Project: Controls Evaluation and Partitioning Framework

Project Completion: Ongoing

Output:

A framework for evaluation system-level shipboard power systems has been developed. The proposed framework is specifically designed for HIL-based testing methods. A testbed to instantiate controls and provide a realistic power system environment has also been developed. This project is still ongoing and improvements continue to be made, in particular, as a better understanding is gained through exercising the framework with control implementations. Several publications have been produced [1, 2], which provide more details; additionally, several workshop presentations have been given [3, 4, 5, 6] .

Outcome:

A medium-scale controls evaluation testbed has been developed with 100 physically separate control platforms. A surrogate controller hardware-in-the-loop infrastructure with flexible interfaces to multiple DRTS vendor platforms has been realized.

Several control evaluation exercises have taken place with the developed testbed in order to refine the framework and processes. These exercises have been with control developed within the team, however, hosting externally developed controls is currently being pursued.

Project Motivation:

Automated power and energy management systems (APEMS) are unifying platform control systems that coordinate individual power system components and present appropriate information to system operators. These systems can be envisioned as three interacting planes comprised of power system components, communication components, and human system interface components. The interactions of components within each plane and across the planes form the APEMS. A multitude of approaches to develop various subsets of the APEMS have been proposed and are currently being worked upon. However, while low-level subsystem controls and top-level coordination algorithms have been addressed, APEMS integration processes that consider simultaneously the power system components, the control system elements, and the communication system have not been determined. Various control functions may be placed differently within the control system hierarchy resulting in a number of possible options each with potentially different requirements and interactions at the control partitions. The trade space in question involves functional and temporal partitioning options across multiple time scales. The objective of the proposed research is to develop a unified methodology for control function partitioning, determination of requirements, and evaluation of the APEMS through consolidated consideration of the power system components, the control system elements, and the communication system. In this initial project, some considerations will be given to the human system interface, but it will not be the focus of this work.

A unified, flexible, and scalable methodology is required in order to effectively evaluate performance and objectively contrast various candidate approaches for overall APEMS control. As such, this project is proposing development of real-time HIL testing methods, capable of realizing test environments of sufficient size and complexity to meaningfully validate and test APEMS control.

Figure 1 illustrates the proposed controls evaluation framework.

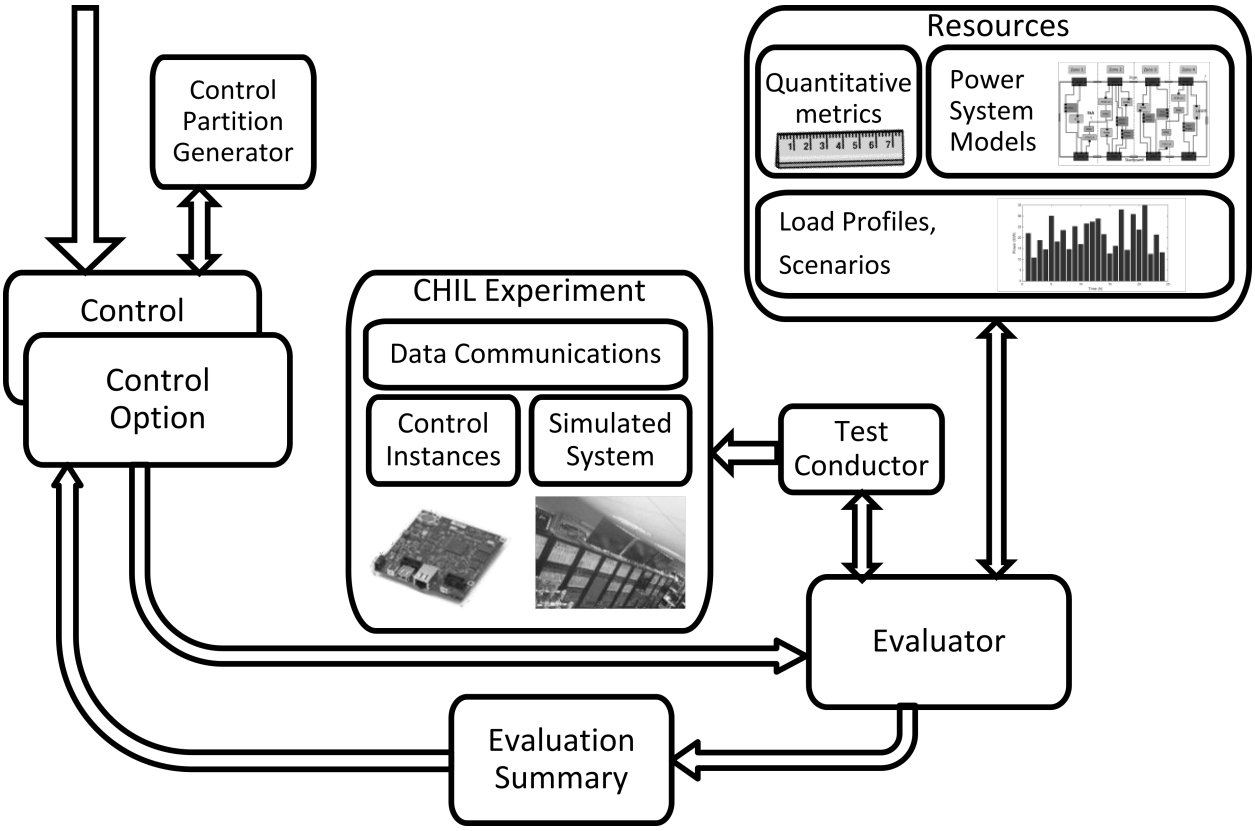

Figure 1: Overview of Proposed Framework

Project Extent:

This project involves multiple researchers from several ESRDC institutions and has been documented in the publications described above. The core team includes FSU-CAPS, USC, Drexel, USNA, and NSWCPD.

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References:

[1] K. Schoder, M. Stanovich, T. Vu, H. Vahedi, C. Edrington, M. Steurer, H. Ginn, A. Benigni, C. Nwankpa, K. Miu, and F. Ferrese. Control evaluation framework for power and energy management controls of shipboard distribution systems. In *Proc. of the IEEE Electric Ship Technologies Symposium (ESTS)*, August 2017.

[2] Mark Stanovich, Mike Sloderbeck, Harsha Ravindra, and et al. Implementation and baseline characterization of a heterogeneous controller hardware-in-the-loop simulation platforms. In *Proc. of the ASNE AMTS*, March 2018.

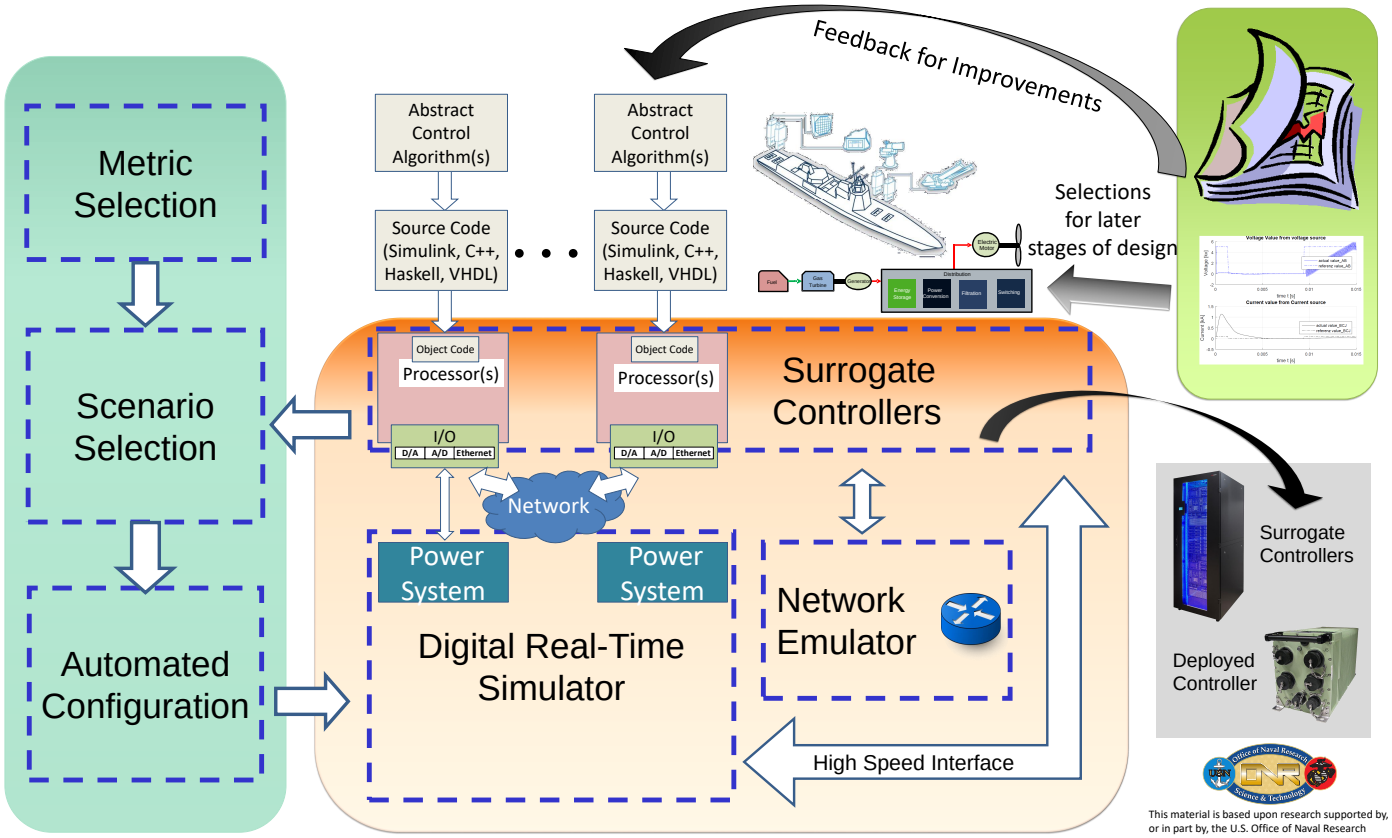
[3] Mark Stanovich, James Langston, Michael Sloderbeck, Matthew Bosworth, Karl Schoder, and Mischa Steurer. General-Purpose Data Recording. In *North American RTDS Applications & Technology Conference*, Winnipeg, Canada, May 2017.

[4] Karl Schoder, Mark Stanovich, Tuyen Vu, Hesan Vahedi, Chris Edrington, Mischa Steurer, Herb Ginn, Andrea Benigni, Karen Miu, and Frank Ferrese. Evaluation framework for power and energymanagement shipboard distribution controls. In *ONR Controls Workshop*, Philadelphia, PA, USA, August 2017.

[5] Mark Stanovich, Karl Schoder, Tuyen Vu, Hesan Vahedi, Chris Edrington, Mischa Steurer, Herb Ginn, Andrea Benigni, Karen Miu, and Frank Ferrese. Onr controls workshop presentation: Esrdc controls evaluation framework models, load profiles, evaluation metrics, partitioning. In *ONR Controls Workshop*, Arlington, TX, USA, March 2018.

[6] Mark Stanovich, Karl Schoder, Tuyen Vu, Hesan Vahedi, Chris Edrington, Mischa Steurer, Herb Ginn, Andrea Benigni, Karen Miu, and Frank Ferrese. Notes from onr controls workshop discussion: Esrdc controls evaluation frameworkmodels, load profiles, evaluation metrics, partitioning, March 2018.

Controls Evaluation Framework



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Controls Partitioning and Evaluation via HIL-based Methods

Objectives:

A. Evaluate and characterize “controls” including approaches and implementations

B. Methodology for partitioning and evaluating control functionality

Approach:

A. Define and categorize “controls” (e.g., algorithms, functions, HW, SW)

B. Metrics to measure control performance (e.g., scalability)

C. Large-scale CHIL capability

D. Surrogate control hardware

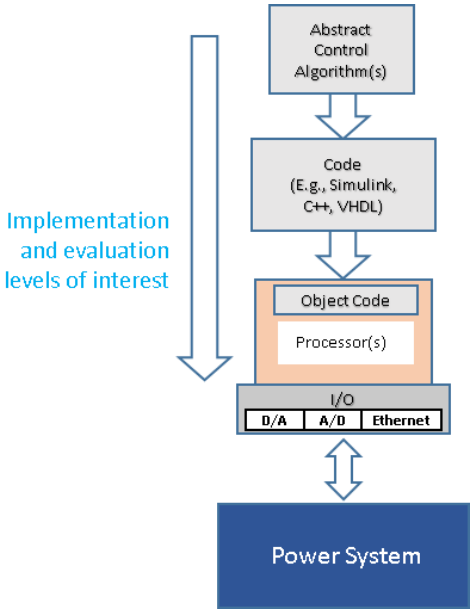
E. Data communications emulation

F. HPC co-simulation

G. Adversarial Testing Methodology

H. Automated testing

I. Standardize HIL port on field deployed controllers



Scientific or Naval Impact/ Results:

- Choose the best control approaches and implementations among many options
- Improve control development efficiency
- More seamless control integration