planned use of the MRTS system at UT-CEM is shown in Figure . When used to accelerate computer simulations (green frame), the MRTS will accept existing (and future) *MATLAB*/*Simulink* models to perform resource-intensive calculations. This will result in accelerated runs, and likely, it will be the most common use as the MRTS will be shared among users on the same network.

When used for HIL (red frame), the MRTS will run models (plants) in real time to aid in controller design and testing. When used as a PHIL (red frame), the plant running on the MRTS will drive real hardware in a lab. The hardware response will be fed back to the MRTS to obtain a completed-interfaced plant (e.g., tactical microgrid model) interfaced to local power apparatus (e.g., a flywheel). When used for RCP (red frame), the MRTS will accept controller models designed in *Simulink* and act as the real-time controller for UT-CEM's actual microgrid. In fact, several controllers will be deployed onto the same MRTS to mimic a decentralized control architecture in real time that will autonomously control the equipment in our existing microgrid.

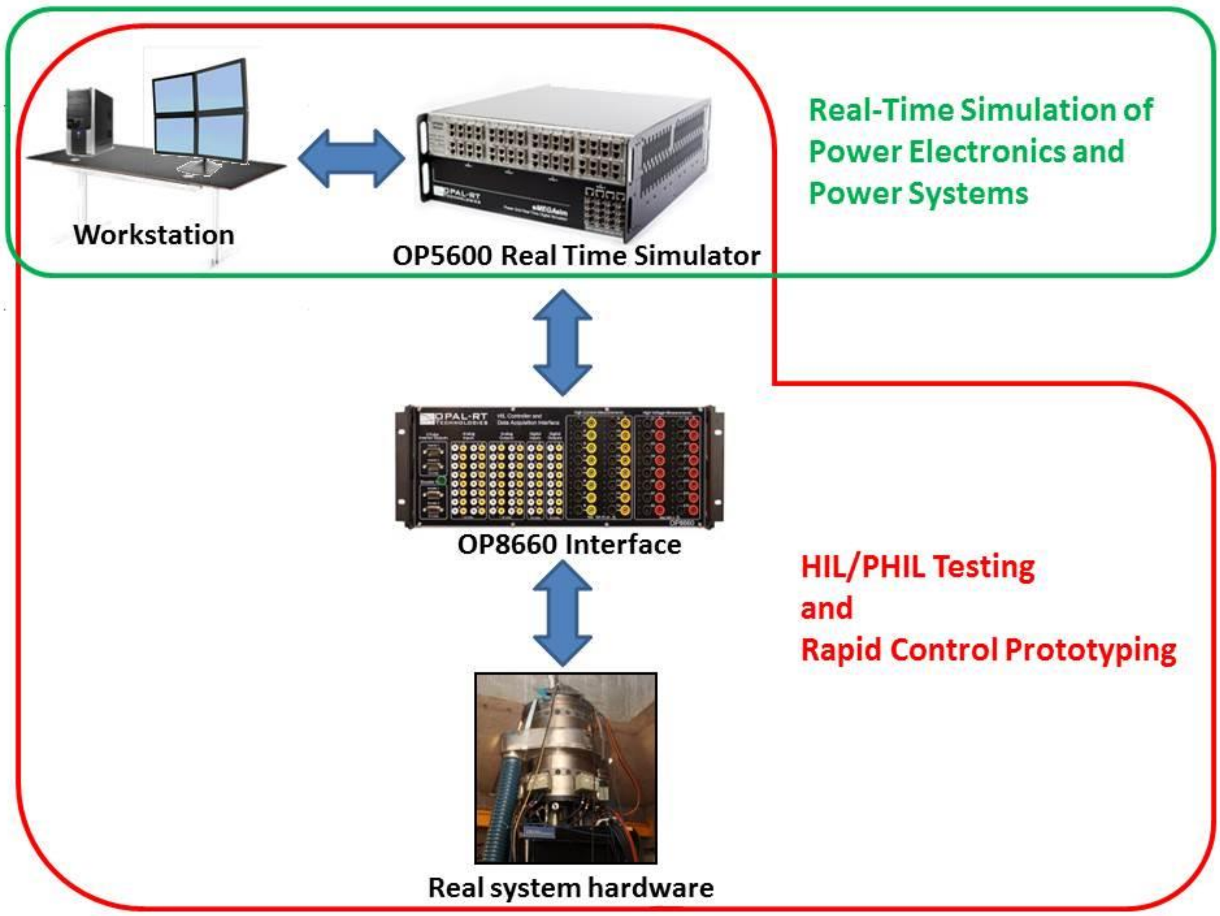

Figure 4: Schematic diagram of the Multi-purpose Real Time Simulator applied at UT-CEM

The full range of the plant simulation capabilities of the system is shown in Figure . Under this DURIP contract, the team was able to purchase eMEGASim licensing to enable multiple cores of computation.

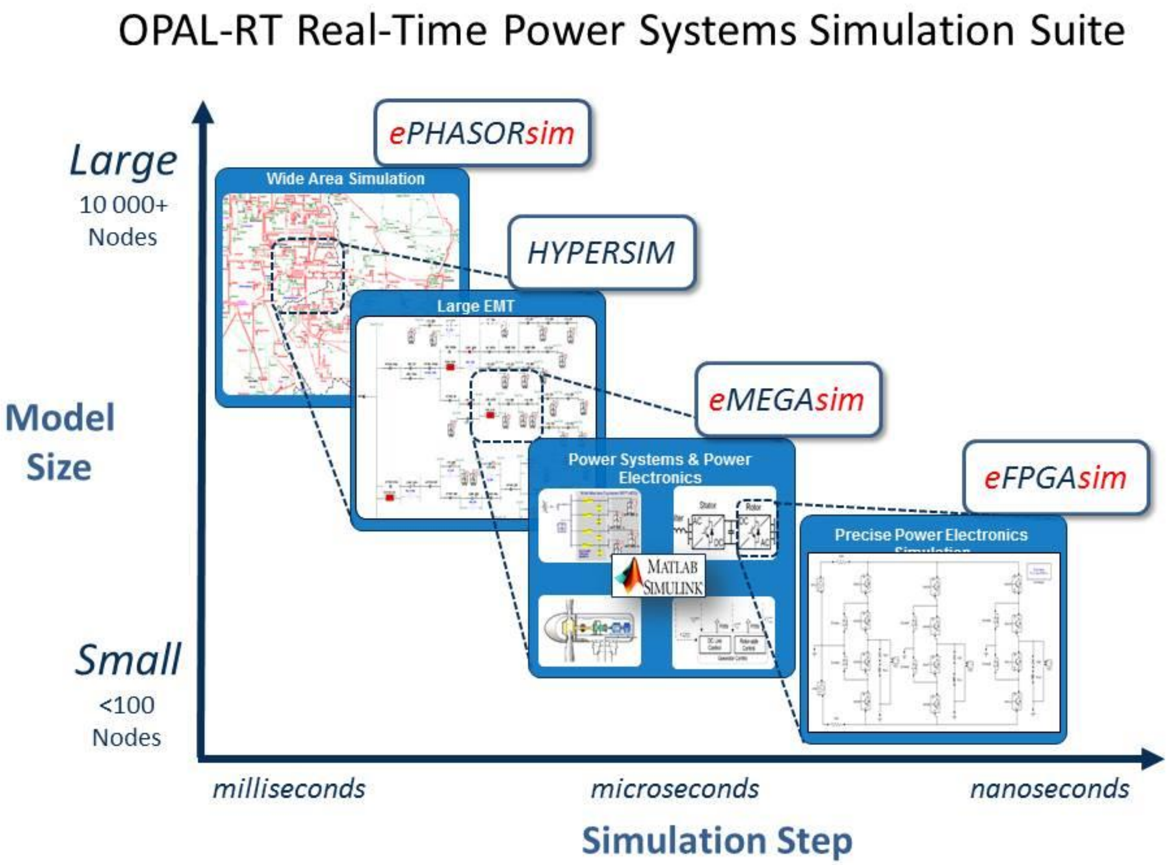

Figure 5: Simulation capabilities of the proposed MRTS system

It should be noted that the proposed MRTS system accepts models created in *MATLAB*/*Simulink*, *SimPowerSystems*, and *SimScape*, which is critical as most models at UT-CEM have been developed using this software. In addition, other program partners have existing models in the same modeling environment. Therefore, programs already developed in these packages would be able to run in the proposed real time simulator immediately with no modifications.

Finally, the proposed MRTS system provides a foundation for an expanded real time computational facility at UT-CEM, as the system can easily be scaled up by adding additional processors and interface units in the future. The initial processor's capabilities are summarized in Figure .

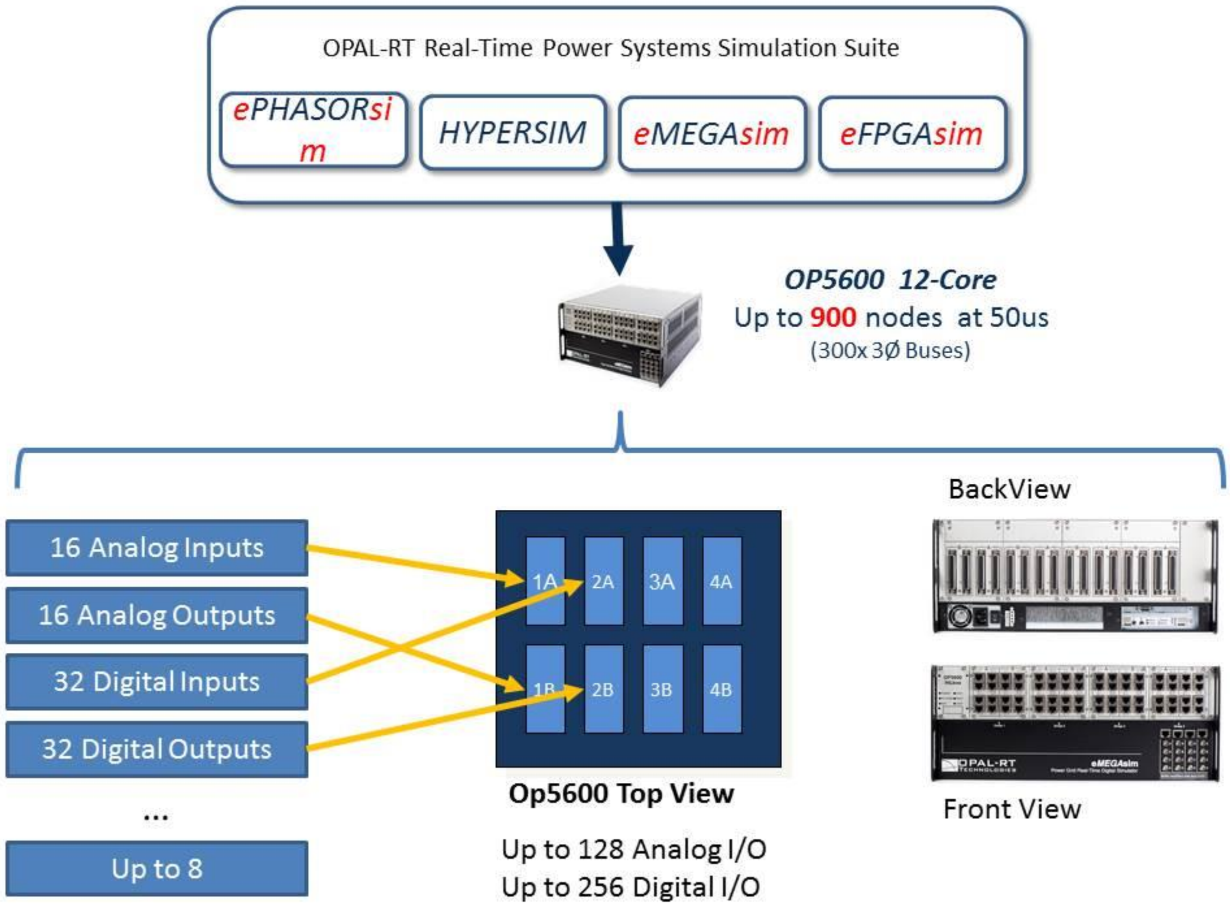

Figure 6: Capabilities of the processor planned for the initial MRTS

Summary of Key Results

The UT-CEM microgrid has already been used to perform experiments relevant to the CEED mission. A series of such experiments has been concerned with the sudden application or dropping off of a large load, and the sudden loss from or insertion into the system of a generating unit. The experimental study of the role of energy storage on the stabilization of the power bus has also begun.

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The MRTS also supports applied research projects for both undergraduate and graduate students focused on power system controls. During Summer 2016, two students from the University of Texas at Austin conducted internships at UT-CEM to learn more about designing power system controls. As a team, the two students developed a library of power system control algorithms. Control Hardware-in-the-loop (CHIL) connected with the MRTS was leveraged to validate the control algorithms. Once a control scheme was developed and tested using MATLAB Simulink, the plant model was migrated to the MRTS system while the controller would reside on a inverter board connected to the system. This configuration was used each time to test and validate each control algorithm. The next stage of testing for these controls will be Hardware-in-the-Loop (HIL) testing leveraging the power converters mentioned earlier in this report.