THE AMERICAN MODELICA CONFERENCE 2020

MARCH 23–25 | UNIVERSITY OF COLORADO BOULDER | WWW.MODELICA.ORG

Modelica

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WELCOME

Twenty years ago, my co-chair Michael Tiller invited to me come to the United States to help establish Modelica technology at the Ford Research Lab in Dearborn, MI. That was the first seed for the use of Modelica in the US: exciting, but a bit lonely. I am glad to recognize how far we have come since then, both internationally and in the United States. Today, Modelica is often the technology of choice when Model Based Design is part of a research project, as is evident from projects by the U.S. government agencies DARPA, ARPA-e, and DOE for the building sector as well as the NASA CHEETA project for all-electric aircraft.

I am personally very much looking forward to this conference. The Modelica community and its conferences are passionate about the technology and collaborative in spirit. As always, there won't be enough time to catch up with colleagues on their research, and the talk at the coffee breaks will be enthusiastic. This friendly, open exchange of ideas has enabled this technology to grow from an idea to several internationally recognized standards.

I would like to thank the Modelica Association and the North American Modelica User Group for their support and the time they put in to make this a great event, and of course also the Program Committee for the reviews that are responsible for making this a high-quality conference. Many thanks are also due to the University of Colorado Boulder, and the local organizers, especially Jessica Stershic and Professor Wangda Zuo, for their engagement and support. This is now the second American Modelica Conference. I am glad that we have been able to establish this conference as a regular event. With that, I welcome all of you to this conference on the beautiful main campus of the University of Colorado Boulder!

Dr. Hubertus Tummescheit
Conference Co-chair

CONFERENCE DETAILS

The workshops will take place on Monday, March 23 in the 3rd and 4th floors of the Center for Academic Success and Engagement (CASE) at CU Boulder in rooms W311, W313, E351, and E422. The conference will take place at the University Memorial Center (UMC) at CU Boulder in the Glenn Miller Ballrooms (rooms 208, 210, and 212) on Tuesday and Wednesday, March 24-25. These buildings can be located on the following maps (p. 8) or via internet mapping services at:

CONFERENCE ADDRESS:
University Memorial Center, Boulder, CO 80302

WORKSHOP ADDRESS: 1725 Euclid Avenue, Boulder, CO 80309

CONFERENCE WEBSITE:
https://modelica.org/events/modelica2020Americas/

All updated conference information can be found at the website, including conference papers, and abstracts.

EMERGENCY INFORMATION: To report an emergency, call 9-1-1, or call the CU Police Department (CUPD) at 303-492-6666.

INTERNET/WIFI: Information to connect to the wireless internet is available at: http://bit.ly/AMC20Wifi

MEALS: Breakfast, coffee breaks, and lunches will be provided during the conference.

DIRECTIONS AND ASSISTANCE: Graduate students from Prof. Wangda Zuo's group here at CU Boulder at the conference have graciously offered to provide directions or other help to the conference attendees. They can be identified by their lab polos or the multicolored ribbon on their jackets.

TRANSPORTATION: Boulder is a very walkable town and has great public transportation. Parking for those driving to the conference from their hotel is available at the Euclid and Folsom parking garages, which are illustrated in the accompanying maps. Guests needing a parking pass can purchase one from the CU Boulder online parking site at https://cuboulder.pmreserve.com/ : click on the link lableled "North America Modelica Conference 2020", and enter 2055987 for the Euclid Parking Garage or 3915987 for the Folsom Parking Garage. Click the Update button. The parking permit price is $17.00, and will be valid for the duration of the conference. You will need to provide the vehicle license plate information when purchasing the parking pass; we would recommend waiting to purchase this pass until after you have obtained your rental car. When parking, please make sure your license plate is visible from the driving lane. Boulder also has Uber, Lyft, and taxis, as well as bikes that are available for rent.

CONFERENCE DINNER: The conference dinner will take place at the Dushanbe TeaHouse on March 24 from 6pm to 11pm, located at 1770 13th St. in Boulder. The TeaHouse is a popular place to visit while in Boulder. It was first built in Tajikistan and then disassembled and relocated in Boulder, and is a symbol of friendship between Dushanbe, Tajikistan, and Boulder. While you are there, make sure to take in the art and surroundings of this beautiful building.

Conference attendees are responsible for their own transportation from the conference site to the Dushanbe TeaHouse. While parking is available at the TeaHouse, some conference attendees may be interested in walking the 20 minutes from the conference site to the restaurant to stretch their legs.

To walk from the University Memorial Center to the TeaHouse, first exit the UMC and head south towards Broadway Avenue. Walk north along Broadway Avenue until you reach Arapahoe Avenue. At this intersection, turn right onto Arapahoe Avenue. Walk along Arapahoe Avenue for 1 block until you reach 13th Street and then turn left. The Dushanbe TeaHouse will be half a block down on the right.

Driving from the UMC to the TeaHouse yields similar directions; find your way onto Broadway Avenue and drive North for 0.7 miles. Turn right onto Arapahoe Avenue and then one block later turn left onto 13th Street.

REGISTRATION DESK: The registration desk is open from Tuesday, March 24 at 7:30am through the duration of the conference.

TOURIST INFORMATION: Boulder is a wonderful town and we recommend taking some time to explore it. The City of Boulder visitor's website (bouldercolorado.gov/visitors) has plenty of information and recommendations. If you fancy a nearby hike, Chautauqua Park is very close. Please be aware of the nearby parking and that conditions vary depending on the weather. Snow activities are also very popular. While skiing, snowboarding, and snowshoeing information can generally be found on Google, ColoradoSki.com/resorts may be a good place to start. Again, make sure to stay informed about local conditions, parking, and weather.

WORKSHOP A-1

Introduction to Modelica with Modelon Impact

Hubertus Tummescheit, John Batteh (Modelon)

DURATION: 4 hours

ABSTRACT: This workshop will give an introduction to Modelica with a focus on model users. We present the principles of modeling with Modelica and efficient use of model libraries using various multi-domain examples selected to make the workshop attractive for engineers from all branches of engineering. Simulations will be run on Modelon's cloud-native Modelica platform, Modelon Impact.

EXPECTED EXPERIENCE: Some familiarity with system simulation.

SOFTWARE REQUIREMENTS: Laptop with recent version of either Google Chrome or Opera installed. 8GB of memory is recommended.

WORKSHOP A-2

Thermo-fluid System Modeling with the Modelica Buildings Library

Michael Wetter (Lawrence Berkeley National Laboratory)

DURATION: 4 hours

ABSTRACT: This workshop will give an introduction on the modeling of thermo-fluid systems and their control using Modelon's latest graphical editor. We will be using applications from the Buildings library, but the course will be structured to also appeal to modelers from other application domains that are concerned with thermo-fluid systems. After an introductory presentation that discusses the scope of the Modelica Buildings Library, we discuss best practice in setting up thermofluid flow models and how to avoid potential problems. In hands-on exercises, participants will build models of simple heating and air conditioning systems, link them to a thermal load, and add feedback control. The models will be built using components from the Buildings library. Simulations will be run on Modelon's cloud-native Modelica platform, Modelon Impact.

EXPECTED EXPERIENCE: Participants are expected to have either basic knowledge of Modelica, or have attended Workshop A-1.

SOFTWARE REQUIREMENTS: Laptop with recent version of either Google Chrome or Opera installed. 8GB of memory is recommended.

WORKSHOP B-1

Python Interface for Modelica simulation in Dymola

Behnam Afsharpoya, Tamer Yanni (Dassault Systèmes)

DURATION: 3 hours

ABSTRACT: Interfacing software languages such as Python with the Modelica language and Dymola provides more capabilities for integration between simulation tools. It also permits flexible scripting for common tasks. This hands-on workshop provides practical examples for implementing these methodologies.

EXPECTED EXPERIENCE: General knowledge of Modelica, basic knowledge of Python for simple scripting

SOFTWARE REQUIREMENTS: Please download and install Dymola ahead of the workshop directly from https://www.3ds.com/products-services/catia/products/dymola/trial-version/

Temporary Dymola license will be provided during the training, while Python packages and example codes will be provided before the class.

WORKSHOP B-2

Web-Based System Simulation and Collaboration

Tom Bancroft, Michael Tiller (Ricardo)

DURATION: 3 hours

ABSTRACT: Web-based tools open up new possibilities for collaboration and data management. In this workshop, we will provide a tutorial on using Modelica with no previous Modelica experience required. Experienced Modelica users can, of course, explore the tooling beyond the examples presented. The tutorial will demonstrate our thoughts on the future of system simulation and collaboration.

EXPECTED EXPERIENCE: No prior Modelica experience required.

SOFTWARE REQUIREMENTS: A computer with a modern browser (preferably Chrome).

WORKSHOP C-1

Introduction to TRANSFORM

Scott Greenwood (Oak Ridge National Laboratory)

DURATION: 3 hours

ABSTRACT: The TRANSient Simulation Framework Of Reconfigurable Modules (TRANSFORM) is an ORNL-developed component library created using the Modelica programming language for the investigation of dynamic thermal-hydraulic systems and other multi-physics systems. This library has been successfully used for a variety of advanced energy applications, including investigations into the performance of nuclear hybrid energy systems, liquid metal and gas cooled reactors, and molten salt applications including kinetic behavior and fission product transport. This tutorial will introduce the user to TRANSFORM by providing step-by-step instruction on the creation of a closed thermal-hydraulic loop. Topics covered in the tutorial include pipe models, fluid media, pumps, discretized heat structures, nuclear kinetics, and controls. Attendees will leave the tutorial with a good understanding of TRANSFORM and the essential skills necessary for creating more complex applications to meet their modeling needs.

EXPECTED EXPERIENCE: Beginner to intermediate experience; no advance knowledge of TRANSFORM is necessary. The training is expected to follow training session 3 and 4 from the TRANSFORM training GitHub repository, and it may be helpful to download those pdfs before attending, available at https://github.com/ORNL-Modelica/TRANSFORM-Training/tree/master/TrainingSlides/2019

SOFTWARE REQUIREMENTS: The training will use Dymola. Attendees must have it installed and functional before attending. Please also download the TRANSFORM library prior to attendance: https://github.com/ORNL-Modelica/TRANSFORM-Library

WORKSHOP C-2

Cyber-physical System Modeling using Modelica for Smart and Sustainable Communities

Jing Wang, Jessica Stershic, Prof. Wangda Zuo (University of Colorado, Boulder), Dr. Sen Huang (Pacific Northwest National Laboratory)

DURATION: 4 hours

ABSTRACT: This workshop is co-organized by the Sustainable Buildings and Societies Laboratory at University of Colorado Boulder and the Pacific Northwest National Laboratory. In this workshop, the basics of equation-based object-oriented modeling using Modelica will be introduced through the demonstration of two libraries. The Net-Zero Energy Community (NZEC) library provides component and system models needed for the modeling of communities with renewable energy, heat pump systems and domestic hot water systems, and other sustainable technologies. Additionally, stochastic simulation methods for predicting occupant arrival and departure times using Modelica will also be introduced. In addition, the Smart and Connected Community (SCC) library has components to build and experiment with interdependent energy, transportation, and communication infrastructures at the community level. Through the pre-built examples, the users can explore the physical, geographical and informational interdependencies among the three systems. This workshop will first have presentations addressing the background, motivations, and challenges for community modeling, during which participants can ask questions. The group will then build example models together, during which instructions will be provided.

EXPECTED EXPERIENCE: Beginner to intermediate experience.

SOFTWARE REQUIREMENTS: Please download and install Dymola ahead of the workshop. Temporary licenses will be provided on-site.

WORKSHOP D-1

Introduction to Object-Oriented Cyber-Physical Modeling and Simulation with Modelica using OpenModelica

Bernhard Bachmann (Bielefeld University of Applied Sciences), Luigi Vanfretti, Marcelo de Castro Fernandes (Rensselaer Polytechnic Institute)

DURATION: 4 hours

ABSTRACT: This tutorial will give an introduction to the fundamentals of the Modelica language for object-oriented modeling and simulation, and to the OpenModelica "ecosystem" of open source tools for cyber-physical modeling and simulation. The tutorial will carry out hands-on examples using the OpenModelica editor (OMEdit) and the OMNotebook interactive notebook software from the Open-Source Modelica Consortium (OSMC). Important mathematical aspects of object-oriented modeling, simulation, and optimization will be demonstrated on basic examples and hand-on exercises. The tutorial is meant for beginners getting started with Modelica, and only assumes the attendee has some familiarity with programming and general computing skills.

EXPECTED EXPERIENCE: No prior Modelica experience required.

SOFTWARE REQUIREMENTS: Please download and install OpenModelica 1.14.1 from https://openmodelica.org/download/download-windows ahead of the workshop.

DAY 1

7:30 AM	9:00 AM	registration and mingle
9:00 AM	10:20 AM	Vendor Session
10:20 AM	10:40 AM	coffee break
10:40 AM	12:00 PM	Vendor Session and News
12:00 PM	1:30 PM	lunch
1:30 PM	2:15 PM	Keynote 1 | Mark Jennings
2:15 PM	2:20 PM	switch rooms
2:20 PM	3:35 PM	Paper Session 1 | 3 Papers/Room
3:35 PM	4:00 PM	coffee break
4:00 PM	5:15 PM	Paper Session 2 | 3 Papers/Room
5:15 PM	6:00 PM	transportation to conference dinner
6:00 PM	11:00 PM	Conference Dinner at Dushanbe Teahouse

DAY 2

7:30 AM	8:20 AM	mingle
8:20 AM	9:35 AM	Paper Session 3 | 3 Papers/Room
9:35 AM	10:00 AM	coffee break
10:00 AM	12:20 PM	User Presentations | 6 Presentations/Room
12:20 PM	1:50 PM	lunch
1:50 PM	2:35 PM	Keynote 2 | Chris Gearhart
2:35 PM	2:40 PM	switch rooms
2:40 PM	3:30 PM	Paper Session 5 | 2 Papers/Room
3:30 PM	4:00 PM	coffee break
4:00 PM	5:00 PM	Podium Discussion and Wrap-Up

ROOM 1

DAY 1

Paper Session 1 Power Systems I

Multi-market Optimization of a Data Center without Storage Systems
Yangyang Fu, Wangda Zuo, Kyri Baker

Micro-grid Design and Cost Optimization using Modelica
Natesa MacRae, John Batteh, Imran Kahn, William Skrivan, Darren Jang

Performance Benchmark of Modelica Time-Domain Power System Automated Simulations using Python
Sergio A. Dorado-Rojas, Manuel Navarro Catalan, Marcelo de Castro Fernandes, Luigi Vanfretti

Paper Session 2 Thermofluid Systems & HVAC

Fast Simulations of Air Conditioning Systems Using Spline-Based Table Look-Up Method (SBTL) with Analytic Jacobians
Lixiang Li, John Batteh, Jesse Gohl, Christopher Greiner, Kai Wang

Data-driven Prediction of Occupant Presence and Lighting Power: A Case Study for Small Commercial Buildings
Jing Wang, Wangda Zuo, Sen Huang, Draguna Vrabie

Development and Verification of Control Sequences for Single-Zone Variable Air Volume System Based on ASHRAE Guideline 36
Kun Zhang, David Blum, Milica Grahovac, Jianjun Hu, Jessica Granderson, Michael Wetter

DAY 2

Paper Session 3 Power Systems II

Hierarchical Multi-Level Electric Power System Simulation with Smart Photovoltaic Systems using the Functional Mock-up Interface on the Lawrencium Computing Cluster
Christoph Gehbauer, Joscha Müller

Modeling Future Heat Pump Integration in a Power Grid Radial
Konstantin Filonenko, Mikkel Copeland, Klaus Jespersen, Christian Veje

ROOM 2

DAY 1

Paper Session 1 Mechanical Systems I

A Modelica Library for Continuous and Discrete Extremum Seeking for Static and Dynamic Systems
Joscha Müller, Maxime Baudette, Daniel Arnold, Michael Sankur

Modeling and Simulation of Filippov System Models with Sliding Motions using Modelica
Mohammed Ahsan Adib Murad, Luigi Vanfretti, Federico Milano

Modeling Contact and Collisions for Robotic Assembly Control
Scott Bortoff

Paper Session 2 Mechanical Systems II

Modelica Component Models for Oceanic Surface Waves and Depth Varying Current
Savin Viswanathan, Christian Holden

Modelica Component Models for Non-diffracting Floating Objects and Quasi-static Catenary Moorings
Modelica Component Models for Non-diffracting Floating Objects and Quasi-static Catenary Moorings

The Rotorcraft Aerodynamics Library: A Modelica Library for Simulation of Rotorcraft Aerodynamics and Whirl Flutter
Cory Rupp, Nicolas Reveles

DAY 2

Paper Session 3 Language & Tools

Application of Model-Based Testing to Dynamic Conformance Evaluation of Functional Mockup Units
Cláudio Gomes, Romain Franceschini, Nick Battle, Casper Thule, Kenneth Lausdahl, Hans Vangheluwe, Peter Gorm Larsen

Contributions to the Efficient and Parallel Jacobian Evaluation and its Application in OpenModelica
Willi Braun, Martin Schroschk, Vitalij Ruge, Andreas Heuermann, Bernhard Bachmann

ROOM 1

DAY 2 (CONTINUED)

Paper Session 3 Power Systems II (continued)

Parameter Estimation of User-Defined Control System Models for Itaipú Power Plant using Modelica and OpenIPSL
Meaghan Podlaski, Luigi Vanfretti, Jonas Pesente, Marcelo de Castro Fernandes

User Presentations Building Applications

Open Source Modelica Models for Data Center Cooling
Open Source Modelica Models for Data Center Cooling

Template-based District Thermal Energy System Models for URBANopt with Modelica
Nicholas Long, Amy Allen, Antoine Gautier, Yanfei Li

Development of a Modelica Building Emulator for Model Predictive Control Applications
Tao Yang, Konstantin Filonenko, Krzysztof Arendt, Christian Veje

OpenModelica Implementation of PCM Ventilation Unit
Konstantin Filonenko, Viktor Ljungdahl, Tao Yang, Christian Veje

A Modeling Framework to Evaluate Energy, Transportation, and Communication Interdependence in Smart and Connected Communities
Jessica Stershic, Xing Lu, Kathryn Hinkelman

Reactive Power Modeling for Building Systems to Support Building-to-Grid Integration Studies
Sen Huang, Yuan Liu, Jianming Lian, Yangyang Fu, Draguna Vrabie, Wangda Zuo

Paper Session 4 FMI

Parameter Estimation Methods for Fault Diagnosis using Modelica and FMI
Ahmad Alsaab, Morgan Cameron, Colin Hough, Purna Musunuru

Nonlinear State Estimation with FMI: Tutorial and Applications
Christopher Laughman, Scott Bortoff

ROOM 2

DAY 2 (CONTINUED)

Paper Session 3 Language & Tools (continued)

Traceability in the Model-Based Design of Cyber-Physical Systems
Christian König, Alachew Mengist, Carl Gamble, Jos Höll, Kenneth Lausdahl, Tom Bokhove, Etienne Brosse, Oliver Möller, Adrian Pop

User Presentations Systems Applications

TRANSFORM: A Solution for Advanced System Modeling
Scott Greenwood

Teaching a Course on Modeling and Simulation for Cyber-Physical Systems using Modelica and FMI Technologies with Hands-on-Laboratories
Luigi Vanfretti

Open Instance Power System Library: a Modelica Library for Phasor Time-Domain Simulations
Marcelo de Castro Fernandes, Maxime Baudette, Manuel Navarro, Luigi Vanfretti

Passenger Cabin Comfort and Operating Environment Impact on Battery Electric Vehicle Range Using Multi-Domain Coupled Analysis
Tamer Yanni, Chin-Wei Chang, Jyothi Matam, Vijaisri Nagarajan, Adrien Mann

Dymola and Simulink in Co-Simulation: A Vehicle Electronic Stability Control Case Study
Theodor Ensbury, Mike Dempsey, Nate Horn

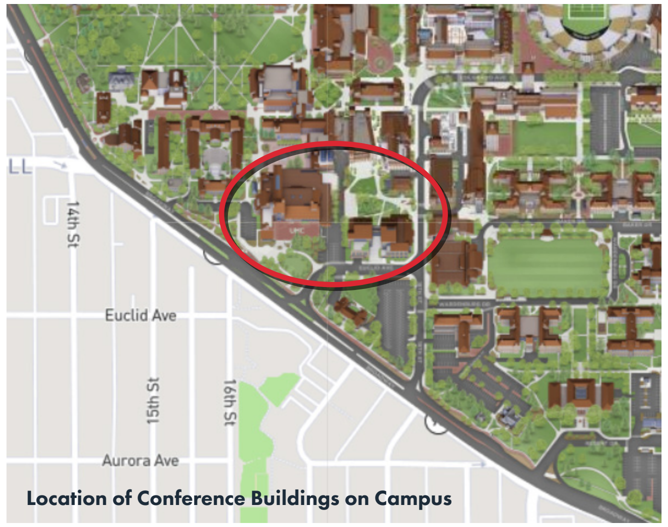
Modelling and Validation of Control Systems Through the Excitation of the Hydroelectric Power Station Sopladora Using OpenModelica
Melissa Ontano, Carla Parra, Edison Pogo, Javier Urquizo

Paper Session 4 Electromechanical Systems

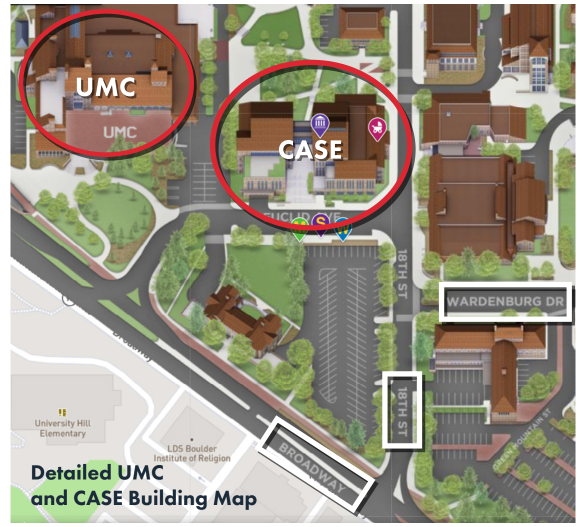
Enhanced Steady-State in Modelon Jet Propulsion Library, an Enabler for Industrial Design Workflows
Clément Coïc, Moritz Hübel, Matthis Thorade

Object Oriented Modeling and Control Design for Power Electronics Half-Bridge Converter using Modelica
Giuseppe Laera, Luigi Vanfretti, Kyle Thomas, Matthew Gardner

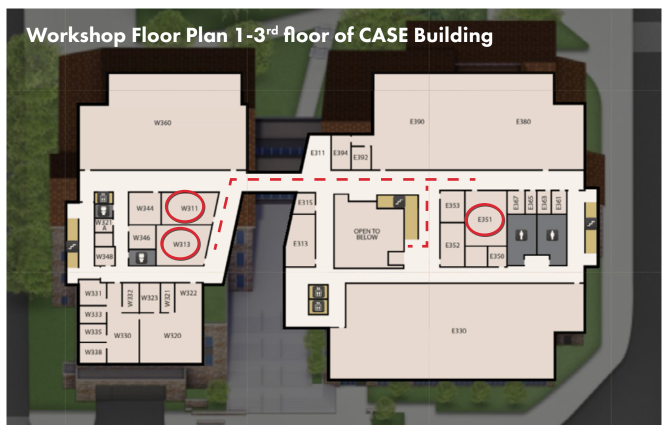
Modelica

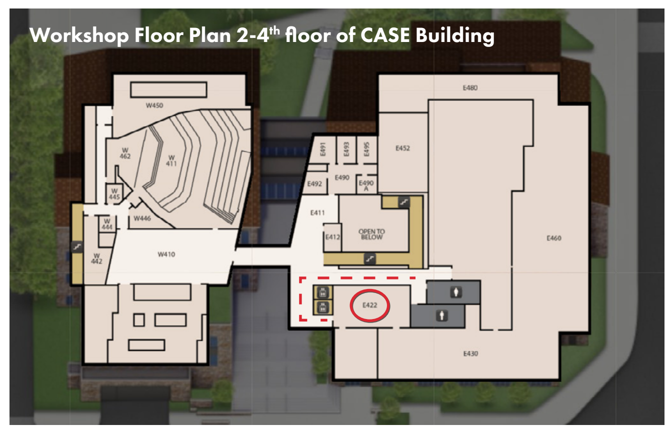


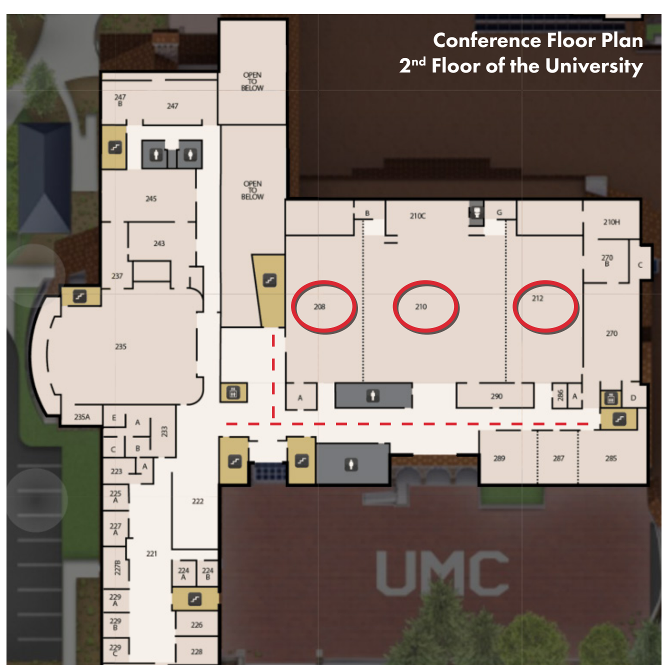
Location of Conference Buildings on Campus



Detailed UMC and CASE Building Map


Workshop Floor Plan 1-3rd floor of CASE Building


Workshop Floor Plan 2-4th floor of CASE Building



Conference Floor Plan 2nd Floor of the University

ABSTRACTS

MARK JENNINGS

Senior Technical Leader, Vehicle Energy Management & Propulsion Systems Analysis; Research & Advanced Engineering, Ford Motor Company

ABSTRACT

Automotive Electrified Vehicle & Powertrain System Modeling, Simulation & Optimization

In recent years, key external drivers and technology trends including societal concern for climate change and emphasis on improvement of air quality, rapid expansion of renewable energy sources and emergence of vehicle connectivity have greatly accelerated the move towards electrification for on road vehicle propulsion. In response, Ford has greatly increased its investments in the electrification of its product portfolio. Core to Ford's product portfolio is a set of electrified powertrain system architectures encompassing HEV, PHEV and BEV systems spanning a range of vehicle applications with both lateral (front wheel drive) and longitudinal (rear wheel drive) driveline configurations.

The aggressive move towards electrification has been accompanied by an equally aggressive move towards reliance on model-based system design, development and optimization. This has been driven by critical needs of the business: the need to reduce development costs; the need to reduce development time for delivery of new technologies to the marketplace; and the need to better understand, manage and optimize critical attribute trade-offs and system interactions in order to realize the full potential of powertrain electrification.

Critical areas of importance to Ford for further expansion of powertrain system modeling and simulation capabilities and methodologies are highlighted and discussed. These include:

- Better optimization of in-vehicle IC engine operation for HEV's
- Thermal management and climate system design optimization
- Energy efficiency trade-offs with drivability
- On road energy management and emissions including interactions with driver assistance technologies and automated driving systems
- Leveraging connectivity for improved powertrain attributes
- Establishment of an enterprise level virtual vehicle development process

BIO

Mark Jennings is Senior Technical Leader for Vehicle Energy Management & Propulsion Systems Analysis for Ford Motor Company working in Ford's Research & Advanced Engineering organization on electrified powertrain systems. Over the past 20 years, he has been leading efforts to establish and apply model-based development and optimization methodologies towards the advancement of electrification technologies for vehicle propulsion. This work has covered a range of modeling & simulation approaches spanning hardware capability assessments leveraging optimal control methods through direct simulation and optimization of complex, coupled feedback control and physical hardware systems.

Mark's work on electrified powertrain systems has covered a range of system technologies encompassing mild/medium hybrid electric vehicle (HEV) systems, full HEV systems, plug-in HEV systems, battery electric vehicles and fuel cell electric vehicles. Throughout his years at Ford, he has led numerous efforts to define and assess new electrified powertrain system concepts. Through this work he has had played a significant role in defining Ford's powertrain electrification strategy.

Mark has pioneered the development of novel model based system engineering methods for electrified powertrain systems including the integration of SysML with highly detailed system simulation methodologies. Mark has led the development of model based calibration methods for HEV system controls. These methods have been successfully deployed in the development of Ford's production HEV systems and resulted in significant savings of engineering time and effort as well as reduction in the use of vehicle prototypes. Mark has also established novel model-based methods for early, pre-hardware development and optimization of new powertrain system technologies including assessing impact as and trade-offs with vehicle attributes.

Mark has BS, MS and PhD degrees in Mechanical Engineering. In addition to his experience in electrified powertrain systems and powertrain system simulation methodologies, Mark has extensive experience in multi-dimensional modeling & simulation of turbulent flows, heat transfer and combustion.

CHRIS GEARHART

Director, Center for Integrated Mobility Sciences

ABSTRACT

Modeling and Simulation in Sustainability Research at NREL

Sustainable transportation research has evolved beyond vehicles and fueling systems to new, innovative, and integrated mobility strategies that have the potential to transform the movement of people and goods, enhance national energy security, boost the domestic economy, and save individuals and businesses both time and money. This can be achieved through an ecosystem that integrates technology advancements with a range of domestic energy resources, power grids and building systems, urban planning and efficient fleet operations. Modeling and simulation play a vital role in understanding these complex interactions. Dr. Gearhart will talk about the growing and evolving role of simulation in sustainability research at NREL's Center for Integrated Mobility Sciences.

BIO

Chris Gearhart joined the National Renewable Energy Laboratory (NREL) in 2012 as director of the Hydrogen Technologies and Systems Center. In 2013 he was appointed to his current position as director of NREL's Center for Integrated Mobility Sciences (formerly known as the Transportation and Hydrogen Systems Center), where he manages a staff of more than 150 scientists and engineers dedicated to understanding the science and engineering needed to efficiently and sustainably move people and goods in a highly integrated system of systems.

Prior to joining NREL, Dr. Gearhart spent 16 years with Ford Motor Company. He started his career at Ford working in computer aided engineering developing finite element, CFD, and multi-body dynamics models. He went on to lead research and development teams in that company's Fuel Cell System, Stack, and Hydrogen Storage division as well as playing pivotal roles in product development, safety research, and reliability engineering.

He holds doctorate and master's degrees in physics from Washington University in St. Louis, where he used computational models to study heavy nuclei and neutron stars. He has bachelor's degree in physics and math from Drake University. Dr. Gearhart has also served on the faculty of Michigan State University and the School for Renewable Energy Science in Akureyri, Iceland.

MULTI-MARKET OPTIMIZATION OF A DATA CENTER WITHOUT STORAGE SYSTEMS

Yangyang Fu[1] | Wangda Zuo[1,2] | Kyri Baker[1,2]

[1]Department of Civil, Architectural and Environmental Engineering, University of Colorado Boulder, USA,
[2]National Renewable Energy Laboratory, USA

Data centers have numerous opportunities to participate in demand response programs considering their large capacities, flexible working environments and work loads, redundant design and operation, etc. Frequency regulation, as one service provided in demand response programs, can also benefits the data centers. This paper aims to develop a real-time multi-market optimization framework for a data center without storage systems to maximize their benefits from participating in both the energy market and the regulation market. Then a case study is conducted to numerically investigate the optimal bids at each hour by considering the energy cost, demand costs, and regulation revenues using a virtual data center located in PJM. Simulation results show that the proposed multi-market optimization framework can help data centers maintain minimum costs by getting maximum regulation revenues while satisfying energy and demand goals.

MICRO-GRID DESIGN AND COST OPTIMIZATION USING MODELICA

Natesa MacRae[1] | John Batteh[2] | William Skrivan[1]
Stéphane Velut[3] | Imran Khan[1] | Darren Jang[1]

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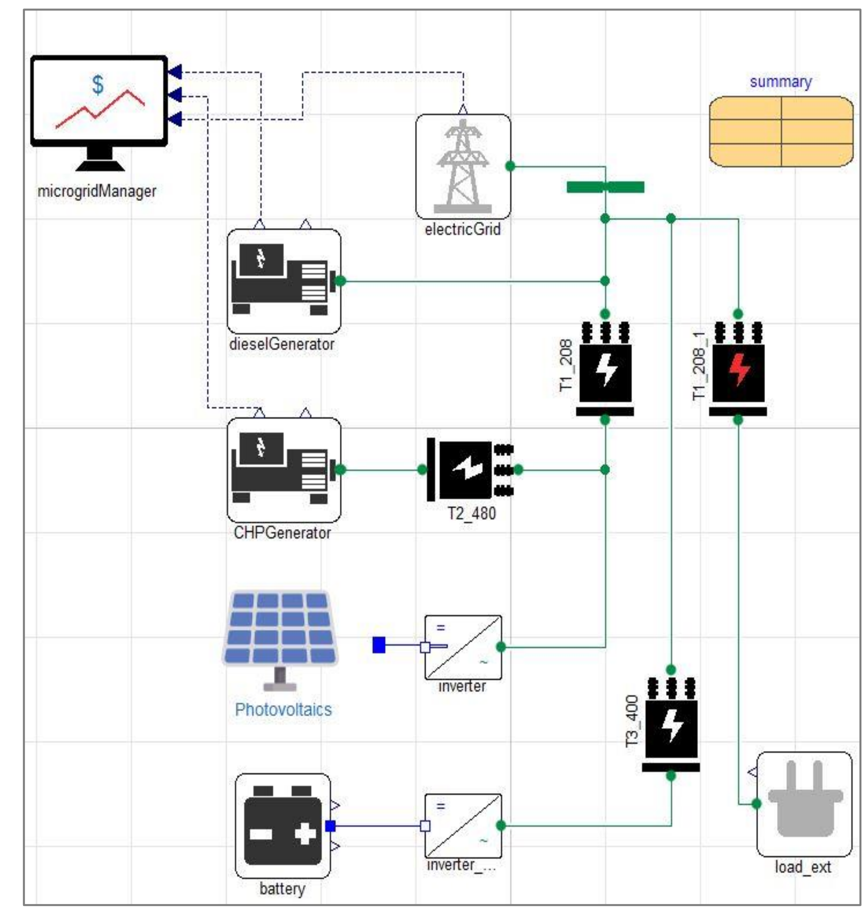
[2]Modelon Inc., USA, {john.batteh}@modelon.com
[3]Modelon AB, Sweden, {stephane.velut}@modelon.com

This paper describes the modeling of the National Research Council of Canada (NRC) Micro-Grid Testing and Training Facility, which will be used to advance energy generation and storage technologies and optimize integrated system operations for a variety of micro-grid applications. First, integrated system models were assembled using the Microgrid Modelica library, developed by Modelon. Next, three use cases were defined based on the Whale Cove, Nunavut micro-grid operating in: 'island mode' without renewables (present mode), island mode with renewables, and grid-connected mode. Various simulations, as well as design and economic optimizations were then performed. Through these analyses, it was shown that each parameter domain could be successfully assessed using this modeling framework, demonstrating the flexibility of both the modeling platform and the potential of the physical test facility to support in-depth analysis for different micro-grid configurations, technologies, and applications.



PERFORMANCE BENCHMARK OF MODELICA TIME-DOMAIN POWER SYSTEM AUTOMATED SIMULATIONS USING PYTHON

Sergio A. Dorado-Rojas | Manuel Navarro Catalán
Marcelo de Castro Fernandes | Luigi Vanfretti

Department of Electrical, Systems and Computer Engineering
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As the Modelica language one tool become a more widespread for modeling and simulation, tool development and performance become more critical. Free tools such as Open-Modelica are fundamental for learning the language at little to no cost and to set a baseline for Modelica tool's performance. Commercial tools such as Dymola, SystemModeler or SimulationX provide advanced functionalities that satisfy particular requirements from their users. However, there is no clear guidance for a user on how to select a tool/solver based on its simulation performance exclusively.

This paper aims to provide a clear benchmark between solvers and Modelica tools for time-domain simulations of a power system model. A Python-based approach is employed to automate Modelica simulations and compute performance metrics. This routine is employed to compare the performance of a commercial (Dymola) against an open source (OpenModelica) simulation tool with different solver settings. The benchmark uses the IEEE14 bus power system model due to its popularity in power system analysis literature (Milano., 1998).

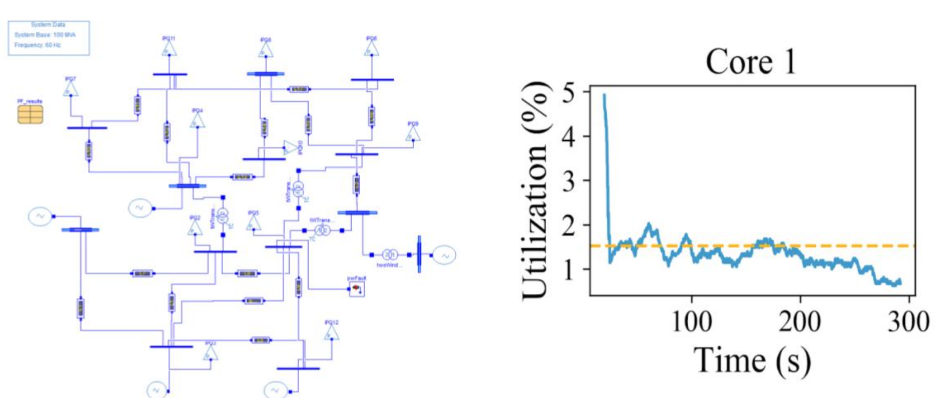

FIGURE 1. Simulation model and core utilization for one of the experiments conducted.

Python scripts were developed to execute the model in both tools, different solvers and in three different scenarios: 1) System Initialization, 2) Line Opening, and 3) Bus Fault. This degree of automation makes it easier to change solver settings and tools during execution. The performance of each of the tools is assessed through metrics such as execution time and CPU utilization. The quantitative comparison results provide a clear baseline of the performance of the tools and solvers for the execution of time-domain simulations with a significant degree of complexity. The commercial tool offers better performance for a variable-step solver, but the performance of the open-source software shows significantly faster results for fixed-step solvers.

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A MODELICA LIBRARY FOR CONTINUOUS AND DISCRETE EXTREMUM SEEKING FOR STATIC AND DYNAMIC SYSTEMS

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Extremum Seeking (ES) is an optimization scheme that has become a popular tool for addressing decision-making problems in settings where system models are unavailable or inaccurate and communications are unreliable. This paper presents an open source Modelica Extremum Seeking library that introduces different continuous and discrete ES controllers and examples for possible ES control applications. The controllers are available for Modelica and in the Functional Mock-up Interface (FMI) standard, which allows the models to be used in a variety of different software environments.

MODELING AND SIMULATION OF FILIPPOV SYSTEM MODELS WITH SLIDING MOTIONS USING MODELICA

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The Modelica Language is becoming an industry standard to model dynamical systems described by a set of Ordinary Differential Equations (ODEs) or Differential Algebraic Equations (DAEs) with mixed continuous and discrete variables, known as hybrid systems. A subclass of hybrid systems referred to as Filippov systems are those where discontinuities appear in vector fields, i.e. in the right hand side of the model's equations. If the solution of Filippov systems enters into a constrained subset of the state space, known as sliding, the formalism given by Filippov allows defining a vector field on the sliding surface to properly handle discontinuities.

A Modelica implementation of Filippov systems without considering Filippov formalism can lead to chattering-Zeno-type deadlocks, which consists of infinitely many instantaneous switches of the discrete variables during time domain simulation. This can significantly reduce the performance of solvers within Modelica simulation tools and can lead to a simulation halt. More importantly, such chattering does not represent actual (i.e. real) chattering phenomena from the physical system being modeled. Therefore a generalized formulation is required for smooth continuation of simulation trajectories.

A generalized modeling formulation for implementation of dynamical system models that exhibit sliding behavior is proposed in this work. The proposed formulation is based on Filippov theory, and is implemented using Modelica. The main advantage of the developed framework is that it effectively removes numerical chattering and trajectory deadlock. The robustness of the formulation is assessed considering three example system models: a stickslip system, a relay feedback system and an anti-windup Proportional Integral (PI) controller in a power system application, i.e. an automatic voltage controller.

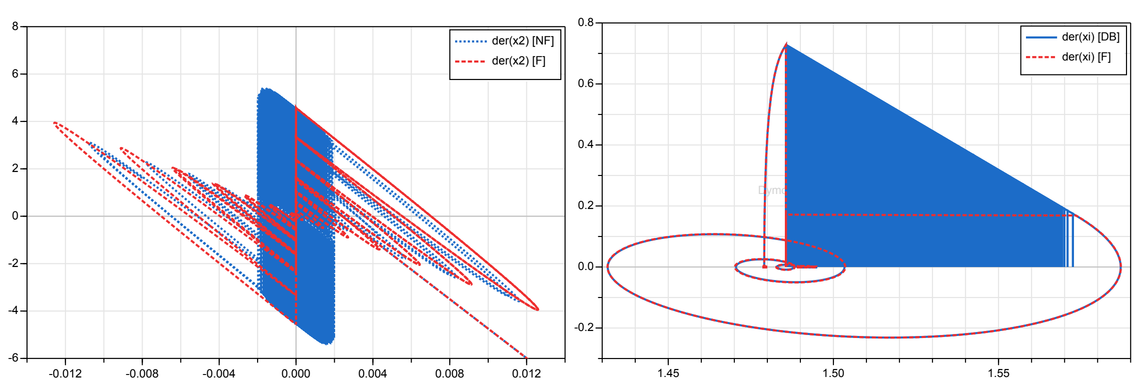

FIGURE 1. (Left) Time derivative of state variable ($\dot{x}_2$) of the relay feedback system model without (NF) and with (F) Filippov theory simulated in Dymola; (Right) Time derivative of the integrator state variable ($\dot{x}_i$) in the anti-windup PI controller using dead-band (DB) and Filippov (F) methods simulated in Dymola.

MODELING CONTACT AND COLLISIONS FOR ROBOTIC ASSEMBLY CONTROL

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We propose an implicit, event-driven, penalty-based method for modeling rigid body contact and collision that is useful for design and analysis of control algorithms for precision robotic assembly tasks. The method is based on Baumgarte's method of differential algebraic equation index reduction in which we modify the conventional constraint stabilization to model object collision, define a finite state machine to model transition between contact and non-contact states, and represent the robot and task object dynamics as a single set of differential algebraic inequalities. The method, which is realized natively in Modelica, has some advantages over conventional penalty-based methods: The resulting system is not numerically stiff after the collision transient, it enforces constraints for object penetration, and it allows for dynamic analysis of the Modelica model beyond timedomain simulation. We provide three examples. First, a bouncing ball illustrates the basic method. Second, a ball maze is described, modeled, and then the model is used to design a feedback control to solve the maze. This is a good use case illustrating both simulation and also dynamic analysis. Third, we show a delta robot controlled to achieve soft collision and maintain soft contact with an object in its environment.

FAST SIMULATIONS OF AIR CONDITIONING SYSTEMS USING SPLINE-BASED TABLE LOOK-UP METHOD (SBTL) WITH ANALYTIC JACOBIANS

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Refrigerant property calculation has a significant impact on the computational performance of vapor compression cycle simulations. In a previous publication, the authors have described the Modelica implementation of a Spline-Based Table Look-Up Method (SBTL) for fast calculation of refrigerant properties. This implementation demonstrated significant improvement in computational speed for a range of complex air conditioning system models. This paper describes further development of the SBTL method to allow the generation of analytic Jacobians. The new implementation with analytic Jacobian capability is tested on a range of air conditioning system models and demonstrates significant further improvement of computational speed when compared to the original SBTL model.

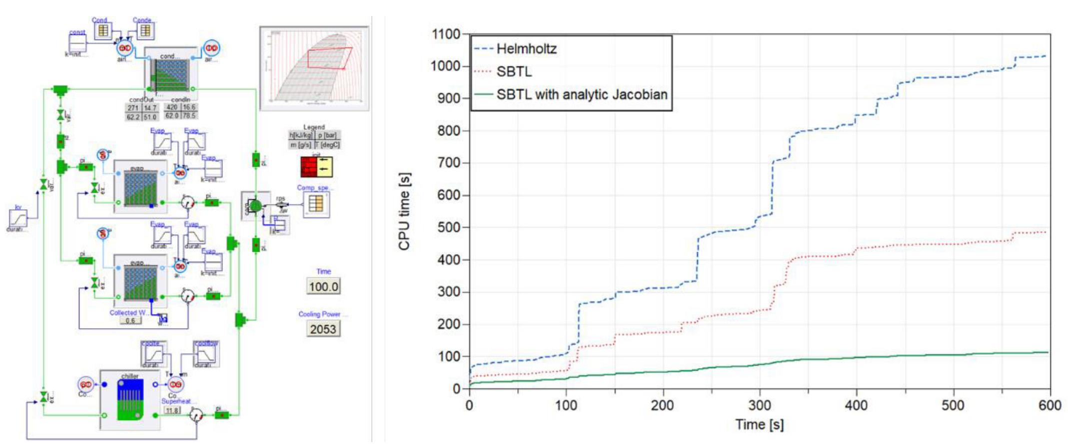

FIGURE 1. CPU time of drive cycle simulations of a three-branch air conditioning system using different methods for refrigerant property calculations.

DATA-DRIVEN PREDICTION OF OCCUPANT PRESENCE AND LIGHTING POWER: A CASE STUDY FOR SMALL COMMERCIAL BUILDINGS

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The stochasticity of occupant behavior and its impact on power and energy consumption presents a challenge to accurate real-time estimation of building electric loads. Traditional building energy modeling tools use static hourly schedules both for occupant presence and building equipment. This leads to discrepancies between the simulated power shape and the actual consumed power (Luo et al. 2017; Kim et al. 2017), especially for short-term prediction scenarios such as those needed for fast demand response. Limited data availability is a second challenge, as due to privacy reasons, occupant sensor data is often unavailable. These challenges must be accounted for in theoretical and model-based studies on occupant behavior and its related impacts on the power consumption and flexibility characterization of the built environment.

In this paper, we propose a new data-driven model to capture occupant behavior in a stochastic manner. Unlike existing models and prediction tools, this new model does not require occupant presence data and can learn occupants' arrival and departure time based on lighting power consumption data, which is more readily available than occupant presence data. We applied this occupant behavior model to lighting power consumption prediction and implemented the entire prediction process in Modelica. We then validated the Modelica model by comparing the predicted daily, weekly and monthly peak lighting power with measurements from two small commercial buildings. The results suggest that the prediction matches the measurement within acceptable deviations of 7%. The results also indicate that the proposed stochastic model performs better for long-term prediction of lighting power (monthly and weekly) than the short-term (daily).

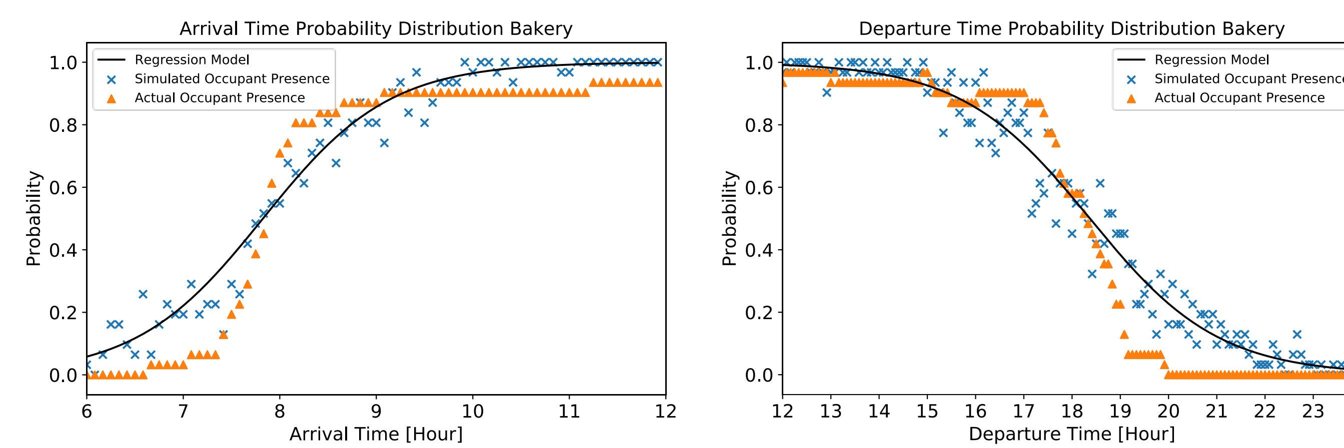

FIGURE 1. Arrival and departure time probability distribution.

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DEVELOPMENT AND VERIFICATION OF CONTROL SEQUENCES FOR SINGLE-ZONE VARIABLE AIR VOLUME SYSTEM BASED ON ASHRAE GUIDELINE 36

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This paper presents work on the development and verification of ASHRAE Guideline 36-2018 control sequences for single-zone variable air volume air- handling unit (AHU) systems. The Control Description Language, a subset of the Modelica Language, is used to implement those advanced control sequences. The sequences address control for components such as the economizer, supply air temperature setpoint reset, fan speed control, and zone heating/cooling states determination. Each component sequence is validated in open-loop tests and then used to compose a single comprehensive controller. This controller is also first validated in open loop and then tested in closed loop with an AHU system and building envelope model constructed using the Modelica Buildings library. The Guideline 36 controller is compared with a conventional control strategy applied to the same AHU and building model. Annual simulations show that the Guideline 36 control sequences yield 17.3 % of annual HVAC energy savings against the conventional control strategy in this case study.

MODELICA COMPONENT MODELS FOR OCEANIC SURFACEWAVES AND DEPTH VARYING CURRENT

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In this paper, the theory of progressive ocean-surface gravity-waves is discussed, followed by the concept of the representation of the irregular sea-state by a sea-spectrum. Fourier series decomposition of the irregular sea-surface into its constituent regular waves and the method of realizing unique time-records of the sea-surface-elevation from commonly used sea-spectra is described. A detailed description of the development of Modelica componentmodels to generate regular as well as irregular waves, and depth-varying current, with an eye on the requirements imposed by probable integrated simulation scenarios, is then presented and the results discussed.

MODELICA COMPONENT MODELS FOR NON-DIFFRACTING FLOATING OBJECTS AND QUASI-STATIC CATENARY MOORINGS

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In this paper, the theory behind determining the hydrodynamic response of a floating object in the presence of waves is discussed, followed by a simplification for the case of wave-transparent objects. The Morison equation is introduced as a means to estimate lateral wave and current loads on slender bodies. The quasi-static catenary approach to determine mooring forces is then discussed. Development of Modelica component-models to simulate the hydrodynamic response of free-floating and catenarymoored non-diffracting objects, in the presence of waves and depth varying current, is then dealt with in detail, and the results dicussed.

ABSTRACTS

THE ROTORCRAFT AERODYNAMICS LIBRARY: A MODELICA LIBRARY FOR SIMULATION OF ROTORCRAFT AERODYNAMICS AND WHIRL FLUTTER

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Rotor aeromechanics is a multidisciplinary branch in the field of rotorcraft that involves performance, loads, vibrations, stability, and noise. Aeromechanic analysis in this field is a complex task typically requiring specialized software tools to simultaneously resolve the coupled structural, mechanical, and aerodynamic solutions that contain motion (both rigid and elastic) and forces. One drawback of these tools is that they are often overspecialized and do not lend themselves well to the analysis of the latest rotorcraft advances and concepts, including those utilizing distributed electric propulsion. In this paper, the Rotorcraft Aerodynamics Library is presented that provides an extensible platform for performing analysis and design studies of current and future rotorcraft. Several examples are presented that illustrate how the library can be used to perform aerodynamic and whirl flutter stability analysis as well as control system design for multi-rotor aircraft.

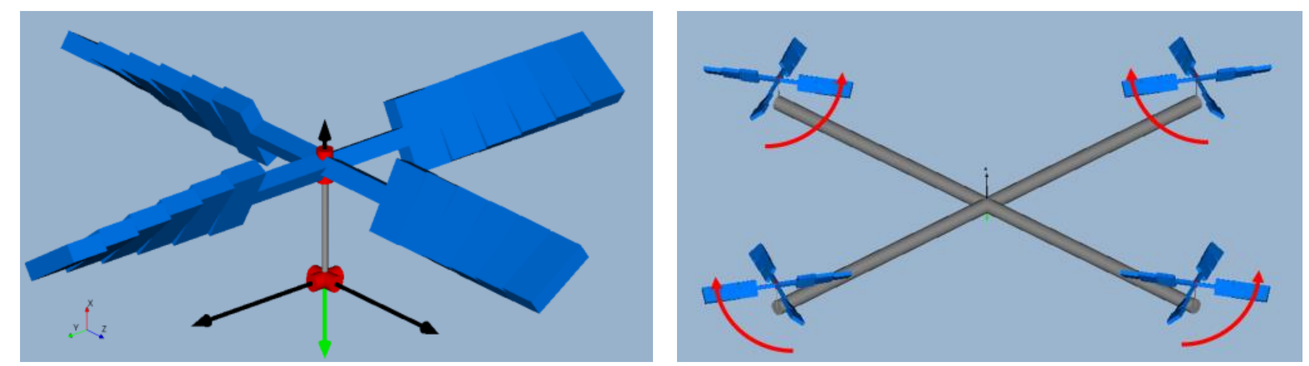

FIGURE 1. Visualizations of Modelica-based rotor models for analysis of (left) whirl-flutter and (right) quadcopter dynamics and control.

HIERARCHICAL MULTI-LEVEL ELECTRIC POWER SYSTEM SIMULATION WITH SMART PHOTOVOLTAIC SYSTEMS USING THE FUNCTIONAL MOCK-UP INTERFACE ON THE LAWRENCIUM COMPUTING CLUSTER

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The adoption of distributed photovoltaics (PV) with smart inverters was one of the first large-scale deployment of grid-interactive, customer owned assets. This paper introduces a co-simulation platform for future scenarios of Distributed Energy Resources (DER), in the context of large-scale deployment, to assess the local and global impact on the electric power grid. The co-simulation platform utilizes the Functional Mock-up Interface (FMI) industry standard to couple 80,851 individual simulators. For this purpose a Modelica package named SCooDER was developed, which includes models for various DERs. The simulation was conducted at the Lawrencium high performance computing cluster. It included a hierarchical structure of multi-level electricity grids (i.e., transmission, medium-voltage distribution, and low-voltage distribution), and PV with smart inverters and time-varying load profiles at 80,000 load buses, in representation U.S. state sized electric power grid. With the flexibility of the simulation framework and the agreed-on industry standard for simulation model exchange, future applications can be very broad by coupling multi-domain simulators.

MODELING FUTURE HEAT PUMP INTEGRATION IN A POWER RADIAL

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Integration of heat pumps in the existing traditional electrical system is supposed to increase energy efficiency compared to fossil fuel-based heating sources. This paper considers integration of heat pumps in Danish low-voltage residential power distribution network, here referred to as "radial", providing a data-driven case study for the electrical package of the Modelica Buildings library. The loads in the distribution grid for year 2030 are estimated based on the requirement of fully sustainable energy system by the year 2050. Combined with local consumption, the total system model is validated by measuring mains transformer signal at the chosen radial. The maximum cable capacity is compared to future current flow estimations for a 2030 grid, simulated based on a specific official Danish scenario. The study shows, that there is no threat to the network cables, if only heat pumps are integrated. However, when maximum load is applied to the grid, the values of cable currents are relatively close to the limit, which may complicate integration of other technologies. To help reducing the risk of the future load exceeding the capacity of the cables, the recommendations for safety measures were given to protect electric lines during periods of rapid technological development.

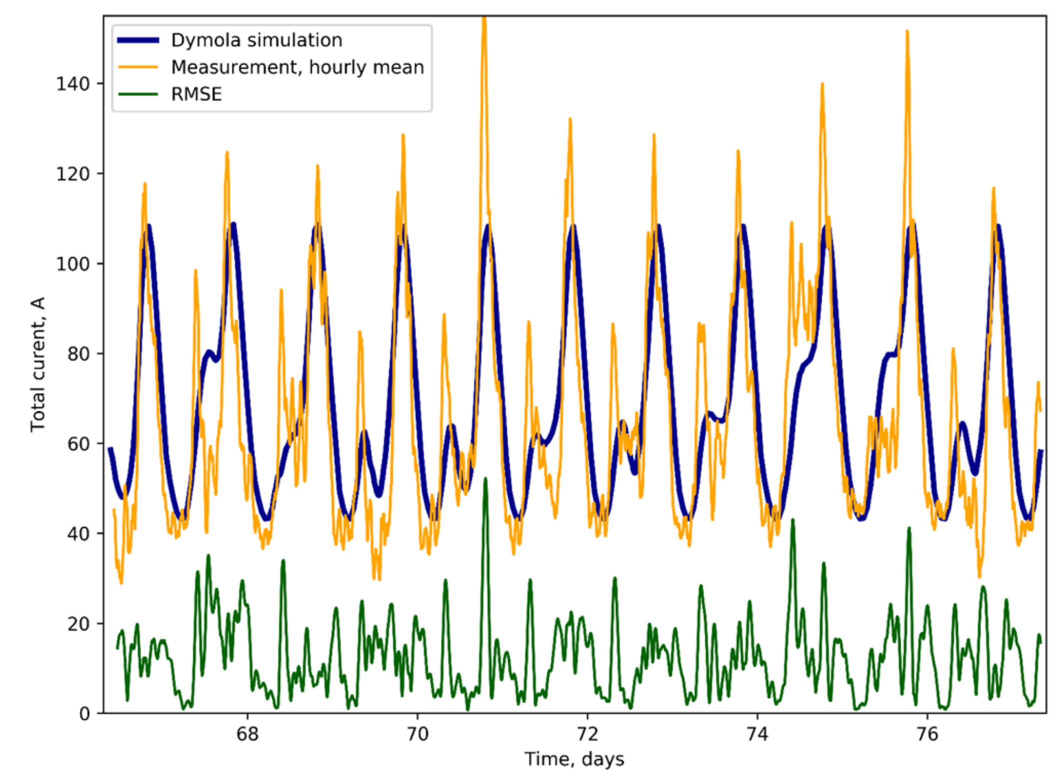

FIGURE 1. Validation of the radial distribution grid model

PARAMETER ESTIMATION OF USER-DEFINED CONTROL SYSTEM MODELS FOR ITAIPÚ POWER PLANT USING MODELICA AND OpenIPSL

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The power industry heavily relies on power system models to understand system operations, perform system planning studies, and identify and correct problems that arise during system operation. Minimizing the error between the models and actual physical system, response (measurements) raises the validity of the simulation studies. Many existing power system component models are user-defined, i.e. they are specialized representations of a specific system component in the system. It is important that these customized models produce an accurate response. Maintaining such models is costly, so it is of value to determine if those models can be replaced with a generic representation. Phasor measurement data can be used to calibrate model parameters and reduce error.

This process is automated for a generator in the Itaipu power plant using RaPId, a MATLAB toolbox that integrates measurements, models using Modelica/FMI standards, and optimization routines. In this paper, optimization is carried out by using a combination of particle swarm optimization (PSO) algorithm and classical gradient optimization routines to calibrate the model parameters. This paper presents the parameter calibration of a generic model of a synchronous generator, automatic voltage regulator, power system stabilizer, and turbine governor and compares it to the estimated parameters of user-defined models for an automatic voltage regulator, power system stabilizer, and turbine governor.

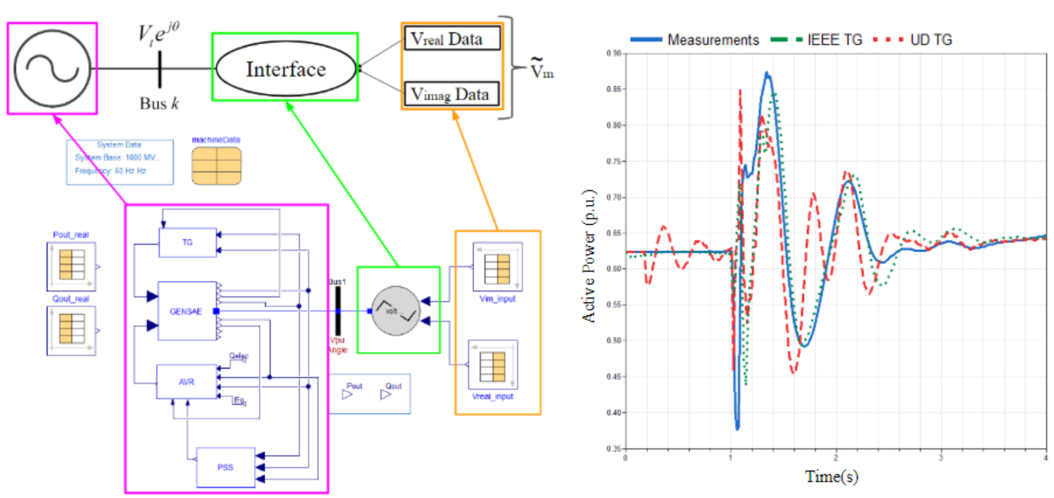

FIGURE 1. Right: Modelica diagram of the power system model mapped to a single line diagram. Left: Sample results from parameter calibration.

APPLICATION OF MODEL-BASED TESTING TO DYNAMIC EVALUATION OF FUNCTIONAL MOCKUP UNITS

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Co-simulation is a technique where the models are integrated through their corresponding simulators. Each simulator, given inputs to the model, is capable of producing outputs, both function over time. Therefore simulators cooperate in producing the overall behavior of the system. While co-simulation can only be used to answer questions about a system's behavior, it has the advantage that the contents of each model need not to be disclosed, as the model and solver can be encapsulated in a black box. It is therefore a suitable technique to address the challenges arising from concurrent and distributed development processes, where many tools/formalisms might be used and external suppliers may play a role.

Co-simulation standards are crucial enablers. These prescribe the interfaces with which inputs/outputs/parameters can be set/obtained and, optionally, the interaction protocol that each simulator abides to. For example, the Discrete Event System (DEVS) specication that prescribes the integration protocol between simulators. On the other hand, the Functional Mock-up Interface (FMI) Standard for co-simulation prescribes the interfaces, but under-species the interaction protocol. In this paper, we focus on the FMI version 2.0. In the FMI terminology, the simulators are referred to as Functional Mock-up Units (FMUs).

Past research, and the co-authors' experience, have shown that there are some ambiguities in the FMI standard, which lead to not only technical diculties, but also numerical diculties. For instance, the second and third most eminent barriers in the adoption of the FMI standard are: "Lack of transparency in features supported by FMI tools" and "insucient documentation and a lack of examples, tutorials, etc.". Other somewhat barriers include: "It is dicult to implement FMUs", and "There is a lack of tools that suciently support FMI". In the same empirical study, the authors identied the most experienced issue to be "Diculties in practical aspects, like IT-prerequisites in cross-company collaboration."

GOAL: We aim at rooting out possible ambiguities and improving the conformance to the standard. We propose an approach to the development of an evaluation tool for a co-simulation standard, using Model-Based Testing (MBT). This has the benet that the model used to describe the possible behaviors of a simulator can also be used to test it, and can be applied with minimal setup. We describe a tool that embodies these principles and tests co-simulation Functional Mock-up Units (FMUs) exported by tool providers. The tool does not test the numerical performance of an FMU. This tool is open source and available online with documentation and examples. It is our goal that it helps in the development of FMUs and that our approach inspires standardization bodies to adopt the same technique.

CONTRIBUTIONS TO THE EFFICIENT AND PARALLEL JACOBIAN EVALUATION AND ITS APPLICATION IN OPENMODELICA

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Many algorithms related to Modelica-based simulations heavily rely on the efficient provision of Jacobian matrices. Besides the accuracy of the derivative information, the performance of the derivative evaluation is also of great interest. From a mathematical point of view there are several techniques to provide derivatives. A very common numerical method are finite differences, which are very well suited for algorithms that do not require exact derivatives. On the other hand, the symbolic derivative module of OpenModelica (Braun, Ochel, and Bachmann, 2011) provides accurate derivatives within machine precision. These are used by algorithms for optimization and solving algebraic loops.

In this paper, we propose two complementary approaches to accelerate Jacobian evaluation of Modelica-based models. The first technique identifies recurring calculations with constant parts in the directional derivatives. These constant parts need to be evaluated only once and the results will be reused in the construction of the Jacobian matrix. The second approach introduces a parallelization approach for the symbolical Jacobian evaluation in order to use the parallel hardware resources today's multi-core processors offer. The implementations of these techniques in the open-source Modelica tool OpenModelica and its C runtime are discussed. The gained speedup in Jacobian evaluation is demonstrated on benchmark models of the ScalableTestSuite.

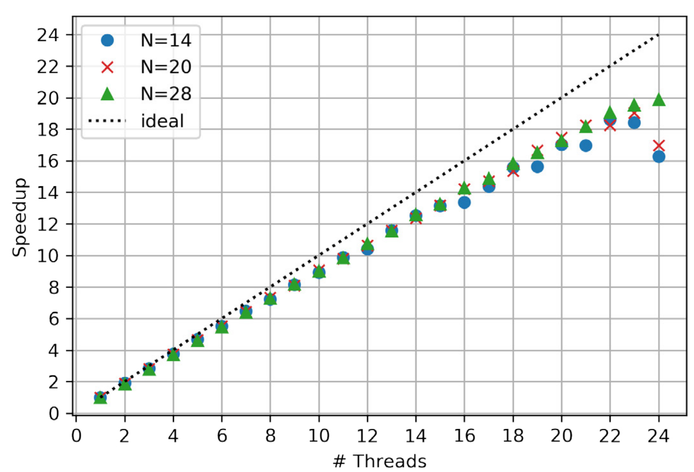

FIGURE 1. Speedup of Jacobian evaluation for scaled model with size *N* = 14; 20 and 28.

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ABSTRACTS

TRACEABILITY IN THE MODEL-BASED DESIGN OF CYBER-PHYSICAL SYSTEMS

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Design, development, and analysis of complex Cyber Physical Systems (CPSs) using models involves a collaboration of expertise from different engineering domains. Heterogeneous artefacts are generated, often using different lifecycle modeling languages and simulation tools. Capturing the traceability information among these artefacts can be used to support several activities such as requirements tracing, impact analysis of change requests, verification, validation, and documentation. However, creating trace links among these heterogeneous artefacts is challenging as different tools in the development lifecycle are usually disparate and there is no precise semantic in the terminology used between requirement engineers, verification engineers, and system modelers. In this paper, we present a linked data-based approach to capture traceability information and create trace links that relate heterogeneous artefacts in the model-based design process of CPSs through a standardized interface and format using OSLC[1]. This enables artefacts from different tools to be connected and queried through a standardized interface and format. A practical prototype system for supporting traceability is designed through integration with the INTO-CPS[2] tool-chain of CPS design. The traceability data is stored in Neo4j[3] graph database which can be queried for generating various reports such as impact analysis, variant handling, etc.

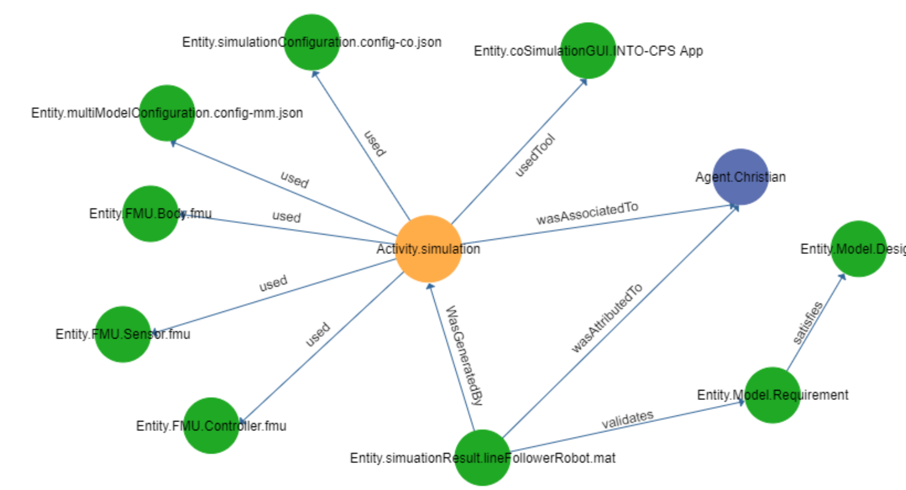

FIGURE 1. Visualisation of relations between different entities, actions and agents in Neo4J.

[1]https://open-services.net/
[2]https://into-cps.org/
[3]https://neo4j.com/

OPEN SOURCE MODELICA MODELS FOR DATA CENTER COOLING

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Data center cooling accounts for about 1% of electricity usage in the United States. Computer models are pivotal in designing and operating energy-efficient cooling systems. Compared to conventional building performance simulation programs, the equation-based object-oriented modeling language Modelica is an emerging approach that can enable fast prototyping and dynamic simulation of cooling systems. In this project, we introduce a newly developed open source data center package in the Modelica Buildings library to support modeling and simulation of cooling and control systems of data centers. The data center package contains major thermal and control component models, such as Computer Room Air Handler, Computer Room Air Conditioner, models of different subsystem configurations such as chillers with differently configured waterside economizers, as well as templates for different systems. A case study is performed using the developed Modelica models. In this case study, we first modeled the cooling and control systems of an actual data center located in Massachusetts, and then calibrated a baseline model based on measurement data. The simulation of the baseline model identified several operation-related issues in the cooling and control systems, such as degraded cooling coils, improper dead band in control settings, and simultaneous cooling and heating in air handlers. Afterwards, we used a sequential search technique as well as an optimization scheme to investigate the energy saving potentials for different energy efficiency measures aiming to address the abovementioned issues. Simulation results show potential energy savings up to 24% by resolving identified control-related issues and optimizing the supply air temperature.

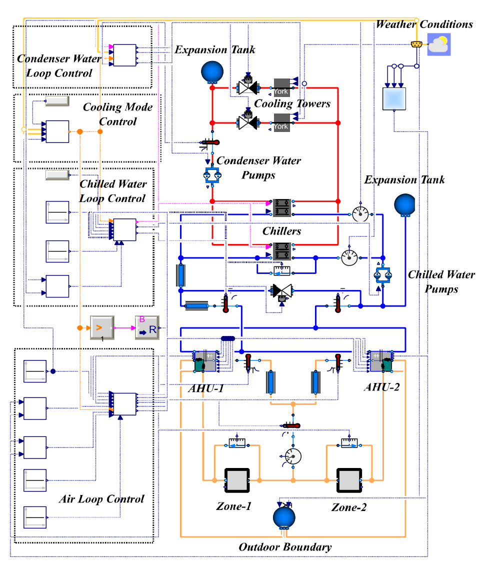

FIGURE 1. Modelica models of the cooling system for a data center in Massachusetts.

TEMPLATE-BASED DISTRICT THERMAL ENERGY SYSTEM MODELS FOR URBANOPT WITH MODELICA

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The Department of Energy has been developing an urban analysis software development kit utilizing OpenStudio/EnergyPlus as well as various other 3rd party engines (e.g., Ditto, OpenDSS, REopt, etc.) to evaluate grid impact. In parallel, an effort has been underway to enable more advanced district energy system (DES) analysis using Modelica. This presentation will discuss the development and initial results of a) new component models for DES analyses, b) the development of a templating framework, and c) dynamically generating district energy system topologies and buildings from a GeoJSON file. The newly developed components support a myriad of system configurations including 1st, 4th, and 5th generation DES. The templating framework allows a user to specify at a higher level the desired configurations of central plant equipment, energy transfer stations, topology layout, and building models to be 'stitched' together, ultimately scaffolding an entire Modelica project that is simulatable. The principal objective of the Modelica-based DES tool is to allow engineers and designers to effectively evaluate the impact of various topologies and components during the design phases of urban projects.

DEVELOPMENT OF A MODELICA BUILDING EMULATOR FOR MODEL PREDICTIVE CONTROL APPLICATIONS

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An accurate and fast model is essential for implementation of model predictive control (MPC), a promising approach applied in building management systems to facilitate energy-efficient operation without sacrificing occupant comfort. In this presentation, the development of a simplified one-zone emulation model for a Danish university building for application in the MPC toolchain BOBTEST within the IBPSA project 1 WP 1.2 (Blum et al. 2019) is described.

The building consists of (1) a district heating system supplying heat to a building zone and ventilation unit and (2) a CO2-driven ventilation system that controls indoor CO2 concentration below required level. The model was developed using Modelica Buildings Library (Wetter et al. 2014). Realistic occupancy and the Typical Meteorological Year weather data were implemented, and the model was calibrated based on data measured by various meters installed in the building. Simulation and sensitivity analysis were performed on controllers and electricity-consuming devices, which helped identifying performance bottlenecks and accuracy/performance tradeoffs of the model. This improved the model implementation and made it BOBTEST-ready. Results indicate that (1) the model is physically realistic in terms of heat load, electric load and thermal comfort estimation and (2) a new control/actuation setup considerably improves simulation time, achieving a relatively small monthly simulation time of 6.4 minutes.

The model is open for public use in GitHub (https://github.com/sdu-cfei/ou44-modelica-emulator) and can be served as a case study to compare performance of diverse control strategies in large university buildings, which may assist stakeholders in energy-efficient building design, operation and commissioning.

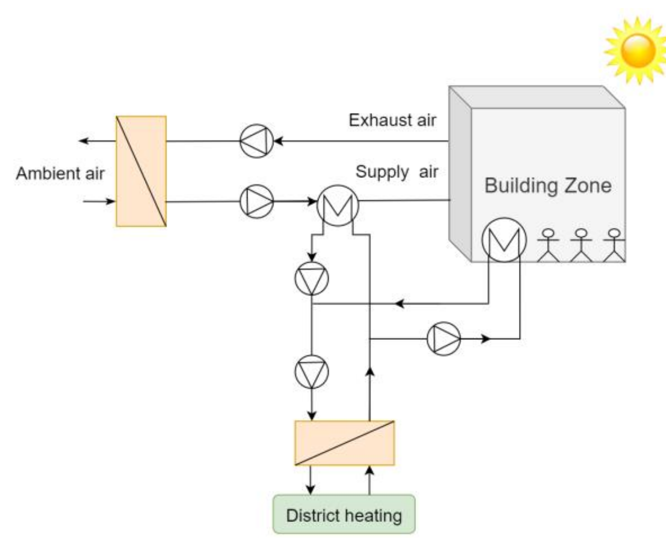

FIGURE 1. Schematics of the building energy system

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MODELICA IMPLEMENTATION OF PCM VENTILATION UNIT

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The building sector is responsible for approximately 40% of the total energy consumption around the world (Cao, Dai, and Liu 2016). Meanwhile, heating, ventilation and air conditioning (HVAC) is considered the major energy consumer among all building services. Reducing energy consumption through use of latent thermal energy storage (LTES) in HVAC system has been extensively investigated in recent research studies. In particular, phase change material (PCM), as a storage medium in LTES system, has received considerable attention. In this presentation, the development of a simplified PCM-driven ventilation system with four stacks supplying "free cooling" is described.

A one-dimensional PCM component was simplified and developed as a lumped heat capacitor and conductor in Dymola using Modelica standard library and Buildings Library (Wetter et al. 2014). Phase change logic considering heating and cooling hysteresis was implemented. Subsequently, the PCM component was used in the development of the PCM-driven ventilation system. Validation of the ventilation system was performed based on measurements from experimental setup. Results show that the simplified model is capable of capturing the thermal behavior of the PCM and demonstrates ability of providing "free cooling". It yields sufficient accuracy in terms of mimicking PCM and air temperature. The model exhibit transferability and it can be easily reproduced or modified for personal use by any users and also further applied to investigate performance of various control setups on PCM-based ventilation system.

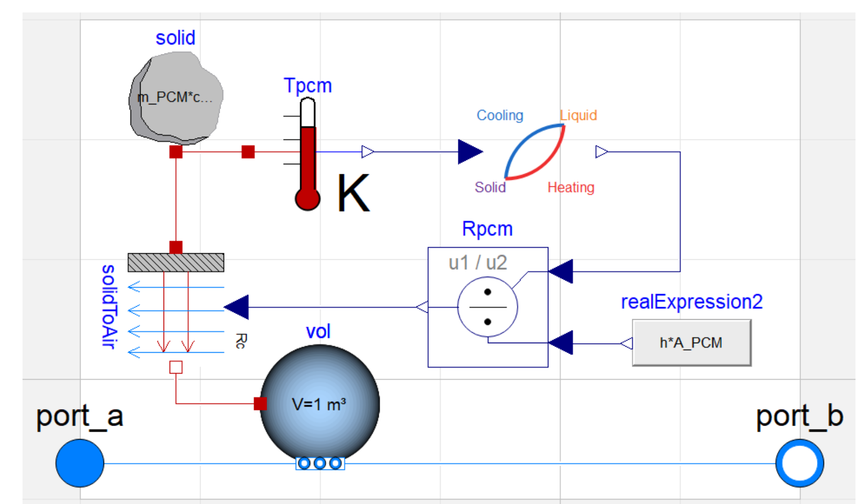

FIGURE 1. PCM ventilation unit

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A MODELING FRAMEWORK TO EVALUATE ENERGY, TRANSPORTATION, AND COMMUNICATION INTERDEPENDENCE IN SMART AND CONNECTED COMMUNITIES

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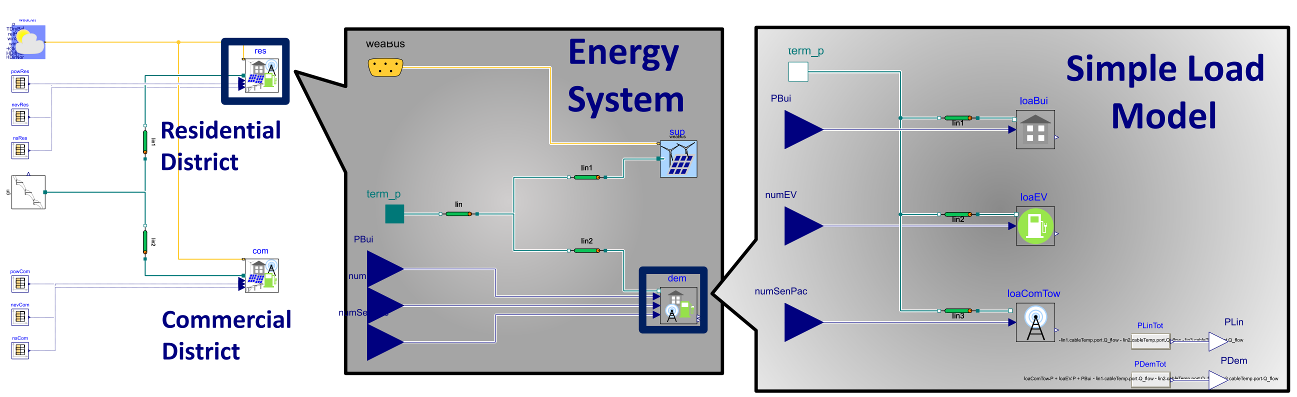
Public infrastructure in future smart and connected communities is envisioned as a complex intertwined system of services such as energy, transportation, and communication. Few prior studies have examined the interdependencies among these services and quantified their impacts even though their inherent linkages may significantly influence the design and operation of each system. To change this way of design, we propose an open-source, integrated modeling framework to gauge the impact of energy, transportation, and communication systems on public infrastructure operation. An innovative multi-level, multi-layer, multi-agent approach is proposed to model the interconnections between these systems. Individual component and system level models of energy, transportation, and communication systems are designed using Modelica. Three case studies of increasing complexity are examined (energy, energy + transportation, energy + transportation + communication) to evaluate the impacts of the interdependencies. The proof of concept results show that the power draw from the grid can differ by 7% during peak commute time with or without considering the transportation and communication systems. This shows an inherent interdependence even when all of the systems are not considered. Additionally, the velocity on the road can decrease by up to 10.5%, also during peak commute times. This framework can and will be applied to more modeling scenarios such as dynamic modeling and optimization, resilience analysis, and integrated decision making.



REACTIVE POWER MODELING FOR BUILDING SYSTEMS TO SUPPORT BUILDING-TO-GRID INTEGRATION STUDIES

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Demand response (DR) of building systems is a promising approach to enhance the reliability of power grid operation, especially when there is a high penetration of renewable generation (Palmintier et al, 2017). Prior to large scale testing and deployment of DR it is necessary to evaluate the reliability level of power systems under DR control. However, common design practice or DR methods ignores their effect on reactive power for the sake of design simplicity. Existing power system models tend to ignore interactions between power grid systems with building loads while buildings models usually only consider the real power characteristics of building devices. Most simulation software was not developed to incorporate reactive power modelling. The lack of reactive power modeling for building loads at both individual level and aggregated level impedes evaluation of effects of DR on reactive power dynamics. Modelling reactive power is a challenging task as it requires not only cross-disciplinary knowledge to capture interactions between different systems or components when establishing the mathematic models, but also a flexible software setup to simulate the resulting models in a scalable and efficient manner.

In this presentation, we demonstrate an approach for modelling reactive power to support the study of buildings DR on power system reliability. This proposed approach consists of one set of high-fidelity models of building loads and one simulation software setup. The high-fidelity models are developed in Modelica, an equation-based and object-oriented modelling language. Modelica models offer flexibility and can be integrated in co-simulation frameworks as governing equations can be easily added to the system without affecting existing models. In addition, object-oriented implementation of Modelica models also makes them more suitable for large-scale simulation in power systems. The simulation software setup is for supporting the large-scale co-simulation among end-use loads, distribution systems, and transmission systems. When performing co-simulation, existing distribution and transmission models are leveraged. To realize the time synchronization between various simulators, a co-simulation engine, HELICS, and a data exchange protocol, Functional Mockup Unit, are included in this software setup. A Docker-based deployment method is also developed to further simplify the large-scale power system simulation. Finally, to demonstrate the usage of the developed approach, we perform a case study where commonly used DR methods are evaluated for standard IEEE test feeders. To facilitate the evaluation, metrics about the power system reliability are developed and implemented in the simulation software setup. The evaluation results could, on one hand, provide insights on how to enhance the existing DR method, and on the other hand, help identify the future power systems research challenges.

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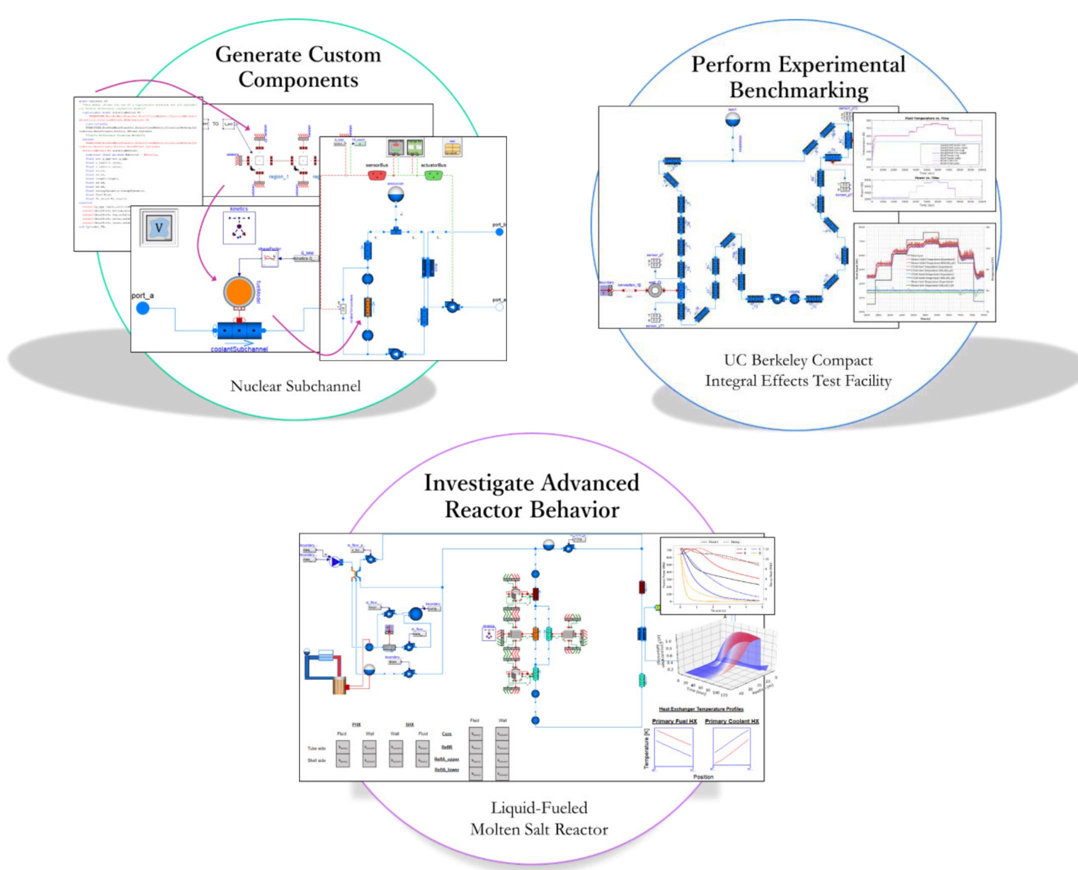
TRANSFORM: A SOLUTION FOR ADVANCED SYSTEM MODELING

M. Scott Greenwood

The TRANSient Simulation Framework Of Reconfigurable Modules (TRANSFORM) is an ORNL-developed component library created using the Modelica programming language for the investigation of dynamic thermal-hydraulic systems and other multi-physics systems. The TRANSFORM library has been successfully used for a variety of advanced energy applications including investigations into the performance of nuclear hybrid energy systems, liquid metal and gas cooled reactors, and molten salt applications including kinetic behavior and fission product transport. This presentation will introduce the audience to the TRANSFORM library by providing an overview of capabilities and applications.

https://youtu.be/esUoh9zBK-M



ABSTRACTS

TEACHING A COURSE ON MODELING AND SIMULATION FOR CYBER-PHYSICAL SYSTEMS USING MODELICA AND FMI TECHNOLOGIES WITH HANDS-ON-LABORATORIES

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The Modelica standard provides rich language features enabling the development of complex Cyber-Physical System models. Meanwhile the success in the adoption of the FMI standard allows engineers to share models between tools, facilitating collaborative design. Despite these, and many other advantages, Modelica and the FMI have limited adoption in the academic community, especially in North America (NA). This poses both a challenge for the NA industry seeking talented students with the right skills set, and at the same time for universities to train students with such valuable knowledge. This presentation gives an overview of the efforts of the author in developing, piloting and integrating into the curriculum a new course on modeling and simulation (M&S) for CPS based on Modelica and FMI technologies.

The main goal of this presentation is to provide the basis for the introduction of a Modelica and FMI-based course on M&S for CPS suitable for the North American-style course curriculum, using the presenter's experience as an example.

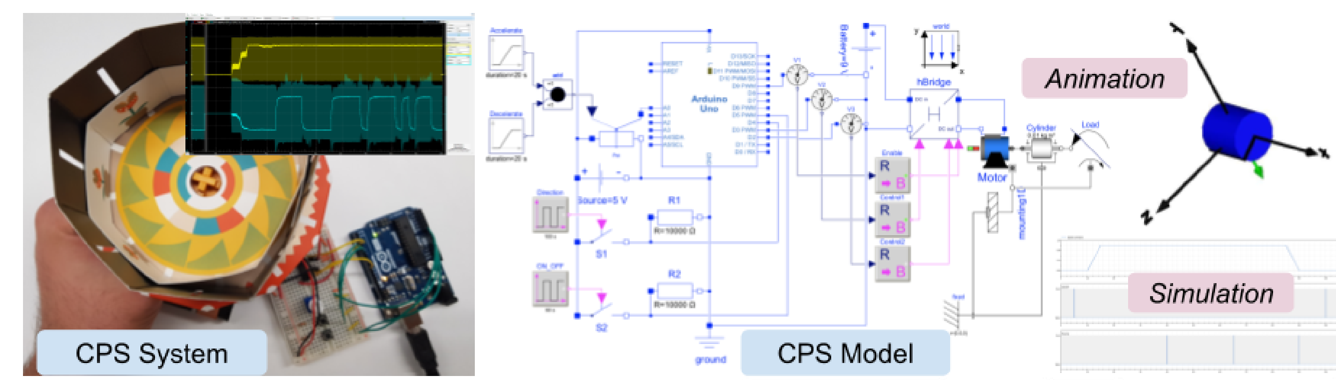

FIGURE 1. Example Hands-on-Laboratory Assignment using the Modelica Arduino Library and Dymola (Zoetrope Project)

The presentation will cover the different teaching and learning activities carried out in the course. In addition to lectures and homeworks, the students carry out two hands-on labs which make use of the Arduino Starter Kit (ASK) and the Modelica Arduino Library. The first consists of building projects from the ASK both the physical prototype and model, and comparing measurements to simulations. The second aims on interacting with models via hardware-in-the-loop simulation using three experiments, learning to interface real-world IO with real-time simulation. For their final assessment, the students carry out a project where they have to apply the knowledge and skills gained from the course. The presentation will provide a few examples of interesting projects carried out by the students.

Another goal of this presentation is also to obtain feedback from industry and academia towards developing a sort of template that can be shared and replicated in other NA institutions with the goal of students use Modelica and the FMI for CPS design and analysis, and more importantly, to expand the existing Modelica community in North America.

THE OPEN INSTANCE POWER SYSTEM LIBRARY (OpenIPSL): A MODELICA LIBRARY FOR PHASOR TIME-DOMAIN SIMULATIONS

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The evolution of power systems simulation shows that tools have always been created in order to assist studies addressing evolving power network requirements. As networks increased in size and complexity, tools were adapted and enhanced to meet the demand for new analysis. Modelica language has many features that make it a promising alternative for modeling complex power grids. In this context, the Open Instance Power System Library, or OpenIPSL, offers a wide set of power system components that are made in Modelica to meet the demand for tools to analyze modern power systems, which are complex cyberphysical networks. The main goal of this library is to provide power system models that can be used for teaching and research. The OpenIPSL can be used for power system dynamic analysis, such as phasor time-domain simulations and it is developed to be used in research and education. This user presentation will give an introduction to the library, illustrating recent modeling developments with sample applications, like the one depicted in Figure 1. In addition, the user presentation will also discuss on-going work, such as automated tests based on continuous integration (CI) software technologies, and the plans for a new release of the library in 2020.

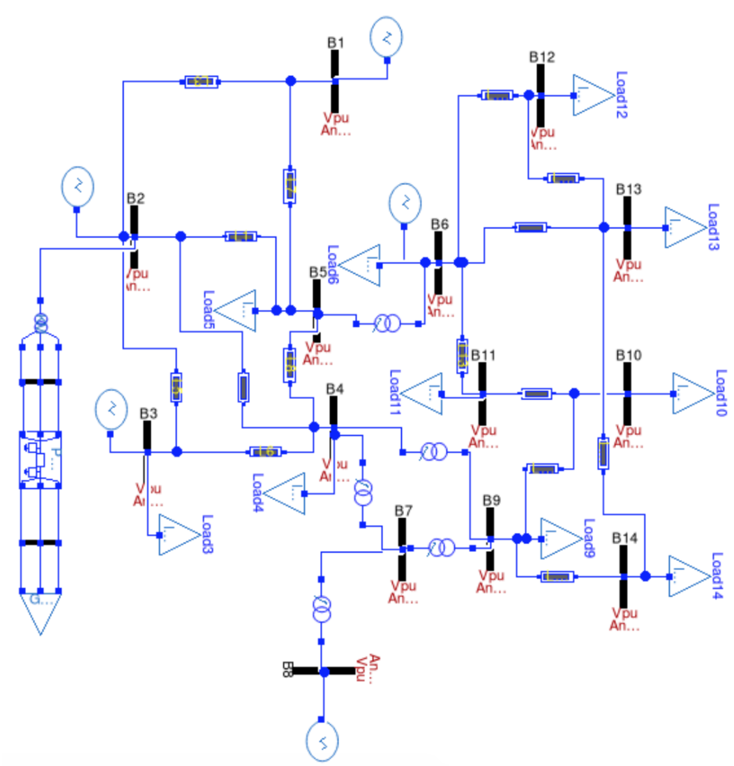

FIGURE 1. Interconnection of a small-scale distribution feeder (shown in the left hand side of the figure) to a transmission system modeled with OpenIPSL.

ASSESSING THE IMPACT OF PASSENGER CABIN COMFORT AND OPERATING ENVIRONMENT ON BATTERY ELECTRIC VEHICLE RANGE USING MULTI-DOMAIN COUPLED ANALYSIS

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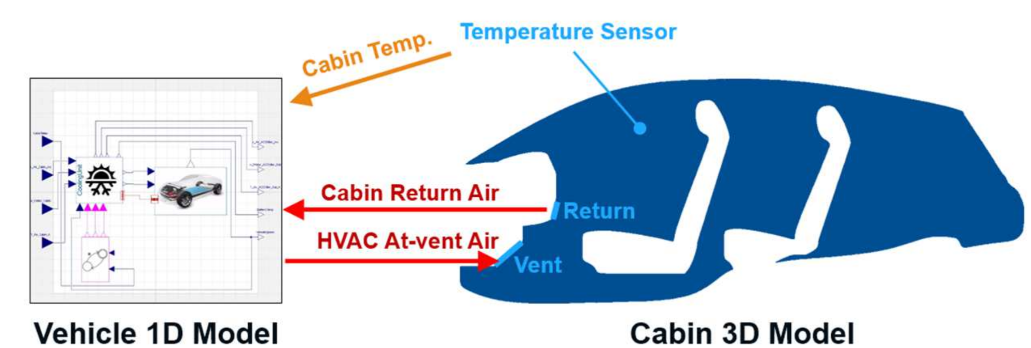
Driving range is a key performance metric for Battery Electric Vehicles (BEVs), but it can be reduced under cold weather conditions, mainly due to energy consumption from the cabin heating system [1]. New technologies for Heating Ventilating and Air Conditioning (HVAC) systems and cabin heating are proposed for BEVs to address such issue. It is essential to accurately assess their effectiveness with quick turn-around simulation methodology. Simulation approaches exist to simulate the full-vehicle systems in 1D model, or to simulate standalone 3D Computational Fluid Dynamic and Conjugate Heat Transfer (CFD/CHT) model. Nonetheless, such approaches either suffer from lack of accurate local surface flow and temperature information needed for human comfort modelling [2], or from longer turn-around time due to the need for physical testing and inability to simulate interactions between systems. This study proposes a methodology that simultaneously resolves the integrated 1D system and the 3D cabin CFD/CHT models. The interface between them is the HVAC at-vent air and the cabin return air. In cabin air recirculation mode, the HVAC at-vent air leaves the HVAC system and enters the cabin, while the cabin return air leaves the cabin and returns to the HVAC system. At each coupling step, cabin return air properties and the cabin temperature sensor reading is measured from 3D simulation result, and is applied to the HVAC system model as a boundary condition. The HVAC at-vent temperature from HVAC system model is collected, and is applied as boundary condition in the 3D model for the proceeding simulation. Functional Mockup Interface (FMI) standard is utilized during the process. This study shows the benefit of the integration between 1D vehicle system model and cabin 3D CFD/CHT model, which provides high fidelity result in short turn-around time. Increase in battery range and decrease in time for thermal comfort with the inclusion of local radiant heating panels on specific regions of the cabin, added insulation on cabin parts etc. This can be analyzed with this integrated simulation approach and design changes can be made at the early stage. The methodology helps vehicle manufacturers and suppliers to quickly assess the efficiency of different technologies, and to improve simultaneously the BEV driving range and passengers' comfort with rapid digital design iterations.



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DYMOLA AND SIMULINK IN CO-SIMULATION: A VEHICLE ELECTRONIC STABILITY CONTROL CASE STUDY

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Vehicle development processes have evolved in line with the evolution of vehicles themselves. As vehicles have become ever more complex, integrating electro-mechanical systems into the driving experience, Original Equipment Manufacturers (OEMs) by necessity have had to review and update development processes. Coupled with a desire to eliminate waste for efficiency reasons, OEMs have been driven to use simulation as a core element during development, where the modern vehicle is a classical multi-domain simulation problem. This presentation is a case study, using the Modelica VeSyMA – Suspensions library as a basis for full vehicle control systems development within Simulink, where the user wishes to take advantage of the individual benefits of Dymola and Simulink.

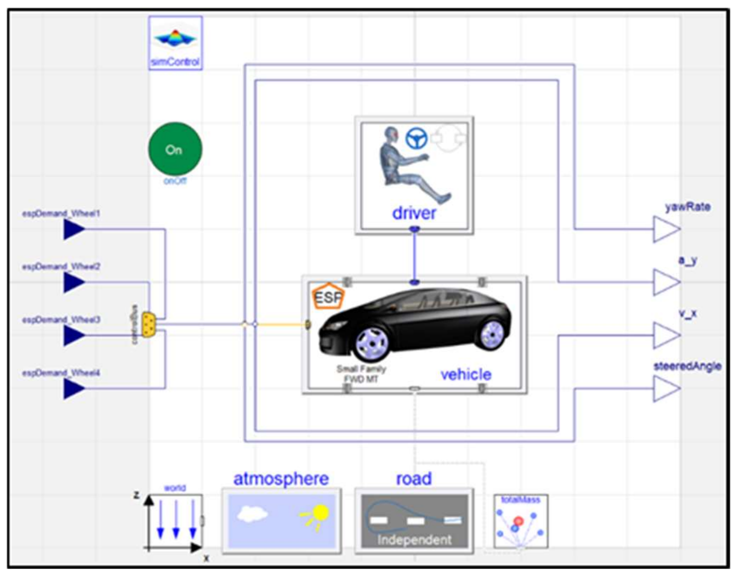

FIGURE 1. A VeSyMA - Suspensions library slalom test configured for interfacing an external controller.

Deploying models as FMUs using the FMI standard interface is a common solution to this; co-simulation enables models to be simulation environment agnostic. Whilst a robust answer to the question of how to deploy models across different simulation tools, it does present a new skill and another variable for users to understand. This case study offers insight with regards the effect of utilizing FMU deployment in such a multi-domain vehicle simulation task.

In order to understand the effects of deploying VeSyMA based vehicle experiments outside Dymola, an Electronic Stability Control (ESC) experiment is presented, benchmarked across both simulation platforms with and without control software in both Dymola and Simulink. An off the shelf vehicle slalom experiment is taken from the VeSyMA – Suspensions library and with minimal pre-processing, exported and deployed as an FMU within Simulink. A control model built in Simulink to the same specification as the one found within the VeSyMA – Suspensions library and is used to demonstrate the validity of the vehicle experiment model exported from Dymola when deployed in Simulink, with and without control algorithm presence. Commentary is given as to the effect of FMU deployment on CPU time and results.

MODELLING AND VALIDATION OF CONTROL SYSTEMS THROUGH THE EXCITATION OF THE HYDROELECTRIC POWER STATION SOPLADORA USING OPENMODELICA

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This paper begins with the excitation control system in a machine which is variable according to the needs of each system, and which has particular behaviour in each implementation. At the time of this simulation, there were not enough traditional models to provide us with the libraries of different software for power systems. However, free licensed software is available with object-oriented programming and the capacity to model complex heterogeneous systems; therefore, we built a mathematical model of the AVR (automatic voltage regulator) and PSS (power system stabilizer) of the Sopladora hydroelectric power station. These models were validated in a simple generator system – a bus – load. We compared the response behaviour of the voltage in the generator terminals and the field voltage with a simulation performed in software recognized and certified by its trajectory and application in engineering, and the same software was used as the reference. Once we achieved the right operation of the controllers, we proceeded to simulate the equivalent system of the 230 kV Sopladora bus. For this, we followed a construction process by adding and validating components until the equivalent system was obtained, and was ready to perform the validation qualitatively in both interfaces under the "software to software" modality, by observing the answers in the same flat and quantitatively through the mean squared error. This system was previously developed in the program referenced by a specialist of the National Electricity Operator CENACE.

PARAMETER ESTIMATION METHODS FOR FAULT DIAGNOSIS USING MODELICA AND FMI

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Having an up-to-date estimate of the condition of a real physical system in operation is imperative in order to reduce its maintenance costs and optimize its operational performance. Parameter estimation is a vital tool for tuning parameters in control systems with a wide range of applicability in scenarios such as virtual testing, virtual commissioning, and control optimization.

The modeling of fault is a key part of a model-based approach for a condition-monitoring scheme for physical assets. Recently, a standardized methodology for explicitly representing the physical behavior of faults in Modelica models has been developed that provides an important part of the process of fault identification (Gunderman et al, 2018). With this methodology, faults in the model are directly associated with components. In the present paper, we show how this approach can be combined with state estimation as a means of determining the cause of anomalous behavior of instrumented products.

In the model-based scheme, when a fault occurs in a physical system it can be interpreted as a change in the parameters of the model. The fault can be recognized by monitoring the difference between the output of the model and sensor data measured from the physical system. The value or the degree of fault can be determined by retuning the parameters of the system so that the new parameters give the same output response as the fault.

We present a comparison of different parameter estimation methods and exemplify how they can be implemented using Modelica and FMI in a tool-agnostic way. In presenting the different approaches to parameter estimation, we distinguish between their applicability by categorizing them as either "global" or "local". With the former approach, we consider the system as a whole, perhaps even as a black box. The appeal of these methods is that they do not require a priori knowledge of the system behavior. "Local" approaches, in contrast, use algorithms that are implemented in the system or component model itself, acting directly on its governing equations. They present the appealing prospect of model libraries of self-tuning (individual) components where parameters adjust automatically based on data from measured from physical components. In this paper, we present a novel approach where local estimators such as a particle filter (Liu, 1998) can be implemented directly in the model itself.

As an application we show how these different methods can be combined with component fault modes to provide effective real-time estimates of the health of a physical asset based on thermal sensor data.

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NONLINEAR STATE ESTIMATION WITH FMI: TUTORIAL AND APPLICATIONS

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State estimation methods are often used to characterize the behavior of dynamical systems from sets of observations for the purpose of systematically estimating unmeasured quantities. These estimates can be used for a wide variety of purposes, such as control, performance monitoring, or fault detection and diagnosis. As the Functional Mockup Interface (FMI) standard defines an application programming interface (API) for describing and simulating models of complex multiphysical systems, the capabilities of this interface can also be leveraged to provide a generalizable framework for the construction of state estimators for a wide range of applications. In practice, the complexity of the FMI API as well as the nuances of the implementation of the API in a given language (e.g., Modelica, Python) can make the construction of such state estimators quite challenging. This paper is thus designed to provide a tutorial describing the methodology and implementation of an extended Kalman filter (EKF), and a related particle-based state estimator referred to as an ensemble Kalman filter (EnKF). We demonstrate the efficacy of these state estimators in detail on a simple 4-state model of a permanent-magnet synchronous machine, and provide a complete implementation of the Modelica code for further reference and study. While the ability to construct state estimators for relatively small systems can be beneficial, the promise of this technology lies in its potential to systematically construct state estimators for large-scale Modelica models that have tens or hundreds of states. We therefore also study the implementation of these state estimators on a thermodynamic model of a building and its associated cooling system to study and compare their performance. In the course of this work, we demonstrate that the EKF can work quite well on these building models, but that there are fundamental limitations to implementing particle-based state estimators on physical systems with current FMI standard, related to the need to manage state and output constraints. As such, this work points to further opportunities for extending the FMI standard to augment its already considerable capabilities.

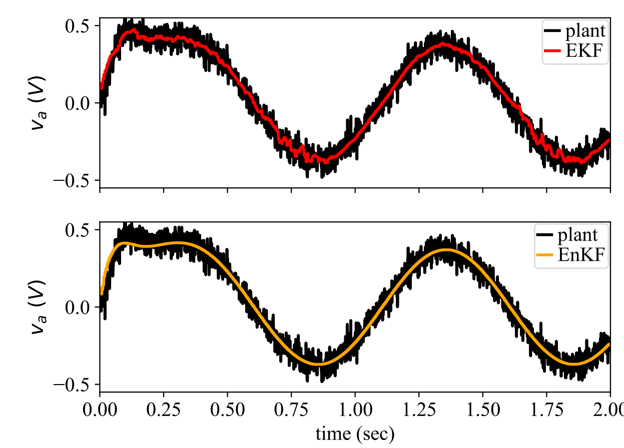

FIGURE 1. Estimated and measured phase A currents for the EKF and EnKF experiments.

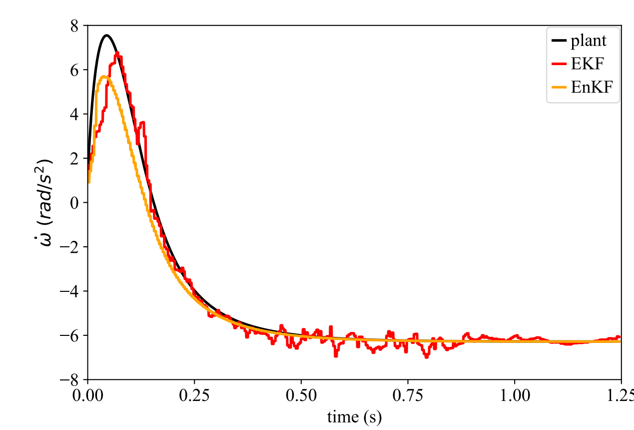

FIGURE 2. Estimated and measured shaft speed for the EKF and EnKF experiments.

ENHANCED STEADY-STATE IN MODELON JET PROPULSION LIBRARY, AN ENABLER FOR INDUSTRIAL DESIGN WORKFLOWS

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The sizing of a gas turbine is typically performed over a set of different scenarios. The design point would be the first step in identifying basic parameters as it would be the most constraining scenario for most components. Computing the component parameters from the boundary conditions on this point will be qualified as on-design simulation. For a jet engine, this would typically be the cruise mode at the top of climb. Other scenarios will be run to validate the design for conditions that are relevant for the expected operation such as takeoff or landing. In addition to the validations, iterative tuning of variables (e.g., cooling flow fraction) can be included – these would be named off-design simulations. On- and off-design simulation modes are typically sequential and iterative steps in a model-based design process of jet engines.

Running these scenarios in a disconnected fashion would be tedious and error prone. Model Based System Engineering applied to the design of gas turbines provides a relevant workflow that is addressed in this paper and serves as source of requirements for augmenting the Jet Propulsion library with additional features. The solution Modelon provides – based on the Jet Propulsion Library, Optimica Compiler Toolkit, FMI Toolbox and pyFMI – enables performing a robust design of a gas turbine for a design point satisfying relevant constraints of typical off-design scenarios. This paper illustrates this workflow with component and system level examples.

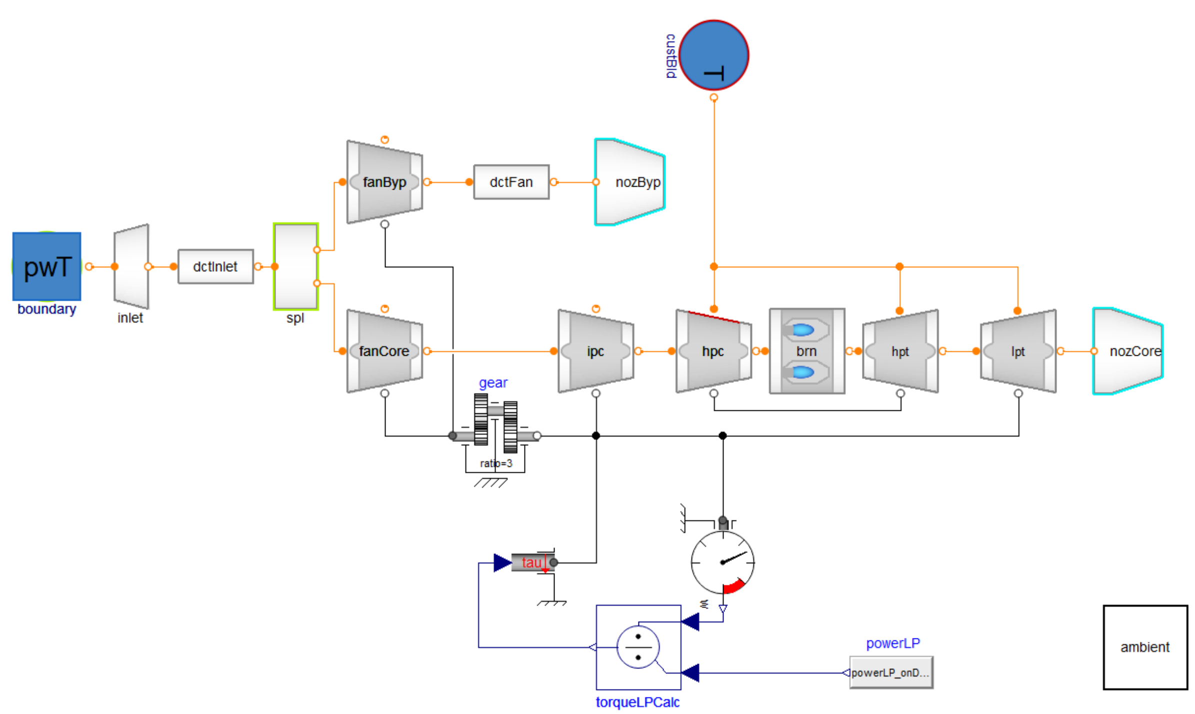

FIGURE 1. Architecture of the geared turbofan to optimize

OBJECT ORIENTED MODELING AND CONTROL DESIGN FOR POWER ELECTRONICS HALF-BRIDGE CONVERTER USING MODELICA

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The development of power semiconductors has led to the application of power electronics in electric power systems improving the efficiency and reliability of the existent infrastructure. The increasing penetration of renewable energy sources has also motivated an extended use of power electronic devices in electric networks.

This paper focuses on the implementation and design of a simple power electronic DC/AC converter, the half-bridge. In the category of the two-level VSC (DC/AC Voltage Source Converter), the averaged model and the switching model of an half-bridge converter are considered. The half-bridge is a building block for multiphase and multilevel converters.

The implementation of the two models of half-bridge converter using Modelica language is described with the structure of the package developed in Dymola. Different control strategies are introduced showing different behavior of the models in the simulations. This paper shows that with the use of Modelica it is possible to perform implementation and studies in the same field where traditional domain specific commercial softwares have been commonly and extensively used. In addition to that, it is also illustrated that the control design studies for an half-bridge converter, typically performed using averaged value models, can result in a set of control parameters values that are not successfully applicable to switching models of the same power electronic device.

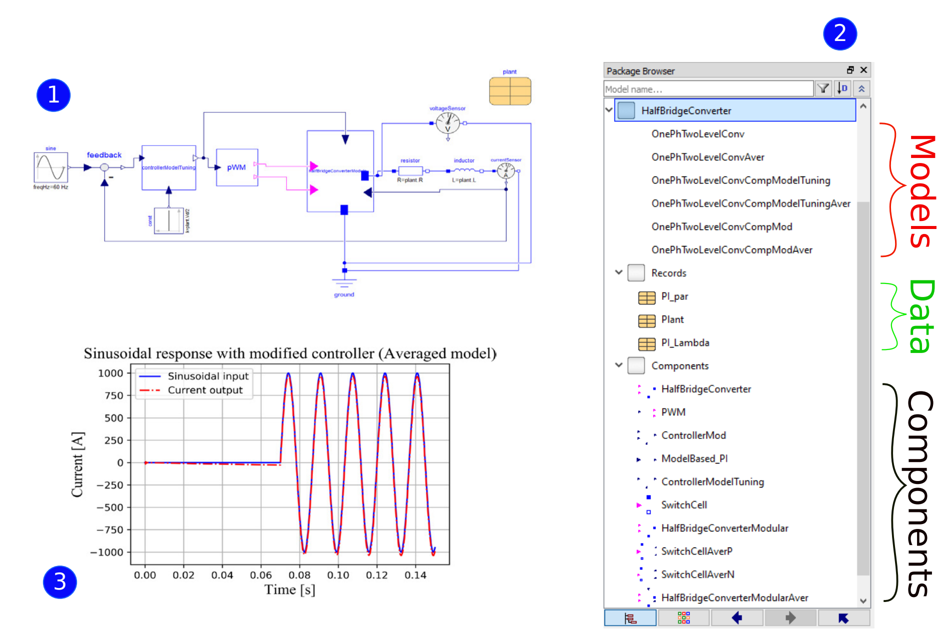


FIGURE 1. Electric network with the averaged model of an half-bridge converter: (1) Block diagram, (2) Structure of the Modelica library, (3) Example of simulation results showing the reference tracking of the converter output with an elaborated control strategy.

VENDOR ABSTRACTS AND SPONSORS

Modelon provides software solutions and expert services to organizations worldwide that use model-based simulation tools to design and develop physical systems. The Modelon Library Suite, Creator Suite, and Deployment Suite deliver a unified picture of product system interaction and performance – from concept to operation. Headquartered in Lund, Sweden, and with global reach, Modelon is an industry leader in model-based systems engineering with a focus on leveraging open standard technologies.

Modelon Library Suite: Our industry leading suite of libraries, built on the Modelica standard, deliver state-of-the-art system models for a wide range of industries including automotive, aerospace, industrial equipment, and energy and process. The Modelon Library Suite is currently compliant to operate in Dymola, OPTIMICA, Twin Builder, SimulationX, IGNITE, and MapleSim.

Modelon Creator Suite: Our creator suite includes Modelon's OPTIMICA Compiler Toolkit, the most advanced Modelica-based mathematical engine on the market. OPTIMICA offers users a powerful solution for the automation, simulation and optimization of system behaviors throughout the model-based design cycle.

Modelon Deployment Suite: Our deployment suite includes FMI Toolbox for MATLAB/Simulink. FMI Toolbox supports all major workflows in control system development and system integration for virtual prototyping, from design and sizing to optimization and MIL/SIL/HIL validation and verification testing in MATLAB/Simulink. The additional FMI Toolbox Coder Add-on provides extensive support enabling users to export FMUs from Simulink and import FMUs to a Simulink Coder target.

Coming soon:

Coming soon is Modelon Impact, a whole new web-based engineering simulation software without boundaries. Modelon Impact is a systems design environment, supporting system-level modeling, simulation, optimization and analysis to enable engineering insight and decision making.

Modelon Impact provides a user-friendly graphical editor, Modelon's comprehensive and customizable suite of libraries, solvers for dynamic and steady-state simulations, and import and deployment capabilities. Modelon Impact is software technology that allows you to work efficiently and collaboratively within your company and around the world.

Modelon Impact is a fully integrated web environment and native to open standards Modelica and the FMI standard. Custom workflow capabilities and available integrations with Python, Jupyter notebook, HTML.

Beta testing now available for commercial customers. Coming June 2020.

Claytex develops a range of FMI tools, Modelica libraries and related tools focused on the modelling and simulation of multi-domain systems. As a consultancy we help our customers apply these tools to simulate many different types of vehicles including electric and autonomous.

The Vehicle Systems Modelling and Analysis (VeSyMA) platform is a suite of compatible Modelica libraries for modelling automotive vehicles and their subsystems. This suite of Modelica libraries was created to provide a modular approach to vehicle modelling, where the user can tailor the complexity of the model to meet their specific needs. The suite builds upon the open-source Vehicle Interfaces Library to promote compatibility with libraries from other vendors. VeSyMA provides application specific extensions for modelling Internal Combustion Engines, Transmissions, Drivelines, Vehicle Dynamics and Cooling.

In addition to VeSyMA, Claytex partners with CAE Tech to develop the Fluid Power Library. This is focused on the modelling and simulation of hydraulic systems and includes thermal effects within the fluid models.

To aid the deployment of simulation models to a larger number of end users, Claytex develops several FMI based tools. These aren't available as off-the-shelf software tools; we use the code base to develop custom applications for our customers. This allows our customers to integrate FMUs into their own custom simulation tools which can be deployed into different application environments whether it be Excel, C#, or even cloud based tools that can be accessed through a web browser.

To support the development of these Modelica libraries, Claytex has also developed the MultiRun tool. This tool is used to automate testing of Modelica libraries and is designed to improve library quality and maintain consistency in results. The tool is designed to work with Dymola and runs multiple instances of Dymola in the background to accelerate testing.

Claytex is also involved in the development of simulator solutions for ADAS and autonomous vehicles. These solutions are built around rFpro and our focus is on the development of the sensor models and integration of the complete solution (sensors, vehicle model, control, and more.) This allows us to deliver a simulator designed for scenario-based testing of these complex systems.

At Ricardo Software, our aim is to help you solve the problems that matter through technology exploration and process innovation.

Drawing on the experience of our extensive consulting business, Ricardo Software creates tools that address a wide range of today's key engineering problems. Covering engineering domains as diverse as combustion modeling, virtual calibration, electrification, vehicle dynamics, and mechanical analysis, Ricardo Software translates our expertise into proven tools and techniques that you can immediately apply to your real world problems.

At this conference, we'll be giving you a peek at some of the things we have been working on to improve engineering collaboration. Behind the scenes, we've been digging deep into a number of technologies that we think will change the way engineering analysis is done. Built on top of Ricardo's proven engineering expertise we are crafting new ways to deliver that expertise to our customers while, at the same time, finding new ways to extract value from leading edge technology.

Of course, because many of these innovations involve Modelica, they can be applied to any domain which leverages Modelica which, as we know, covers an enormous range of applications. So we hope you'll enjoy our presentation and give us feedback so we can provide you with the best possible tools for your particular business.

MapleSim 2020: A Powerful Modelica Platform

MapleSim is a Modelica-based platform that combines system-level modeling and simulation with powerful analytic capabilities. Our goal with MapleSim is to provide engineers with an easy to use tool for design exploration and simulation. This session will provide an overview of some of MapleSim's unique offerings: its connection to CAD, simple to use analysis apps, and the coupling between modelica and Maple's symbolic capabilities. Additionally, we'll outline some of MapleSim's new visualization options for the upcoming 2020 release.

ANSYS Twin Builder: Build, Validate and Deploy Complete Systems Simulations and Digital Twins for Predictive Maintenance

ANSYS Twin Builder is a predictive maintenance product that allows you to save on warranty and insurance costs and optimize your product operations. To build your system easily and quickly, ANSYS Twin Builder combines the power of a multidomain systems modeler with extensive 0D application-specific libraries, 3D physics solvers, ROM capabilities and embedded software tools. To validate your system, ANSYS Twin Builder combines multidomain systems simulation capabilities with rapid HMI prototyping, systems optimization and XIL validation tools, ensuring that your system design will perform as expected. To connect your twin to test or analyze real-time data, ANSYS Twin Builder easily integrates with IIoT platforms and contains runtime deployment options, allowing you to perform predictive maintenance on your physical product.

Please join this session to learn more about ANSYS Twin Builder's support for Modelica standard and add-on libraries, combined with multi-domain behavioral models, Reduced-Order Models from 3D physics simulation and support for leading IIoT platform can accelerate the product development and IIoT adoption.

Wolfram System Modeler is an easy-to-use, next-generation modeling and simulation environment for cyber-physical systems. Adding the power of the Wolfram Language gives you a fully integrated environment for analyzing, understanding and quickly iterating system designs. Driving insight, innovation and results.

SystemModeler is used in education, research, and industry around the world. This vendor session will focus om how SystemModeler is used to make teaching come alive.

The Wolfram vendor session will focus around the four Wolfram Virtual Labs that we have launched during the last few months: CollegeThermal, CollegeBiology, HighSchoolChemistry, and HighSchoolBiology.

These are open educational resources, for college and high school respectively, in the form of interactive courseware that are used to explain different concepts in the classroom. Our ambition is to provide an easy way to study difficult concepts and promote student curiosity while at the same time spreading Modelica.

As part of the presentation we will also present upcoming libraries as well as some of the latest SystemModeler features.

Dassault Systèmes will present an overview of recent updates in Dymola and its integration with more engineering, CAD, and simulation tools. The user interface of Dymola has been modernized to the benefit of both novice and experienced users. The new interface provides easier access to all operations and has been re-grouped to better support the natural workflow of model development and simulation. It also looks more modern, with a ribbon-based command interface and improved icons.

3DExperience Platform leverages the flexibility, robustness and integration power of Modelica language to utilize it for CATIA applications to rapidly develop, simulate and validate, complex kinematics, electrical, and fluidics systems. The 3DExperience platform leverages the Modelica language and FMI for evaluation and validation of requirements, functional and logical models in Model Based Systems Engineering.

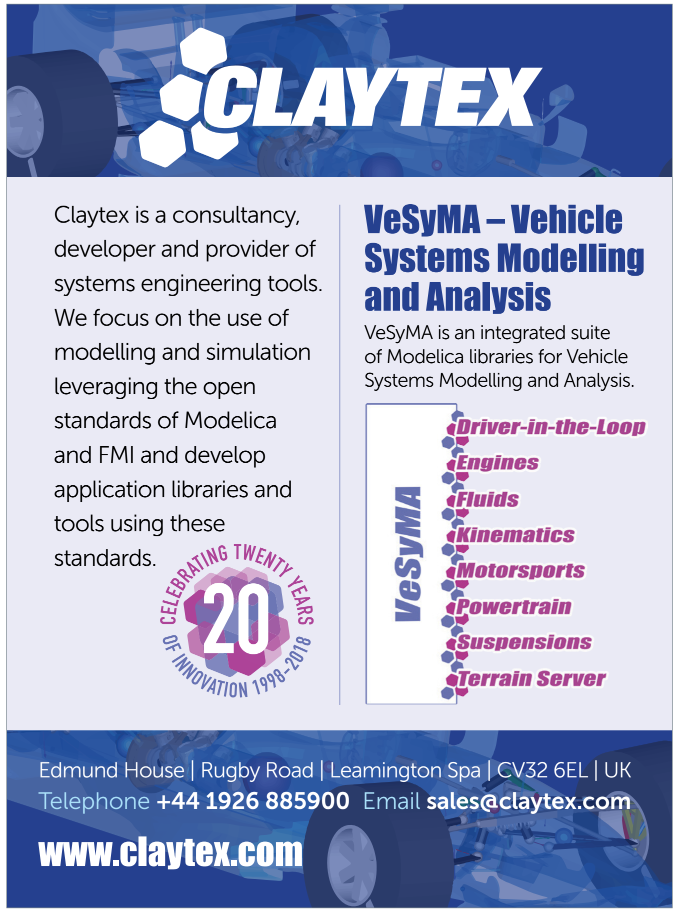
With the new platform for cloud-based simulation, Dassault Systèmes will facilitate large-scale deployment of Modelica-based applications without sacrificing any of the Dymola processing power, package in an easy-to-use environment for model simulation and experimentation and providing industry-leading security through 3DEXPERIENCE.

Altair's Open Integration Platform for Multi-Disciplinary System Simulation

In today's world of increasingly complex, smart devices, accelerating product development while managing risk has never been more challenging. To help companies and their engineers bring their innovative new mechatronic products to market faster, Altair has developed a platform for model-based development of complex systems. This integration platform combines the use of 3D, 1D, and 0D modeling, is inherently multi-disciplinary and powerful, yet also intentionally open and easy to extend.

This presentation will spotlight several digital twin examples showing how Altair Activate™ serves as the basis for this open integration platform for multi-disciplinary system simulation – including through its support for open standards such as Modelica, SPICE, and FMI. Naturally, Activate couples well with other software apps from Altair in its HyperWorks™ suite, but also with 3rd-party software apps which support these modeling standards.

Come see, hear, and learn how thought-leading companies around the world (including Schneider Electric, Sarcos Robotics, Mabe, FCA, Porsche, and Mercedes AMG) are breaking down the silos between their mechanical and electrical engineering teams through their use of Altair's flexible and robust system simulation capabilities.


CLAYTEX
Claytex is a consultancy, developer and provider of systems engineering tools. We focus on the use of modelling and simulation leveraging the open standards of Modelica and FMI and develop application libraries and tools using these standards.
CELEBRATING TWENTY YEARS OF INNOVATION 1998-2018
20
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VeSyMA is an integrated suite of Modelica libraries for Vehicle Systems Modelling and Analysis.
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MapleSim is a Modelica®-based system-level modeling and simulation tool that applies modern techniques to dramatically reduce model development time, provide greater insight into system behavior, and produce fast, high-fidelity simulations. The combination of Modelica with the symbolic computation power of MapleSim enables a level of understanding, power, and extensibility not possible with "black-box" tools.
Maplesoft
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