THE AMERICAN MODELICA 2022 CONFERENCE

DALLAS
OCTOBER 26-28

Modelica

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WELCOME

I think I speak for all the organizers when I say that we are very excited to see you all in person this year. Life during a pandemic has not been easy, and we have tried to do what we could to facilitate communication in the North America Modelica community over the last two years. While the pandemic has not subsided entirely, we felt that the continuing progress and improvements in public health measures had prepared our community for a return to face-to-face events.

Hopefully this year will mark the return of this and other events as places where those with similar interests can gather, present, converse, critique, and enjoy a great meal together. To encourage such activities, we made a conscious decision to allow limited hybrid participation (a "read-only" version, if you will). This was a tough call, but we felt that the viability of the in-person event necessitated a focus on the experience of in-person participants. The in-person turnout is an important part of what makes sponsorship possible and sponsorship is an important component of managing the financial aspects of such an event. I just wanted to be fully transparent with the community about our thinking here and we hope you understand.

This year's event will be held at the Davidson-Gundy Center in Richardson, Texas. We'd like to extend our deep appreciation and thanks to Prof. Yaoyu Li from UT Dallas for hosting this year's event. The facilities are fantastic and are nicely equipped to handle live streaming and the recording of all talks. I hope everybody brings an appetite for some Texas BBQ. As a former Texas resident, I can honestly say it is the thing I'm looking forward to most after seeing all of you (and your work) again in person.

Welcome (back) to the American Modelica Conference!

Dr. Mike Tiller
Conference Co-chair

CONFERENCE DETAILS

The conference will take place at the Davidson-Gundy Alumni Center at the University of Texas at Dallas in the main Ballroom (ABC) on Wednesday and Thursday, October 26 and 27.

These buildings can be located on the maps available online at **https://map.utdallas.edu/** or via other internet mapping services.

CONFERENCE ADDRESS:
Davidson-Gundy Alumni Center, 800 West Campbell Road
Richardson, TX 75080

CONFERENCE WEBSITE:
https://2022.american.conference.modelica.org/

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

WORKSHOP ADDRESS:
The workshops will take place on Friday, October 28 in the Naveen Jindal School of Management (JSOM) building] in rooms 1.502, 1.516, 1.517, and 11.305 (see p. 8 for room map).

EMERGENCY INFORMATION:
To report an emergency, call 9-1-1, or call the UT Dallas Police Department at 972-883-2222.

INTERNET/WIFI:
Information to connect to the wireless internet is available via UTDGuest, which is an open wireless network available on campus to accommodate short-term guests who simply need internet without full access to UTD network resources. UTDGuest is available at https://atlas.utdallas.edu/TDClient/30/Portal/Requests/ServiceDet?ID=172

DIRECTIONS AND ASSISTANCE:
Graduate students from Prof. Yaoyu Li's group at UT Dallas have graciously offered to provide directions or other help to the conference attendees. They can be identified by their UT-Dallas T-shirts.

REGISTRATION DESK:
The registration desk is open from Wednesday, October 26 at 7:30 am through the duration of the conference.

TOURIST INFORMATION:
Dallas Fort-Worth (DFW) Metroplex area offers many exciting attractions to tourist, from the Downtown Dallas Sixth Floor Museum at Dealey Plaza, Perot Museum of Nature and Science, Reunion Tower, Fort Worth Stockyards National Historical District, Six Flags over Texas, to Dallas Cowboy Stadium. Late October is normally the best season for seeing the DFW area, with daily temperatures between 50s to 70s F. White Rock Lake is a great place for walking, jogging and boating, with a 9.3 mile trail and Dallas Arboretum at its east side. Tourism information for the top attractions can be found at: https://dallascityhall.com/Pages/tourism.aspx and https://theculturetrip.com/north-america/usa/texas/articles/20-must-visit-attractions-in-dallas-ft-worth/.

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

CONFERENCE DINNER:
The conference dinner will take place at the Ten50 BBQ restaurant located at 1050 N. Central Expy in Richardson, Texas from 6pm to 11pm on October 26.

PARKING:
The conference attendees who drive to campus can use the metered parking spaces in parking structures PS1, PS4 or PS3 (see the parking map at: https://services.utdallas.edu/download/Parking_Map.pdf).

To use one of these spaces, remember your parking space number or stall number and go up to the nearest payment kiosk, tap any key to wake it up, then follow its instructions. You have the following ways to pay:

1) Swipe your credit card or debit card through the kiosk;

2) If you already have an account with the PayByPhone service, you can pay through their web site; through their Android™, BlackBerry™, or iPhone® app; or

3) by calling 888.450.7275. Their normal services fees will apply. Current Rates: $2 for the first hour, plus $1 for each additional hour.

Please remember to keep your receipt, as it shows the time when your meter expires. If your time has not yet expired, and you paid via credit/debit card, you can return to the kiosk and add more time. If you used PayByPhone, you can add more time remotely, and even set up the service to send you an SMS five minutes before your time expires.

More information is available at:
https://services.utdallas.edu/transit/park/#metered.
Since there are generally no convenient public transportation available from nearby hotels to UT Dallas campus, ride-sharing services may be best for those who do not drive.

DAY 1: 26 OCTOBER 2022

7:00 AM – 9:00 AM	Registration and Mingle Inspiration Hall (DGA 1.1)	
9:00 AM – 11:30 AM	Vendor Session Ballroom A (DGA 1.102A)	
11:30 AM – 1:00 PM	Lunch Break Inspiration Hall (DGA 1.1)	
1:00 PM – 1:55 PM	Keynote 1 Ballroom A (DGA 1.102A)	
1:55 PM – 2:00 PM	Switch Rooms	
2:00 PM – 3:15 PM	**ROOM 1** Building Energy 1 Ballroom B (DGA 1.102B)	**ROOM 2** Aerospace Ballroom C (DGA 1.102C)
3:15 PM – 3:45 PM	Coffee Break Inspiration Hall (DGA 1.1)	
3:45 PM – 5:00 PM	**ROOM 1** Power Generation Ballroom B (DGA 1.102B)	**ROOM 2** Language/Tools Ballroom C (DGA 1.102C)
5:00 PM – 6:00 PM	Transit to Conference Dinner	
6:00 PM – 9:00 PM	Conference Dinner Ten50 BBQ	

DAY 2: 27 OCTOBER 2022

7:30 AM – 8:05 AM	Mingle Inspiration Hall (DGA 1.1)	
8:05 AM – 9:00 AM	Keynote 2 Ballroom A (DGA 1.102A)	
9:00 AM – 10:15 AM	Modelica Association/FMI updates Ballroom A (DGA 1.102A)	
10:15 AM – 10:45 AM	Coffee Break Inspiration Hall (DGA 1.1)	
10:45 AM – 12:00 PM	**ROOM 1** Building Energy 2 Ballroom B (DGA 1.102B)	**ROOM 2** Model-Based Design Ballroom C (DGA 1.102C)
12:00 PM – 1:30 PM	Lunch Break Inspiration Hall (DGA 1.1)	
1:30 PM – 3:30 PM	**ROOM 1** User Presentations 1 Ballroom B (DGA 1.102B)	**ROOM 2** User Presentations 2 Ballroom C (DGA 1.102C)
3:30 PM – 4:00 PM	Coffee Break Inspiration Hall (DGA 1.1)	
4:00 PM – 5:00 PM	Podium Discussion Ballroom A (1.102A)	

DAY 3: 28 OCTOBER 2022

8:00/ 9:00 AM	Workshop A-1 (Room 1.502) Workshop B-1 (Room 1.516) Workshop C-1 (Room 1.517)
12:00 PM	Lunch Break
1:00 PM	Workshop A-2 (Room 1.502) Workshop B-2 (Room 1.516) Workshop C-2 (Room 1.517)

Schedule provided in Dallas, TX, USA local time (UTC-5)

DAY 1

ROOM 1

Paper Session 1 **Building Energy I**

BESMOD – A Modelica Library for Providing Building Energy System Modules
Wüllhorst, F., Maier, L., Jansen, D., Kühn, L., Hering, D., and Müller, D.

Fan and Pump Efficiency in Modelica based on the Euler Number
Fu, H., Blum, D. and Wetter, M.

Transient Simulation of an Air-Source Heat Pump under Cycling of Frosting and Reverse-Cycle Defrosting
Ma, J., Kim, D., and Braun, J.E.

Paper Session 2 **Power Generation**

Applying Design of Experiments Method for the Verification of a Hydropower System
Pham, L.N.H., and Winkler, D.

Using Multi-Physics Simulation to Estimate Energy Flexibility for Local Demand Response Strategies in a Microgrid
del Barrio, I.L., Cestero, J., Quartulli, M., Olaizola, I.G., Aginako, N., and Ugartemendia, J.J.

Power System Real-Time Simulation using Modelica and the FMI
del Castro Fernandes, M., et al,

ROOM 2

Paper Session 1 **Aerospace**

Simulation of the On-Orbit Construction of Structural Variable Modular Spacecraft by Robots
Reiner, M.

Extending a Multicopter Analysis Tool using Modelica and FMI for Integrated eVTOL Aerodynamic and Electrical Drivetrain Design
Podlaski, M., Vanfretti, L., Niemiec, R., and Gandhi, F.

Multirotor Drone Sizing and Trajectory Optimization within Modelon Impact
Coïc, C., Budinger, M., and Delbecq, S.

Paper Session 2 **Language/Tools**

A Playground for the Modelica Language
Tiller, M.

Towards an Open Platform for Democratized Model-Based Design and Engineering of Cyber-Physical Systems
Nachawati, M.O., Bullegas, G., Gregory, J., Vasilyev, A., Pop, A., Elaasar, M., and Asghar, A.

Enhancing SSP Creation using sspgen
Hatledal, L.I., and Fagerhaug, E.

DAY 2

ROOM 1

Paper Session 3 **Building Energy 2**

Development and Validation of a Modelica Model for the Texas A&M Smart and Connected Homes Testbed
Firsich, T., Yang, Z., and O'Neill, Z.

Performance Enhancements for Zero-Flow Simulation of Vapor Compression Cycles
Qiao, H., and Laughman, C.

Tradeoffs Between Indoor Air Quality and Sustainability for Indoor Virus Mitigation Strategies in Office Buildings
Faulkner, C.A., Castellini Jr., J.E., Lou, Y., Zuo, W., Lorenzetti, D.M., and Sohn, M.D.

User Presentations I

Model-Based Optimization for a Campus District Cooling System
Zuo, W. et al.

Hybrid Model Predictive Control of Chiller Plant with Thermal Energy Storage Evaluated with Modelica-Python Co-Simulation
Pan, C., and Li, Y.,

The Use of Modelica and the Functional Mockup Interface for the Building Optimization Testing Framework (BOPTEST)
Blum, D.

Use of TRACE 3D Plus Models with Spawn for Rapid Prototype Development in Modelica Environment
Phalak, K., and Gupta, D.

Comparative Analysis of Price-Based Control Strategies for a High Temperature Thermal Energy Storage System
Yang, T., Filonenko, K., Zuluaga, I., and Veje, C.,

ROOM 2

Paper Session 3 **Model-Based Design**

Guidelines and Use Cases for Power Systems Dynamic Modeling and Model Verification using Modelica and OpenIPSL
Laera, G., et al,

Material Production Process Modeling with Automated Modelica Models from IBM Rational Rhapsody
Batteh, J., Gohl, J., Ferri, J., Le, Q., Glandorf, B., Sherman, B., and Opmanis, R.

User Presentations II

Modelica-Based Control of a Delta Robot
Bortoff, S.A.

Prototyping Composable Simplification Passes for Equation-Oriented Models Using ModelingToolkit.jl
Ma, Y., Fischer, K., Rackauckas, C., and Shah, Vm

Modeling and Control of Nuclear-Renewable Integrated Energy Systems for Electricity and Hydrogen Production
Jacob, R., and Zhang, J.

Innovative Concepts and Application for Large-Scale and Multimode Systems: Case Study of Heat Networks
Gavan, V., Chombart, P., Duprat, C., Fricker, J., Radet, B. and Maquin, K.

Reinforcement Learning based Control of Integrated Energy Systems using ModelicaGym
Wang, J., Jacob, R., and Zhang, J.

Modeling an Integrated Energy System in OpenModelica to Utilize the Output of a Nuclear Reactor for Producing Energy and Powering a Desalination Plant
Aziz, A., and Brooks, C.

DAY 3

WORKSHOP A-1

Introduction to Modelica with Modelon Impact

Hubertus Tummescheit, John Batteh (Modelon)

DURATION: 4 hours **LOCATION:** Naveen Room 1.502

START TIME: 8:00 am (note the earlier start time)

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. The workshop is planned to take 4 hours, with a break in the middle.

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

Introduction to Modelica and Thermo-fluid Modeling with Applications from the Buildings Library

David Blum (Lawrence Berkeley National Laboratory)

DURATION: 3 hours **LOCATION:** Naveen Room 1.502

START TIME: 1:00 pm

ABSTRACT: This workshop will give an introduction to the modeling of thermo-fluid systems and their control using Modelon Impact and the Modelica Buildings Library. We will be using applications from the Modelica 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 practices in setting up thermo-fluid 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 Modelica Buildings Library. Simulations will be run on Modelon Impact.

EXPECTED EXPERIENCE: 1) Have prior knowledge in Modelica and have gone through the online Impact tutorial for basic usage Go to https://help.modelon.com/latest/application_overview/getting_started_overview/ or 2) Have participated in the morning workshop provided by Modelon on introduction to Modelica modeling and Impact.

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

WORKSHOP B-1

The DLR Thermofluid Stream Library: From simple components to the prototypic control of a complex thermal architecture

Dirk Zimmer (DLR)

DURATION: 2 hours **LOCATION:** Naveen Room 1.516

START TIME: 9:00 am

ABSTRACT: Are you interested in the efficient simulation of thermal architectures such as battery cooling for electric cars or reversible heat-pumps for stationary applications? Then this tutorial is for you. It provides an introduction into the DLR Thermofluid Stream Library, a free and open-source Modelica package, available at https://github.com/DLR-SR/ThermofluidStream. We explain the underlying methodology that enables the unique robustness of this approach, we present simple examples to follow by yourself, demonstrate the scalability of the approach to complex applications, and perform a small hands-on optimization exercise. You can follow the tutorial without equipment, but having a laptop with OpenModelica, Dymola, or Modelon Impact installed will enable you to get more out of it.

EXPECTED EXPERIENCE: Basic Modelica knowledge.

SOFTWARE REQUIREMENTS: Passive participants possible, while active participants should have either Dymola, Open Modelica, Modelon Impact installed on their laptop.

WORKSHOP B-2

Introducing the Digital Engineering Commons: the First DevOps Platform for Collaborative Digital Engineering

Gianmaria Bullegas & Omar Nachawati (Perpetual Labs)

DURATION: 2 hours **LOCATION:** Naveen Room 1.516

START TIME: 1:00 pm

ABSTRACT: Digital Engineering Commons is the first platform to apply the concept of DevOps to community-driven collaborative Digital Engineering and Manufacturing (DEMOps). It is currently being developed by Perpetual Labs, Ltd in collaboration with the Open Source Modelica Consortium (OSMC) and the OpenCAESAR project. In this workshop, we will demonstrate how such a DEMOps workflow looks like. The workshop will provide an overview of the major functions of the platform including: the breakthrough collaborative Modelica editing environment, the Community Marketplace, the Workbench Environment and the ontological editor. The underlying technologies powering each of these environments such as Git-powered configuration management, various modes of collaboration, semantic interoperability of system's knowledge and automated reporting will also be covered.

The participants will be able to explore the platform through a hands-on DEMOps example aimed to illustrate how Modelica-based modeling and simulation can be integrated into a wider systems engineering design process. The case study will be centered around a simplified environmental control system of a passenger aircraft. During the workshop we will also provide all the necessary theoretical fundamentals about semantic technologies and DEMOps and demonstrate how they are applied in practice on the platform.

EXPECTED EXPERIENCE: Some familiarity with model based systems engineering practices.

SOFTWARE REQUIREMENTS: Laptop with a recent version of Google Chrome.

WORKSHOP C-1

Introduction to Modeling, Simulation, Debugging, and Interoperability with Modelica and OpenModelica

Peter Fritzson, Adrian Pop (Linköping University)

DURATION: 3 hours **LOCATION:** Naveen Room 1.517

START TIME: 9:00 am

ABSTRACT: This tutorial gives an introduction to the Modelica language, the OpenModelica environment, and an overview of modeling and simulation in a number of application areas. Some advanced features of OpenModelica will be presented. A number of hands-on exercises will be done during the tutorial, both graphical modeling using the Modelica standard library and textual modeling.

EXPECTED EXPERIENCE: No prior experience in Modelica is needed.

SOFTWARE REQUIREMENTS: OpenModelica latest version should be installed but it can be done during the tutorial.

WORKSHOP C-2

Acausal modeling in Julia with ModelingToolkit.jl

Chris Rackauckas (Julia Computing/MIT)
Yingbo Ma (Julia Computing)

DURATION: 3 hours **LOCATION:** Naveen Room 1.517

START TIME: 1:00 pm

ABSTRACT: Julia's ModelingToolkit is a recent addition to the space of tools for acausal modeling, featuring a staged compilation system which allows for interleaving computation with symbolic manipulation. In this workshop we will introduce participants to the Julia programming language and its use in ModelingToolkit. We will start by showing how common use cases from the Modelica world, such as building circuit models with the Modelica Standard Library, map over to ModelingToolkit and its ModelingToolkit Standard Library. After becoming comfortable with the basics of DAE modeling, we will dive into handling the extensive solver options available in the Julia-based platform, including how to make use of unique compilation features like SemiLinearODEProblem for implicit-explicit (IMEX) and exponential integrators, along with optimizing the choices between the 300+ available solving methods. Lastly we will turn our focus to some of the unique features in ModelingToolkit, discussing how to use high order adaptive methods on stochastic differential equation systems and the integration of acausal modeling tools into nonlinear optimization solvers. Participants will leave with a strong sense of how ModelingToolkit can complement existing Modelica workflows.

EXPECTED EXPERIENCE: Prior experience with Modelica or other acausal modeling tools, no Julia experience required.

SOFTWARE REQUIREMENTS: We will send instructions for how to install Julia and setup the VS Code editor before the workshop, but will likely dedicate the start of the workshop to this part in case participants are not able to install these tools ahead of time.

Location of Conference on Wednesday and Thursday, October 26–27

Davidson-Gundy Alumni Center

Location of Workshops on Friday, October 28

Naveen Jindal School of Management (JSOM) Building

Naveen Jindal School of Management (JSOM) Workshops

KEYNOTE SPEAKERS

DIRK ZIMMER

Head of Team for Aircraft Energy Systems at
German Aerospace Center (DLR)

BIO

Dr. Dirk Zimmer is head of a research team for the modeling and simulation aircraft energy systems at the German Aerospace Center (DLR). He received his PhD degree at the Department of Computer Science of the Swiss Federal Institute of Technology (ETH). Also, he is lecturer at the Institute of Computer Science at the Technical University of Munich (TUM) and member of the Modelica Association. Recently he developed a new computational scheme for complex thermal architectures and the corresponding library was awarded with the Modelica Library Award in 2021.

ABSTRACT

Mathematical Modeling in Modelica: The Art of Compressing Reality

When we enjoy the freedom of mathematical expression in Modelica, we build on the legacy of many great scientist who condensed the laws of nature into elegant equations. This makes differential-algebraic equations an extremely powerful modeling tool to compress the real system down to an intelligible, computable and hopefully controllable form.

But all too often, this compression is flawed and as simulation engineers we run into errors. For large modeling efforts, the freedom of expression needs to be rigorously constrained by a clear methodology. All experienced modelers know that the dull application of text-book equations will not bode well in a large, challenging simulation project. But how to do better? How to ensure that you reach a computational feasible form that is still effective? How to ensure that what works on component level will work on system level?

In this keynote, I revisit the principles of idealization that modelers often apply without being aware of them. I demonstrate how quickly idealization can lure you into problems rather than solving them. But better understanding the process of idealization also offers an approach leading to a robustly solvable form, even for large complex systems. The immediate practical value is demonstrated by the simulation of complex thermal architectures and the real-time simulation of stiff mechanical contact problems.

SWAMINATHAN GOPALSWAMY

Research Professor, Director
Connected Autonomous Safe Technologies (CAST) Lab
Department of Mechanical Engineering, Texas A&M

BIO

Swami Gopalswamy is a Research Professor in the department of mechanical engineering at Texas A&M University, and the director of the Connected Autonomous Safe (and Sustainable) Technologies (CAST) Lab. His research at A&M is focused on control-enabled technologies that can lead to safer and more sustainable transportation solutions. The research at CAST spans development of fuel-efficient powertrains to new vehicle platooning concepts to techno-business paradigms such as "Infrastructure Enabled Autonomy". He is also working on developing algorithms and software to enable coordinated movement of a fleet of heterogeneous air and ground vehicles autonomously, on off-road terrains. He has introduced Modelica as part of classes that he has taught at Texas A&M.

Previously, Dr. Gopalswamy was the CEO of Emmeskay, Inc., a company that provided modeling, simulation and other advanced technology solutions to the automotive industry. As part of Emmeskay, Dr. Gopalswamy and his colleagues were engaged in advanced modeling and control projects based on Modelica. Subsequently, he was LMS-VP at LMS International and Siemens PL, responsible for managing a global MBSE engineering services team, as also leading the development of Control-design software products. Prior to Emmeskay, Dr. Gopalswamy was a Staff Research Engineer at General Motors R&D Center.

At GM, he was engaged in solving powertrain control challenges (such as smooth clutch-to-clutch shifting) and developing powertrain concepts (such as magnetorheological fluid devices and hybrid electric powertrains).

He holds a doctorate and master's degree in controls from the department of mechanical engineering at the University of California, Berkeley. He has a bachelor's degree in Mechanical Engineering from the Indian Institute of Technology, Madras.

ABSTRACT

Modeling and Simulation for Autonomous Vehicle Research and Development

Along with electrification, one mega-trend that is shaping industry momentum is autonomy, with tremendous strides in the last decade. A majority of the enabling technologies have gone past the R&D stage rather rapidly. However, they are stuck in the verification and validation (V&V) stage, a known process bottleneck even for traditional automotive technologies. Just as with traditional automotive technologies, there is a clear need for Modeling and Simulation (M&S) to enable rapid systems level design, optimization, calibration and V&V. However, autonomous vehicles pose particular modeling challenges because of the high degree of coupling between the environment model and the vehicle models.

Since many of the autonomous algorithms focus on sensors for localizing the ego-vehicle and its environment (treating the vehicle itself as a well-behaved actuator), the modeling efforts have focused on the sensing, and in particular, on photo-realistic rendering to support cameras on-board the vehicles. This has resulted in a trend to using game engines (or game-engine-inspired) technologies for M&S. However, game engines have been developed with the goals of distributed simulation, with focus on user experience, rather than repeatability. This leads to open questions on which value proposition of M&S should be prioritized? The ability to evaluate autonomous algorithms in a scalable fashion, or the ability to have repeatable, deterministic simulations that can be used to perform comprehensive V&V. Is there a role for stochastic simulations in V&V. In addition to the above, most of the existing simulations primarily support rigid body dynamics with techniques to handle collision, and rarely support any multi-physics modeling capabilities. This leads to additional questions such as, if the assumption of the vehicle as a well-behaved actuator falls apart, what happens. For example, how do we model the camera frame rate changing when the vehicle powertrain is stressed?

The talk will pose these open questions to spur thoughts on how the M&S community could respond to the challenges in the autonomous driving space.

ABSTRACTS

BESMOD – A Modelica Library for Providing Building Energy System Modules

Fabian Wüllhorst | fabian.wuellhorst@eonerc.rwth-aachen.de
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Institute for Energy Efficient Buildings and Indoor Climate, E.ON Energy Research Center, RWTH Aachen University, Germany

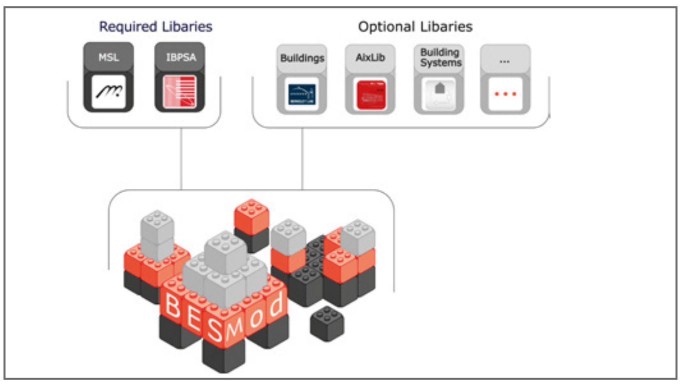

Figure 1.
BESMod is build upon required and optional library dependencies.

Simulation based analysis can aid the development of innovative design and control methods towards the integration of renewable energy into a domain-coupled building sector. While Modelica enables the modeling and coupling of different domains, current open-source Modelica libraries mostly provide component models for single domains. No uniform approach for coupling relevant domains within one building energy system exists. Further, coupled system models encompass large equation systems and countless parameters. While existing libraries are user-friendly on component level, no clear approach is presented for simulation and analysis of complex building energy systems.

To close this gap, we present BESMod, an opensource Modelica library, providing a modular approach towards domain-coupled building energy system simulations (cf. Figure 2). BESMod relies on existing component specialized model libraries for the underlying physics (cf. Figure 1). For the analysis of complex system simulations, we propose user-friendly parameterization, consistent model interfaces, precalculated KPIs and debugging options. The library is available at www.github.com/RWTH-EBC/BESMod.

This contribution motivates the need for this libraryand lays out the interaction with existing model libraries and the library design. We describe the modular approach, the layout for each domain-specific subsystem, and the system aggregation. In addition, we apply continuous integration to secure future modelling standards. An exemplary use case demonstrates the applicability of BESMod, by creating coupled simulations using building envelope models from the Buildings and AixLib library.

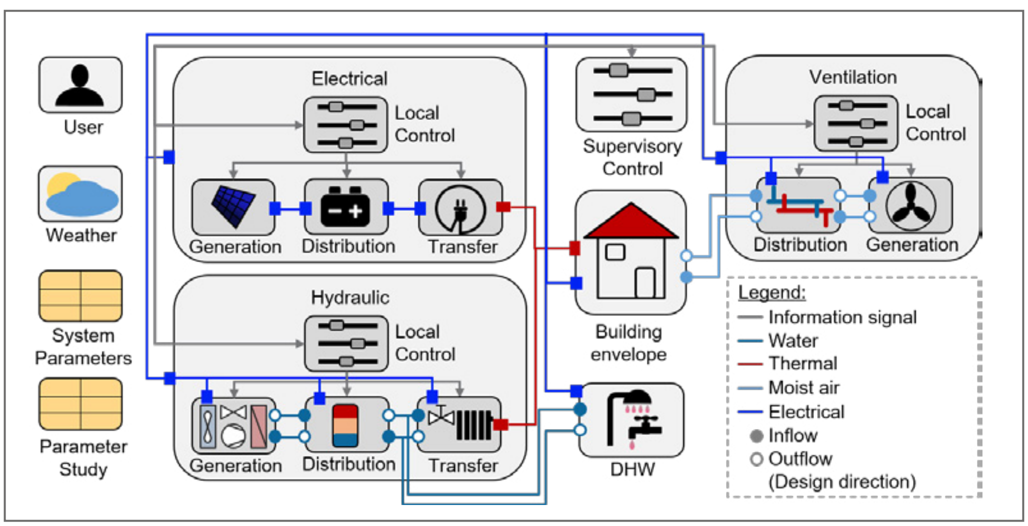

Figure 2.
The aggregation of subsystem into the building energy system

Fan and Pump Efficiency in Modelica Based on the Euler Number

Hongxiang Fu
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Michael Wetter
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Building Technology and Urban Systems Division, Lawrence Berkeley National Laboratory, USA

In this paper, we report a Modelica implementation of a convenient method to represent fan or pump (mover) performance with improved accuracy. It provides an estimate of variable hydraulic efficiency η_{hyd} when such information is unavailable and the user may have to use a constant η_{hyd} otherwise. It only requires the user to provide one data point of ηhyd, flow rate $\dot{V}$, and pressure rise Δp where the efficiency is at its maximum.

The method then uses a dimensionless modified Euler number Eu and a correlation to estimate the hydraulic efficiency η_{hyd} and the shaft power $\dot{W}_{hyd}$ at off-design conditions. This method is applicable regardless of the type, size, or operational region (stall or nonstall) of the mover. In Figure 1 we overlaid operating points from seven sets of fan data and eighteen sets of pump data to the empirical relation to show that the manufacturer data closely followed the correlation. Figure 2 shows that the computed efficiency closely follows the values from the performance map for the full range of $\dot{V}$ and Δp. The computed power is also accurate for most of the range. Across the sample, the errors of the computed power from interpolated data were within 15% for the range of 20% - 70% of $\dot{V}_{max}$ and 40% - 90% of Δp_{max}, excluding outliers.

This method is valuable and applicable at early stages of design or post-retrofit assessment during which detailed mover performance data are generally not available.

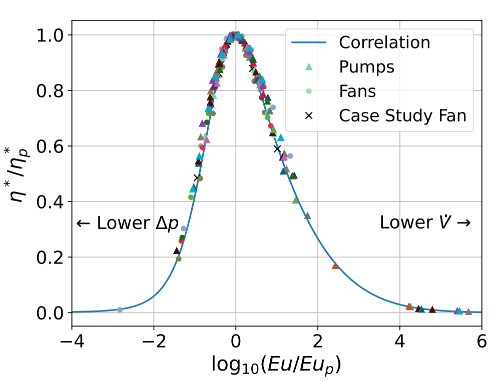

Figure 1. Normalized efficiency curves in dimen-sionless space and mover perfor-mance data. Each colour represents one dataset of seven fan models and eighteen pump models.

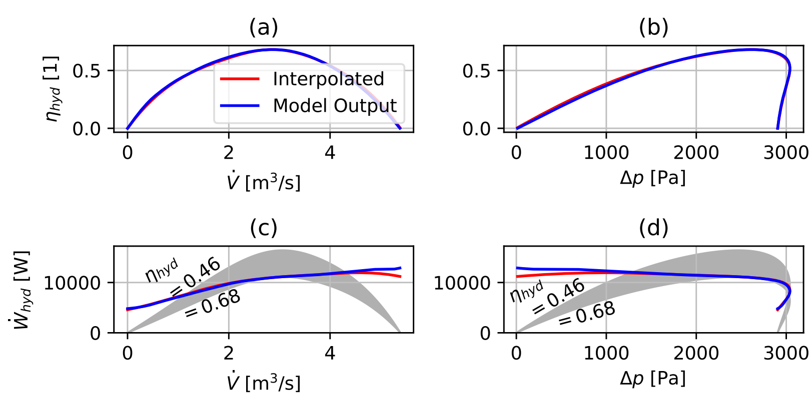

Figure 2. Hydraulic efficiency and power values that were interpolated from the performance map (red lines) and computed by the model (blue lines). The grey shaded area is bounded by the simplified as-sumption of a constant hydraulic efficiency between η_{hyd} = 0.68 (peak of this fan) and η_{hyd} = 0.46 and shown here to visualize the wrong results of this oversimplification.

Transient Simulation of an Air-Source Heat Pump under Cycling of Frosting and Reverse-Cycle Defrosting

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Frost accumulation is a common but undesired phenomenon for air-source heat pump (ASHP) systems in winter operations. The continued buildup of frost eventually necessitates a defrosting mode to remove the accumulated frost and return the system to its normal operating characteristics. Reverse-cycle defrosting (RCD) that applies heat to the outdoor coil by reversing the thermodynamic cycle, is one of the predominant means for periodic removal of the accumulated frost. A simulation tool capable of captureing the system dynamics with continuous mode-switching between heating and defrosting operation is extremely useful in the development and evaluation of improved control designs. This paper presents a dynamic modeling framework for ASHPs under cycling of frosting and defrosting operations. A uniform model structure was applied to frost formation and melting models, which were incorporated into a finite-volume evaporator model, without a need for reinitializing the system when the operating mode switches between heating and defrosting. A switching algorithm based on the Fuzzy logic was developed for multistage frost melting models to improve robustness. The developed cycle model was simulated to predict transients of a residential ASHP unit under multiple cycles of frosting and RCD operations. Simulation results of the refrigerant dynamics and air-side performance yield good agreement with the measurements, and can provide insights into heat and mass transfer phenomena of non-uniform frost formation and melting which are typically challenging to characterize experimentally at a heat pump system level.

Simulation of the On-Orbit Construction of Structural Variable Modular Spacecraft by Robots

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This paper gives an overview on the simulation of the onorbit construction of structural variable modular spacecraft by robots using Modelica.

For this purpose, a new concept using so-called tensor bodies was developed which enables the fast and continuous simulation of complex scenarios even during structural changes. This research was part of the ESA MIRROR and EU MOSAR projects.

An overview of the modeling and simulation approach will be given. The scenarios include the on-orbit re-configuration of a modular satellite with a walking robot manipulator and the construction of a modular space antenna array platform with a walking robot with two arms and a torso (see Fig. 1 and Fig. 2).

Because of the complexity and cost of these types of missions, simulation and demonstrator studies on Earth should be performed before committing necessary resources for a real mission. Future advanced spacecraft and orbital platforms can require on orbit assembly either because of the size of the structures (e.g. large antennas, solar facilities or telescopes) or because of a desired modularity. Since on-orbit human labor is extremely expensive and dangerous, on-orbit assembly and servicing tasks should be done (mostly) autonomously by robots.

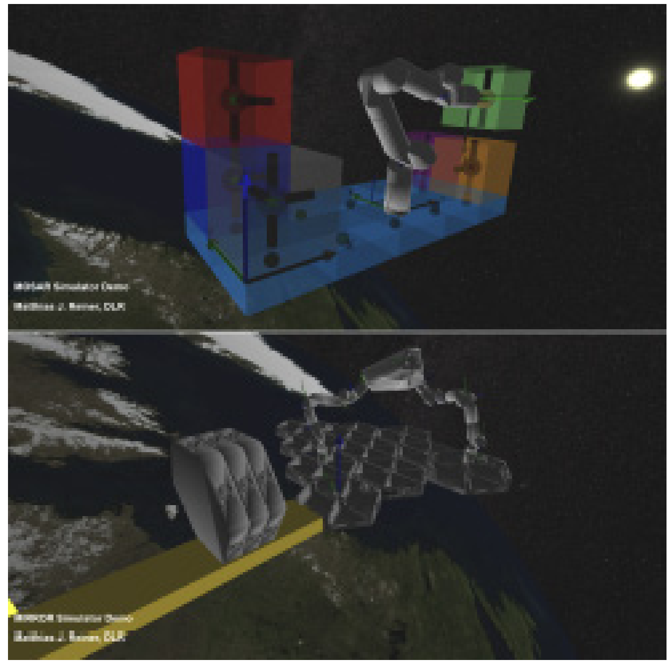

Figure 1. Visualizations generated by the developed simulators for an on-orbit assembly scenario investigated in the MOSAR and for the MIRROR project (lower half).

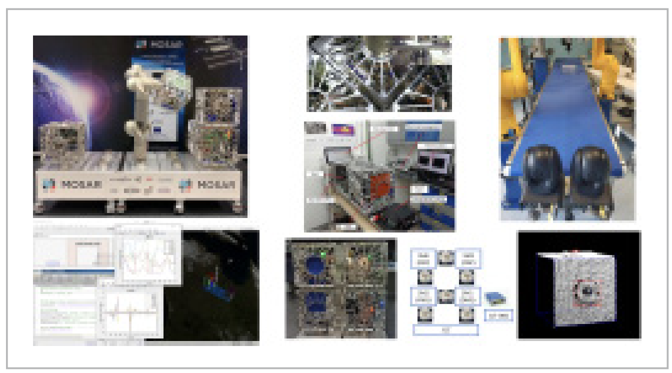

Figure 2. The mosaic overview taken from an internal MOSAR report shows some results obtained within the MOSAR project from the involved project partners SpaceApps, GMV, MAGSOAR, Thales Alenia Space (France and UK), SITAEL, Elidiss Technologies, University of Strathclyde, Glasgow and DLR (SR and RM). The top left shows the physical demonstrator setup with the WM relocating an SM. The top middle gives a closer look on the SIs and a thermal testing setup. The top right shows a setup for the visual inspection of the modules. The lower left shows a screenshot of the MATLAB interface of the FES with plotted simulation results. In the lower middle a closer view of an SM configuration and its corresponding software setup can be seen. The lower right corner shows the result of a camera-based damage inspection of an SM.

Extending a Multicopter Analysis Tool using Modelica and FMI for Integrated eVTOL Aerodynamic and Electrical Drivetrain Design

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The Functional Mock-up Interface (FMI) standard for model-based systems engineering can be used to expand the capabilities of aerodynamic multicopter analysis tools to perform integrated design of electric vertical take-off and landing (eVTOL) systems. Well-defined multi-engineering models at various levels of modeling fidelity aids in the development of distributed electric propulsion systems and the understanding of its system behavior. Expanding domain specific tools to encompass all domains is difficult, so the FMI standard enables the interaction of models that do not exist in domain specific tools. The biggest benefit of this modeling approach is that it allows for collaboration between groups that have created domain specific tools that can be intergrated using the FMI standard. This fully integrates tools created for previous research and development, expanding and enriching simulation studies with relatively low effort.

The proposed eVTOL system was developed using Modelica and was exported to MATLAB/Simulink using model exchange to interact with a domain-specific tool specializing in calculating the aerodynamics of the aircraft. This configuration enables detailed simulation studies, allowing us to study the effects of various battery system architectures and drivetrain modeling fidelity on the handling quality of the aircraft.

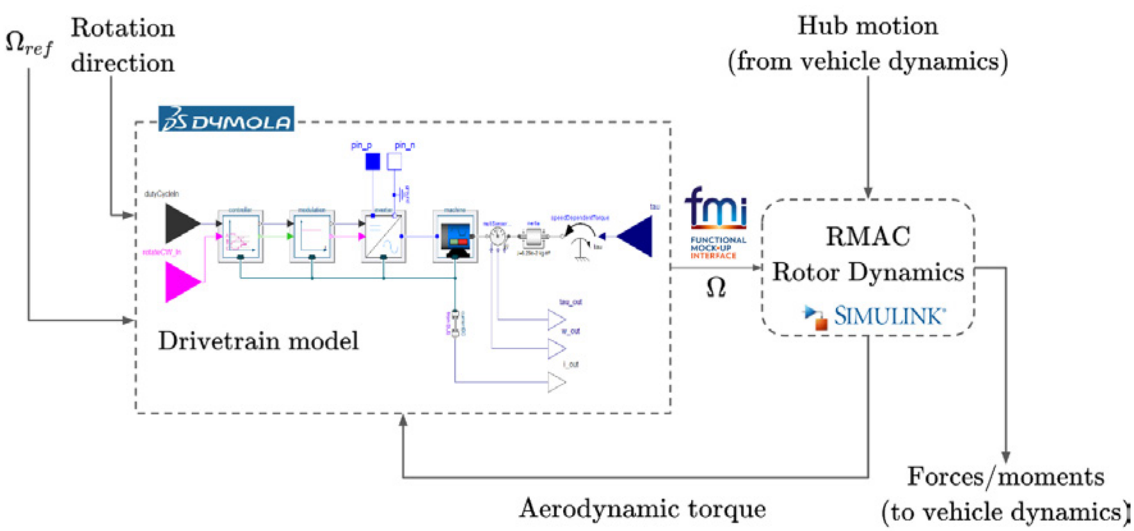

Figure 1. Coupling of drivetrain model in Dymola to RMAC rotor dynamic toolbox in Simulink via FMI.

Multirotor Drone Sizing and Trajectory Optimization within Modelon Impact

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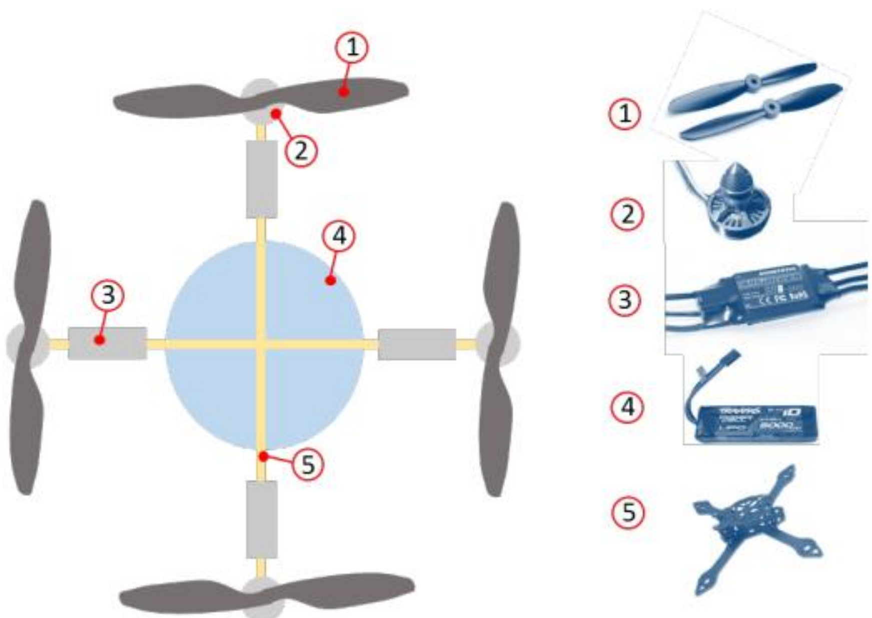
The design of multirotor drones often relies on optimizing its performance in terms of maximum speed requirements and hover time. This is well suited to undefined tasks. In the case of repetitive tasks, the drone trajectory can be added as a third degree of freedom. This paper focuses on the use of Modelon Impact and its dynamic optimization capabilities to reach a multirotor drone design and 1-D trajectory optimization.

The model fidelity is not necessarily the highest but constrains on the numerical aspect of the code are highlighted – e.g. acausality, smoothness, etc. The models shall be "optimization-friendly". The propeller model is detailed to emphasize the level of details sufficient for such a purpose.

In comparison to other options investigated by the authors in a separate publication, Modelon Impact based optimization showed significant advantages in terms of easiness of implementation, speed and robustness.



Applying Design of Experiments Method for the Verification of a Hydropower System

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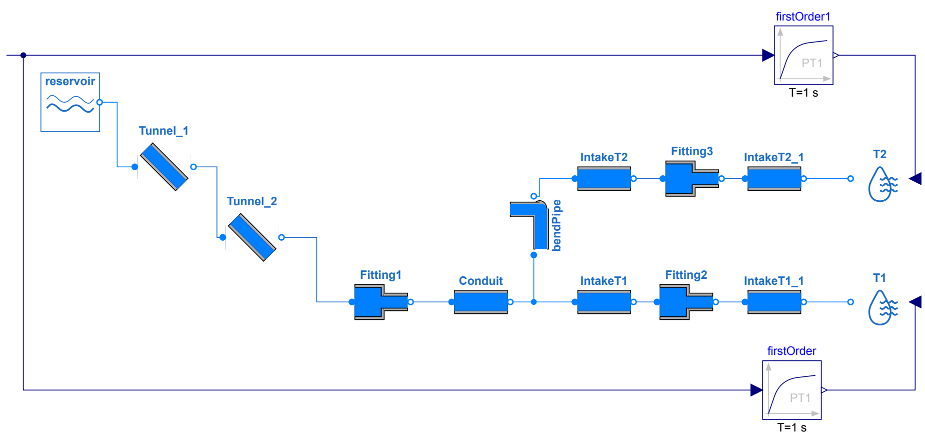
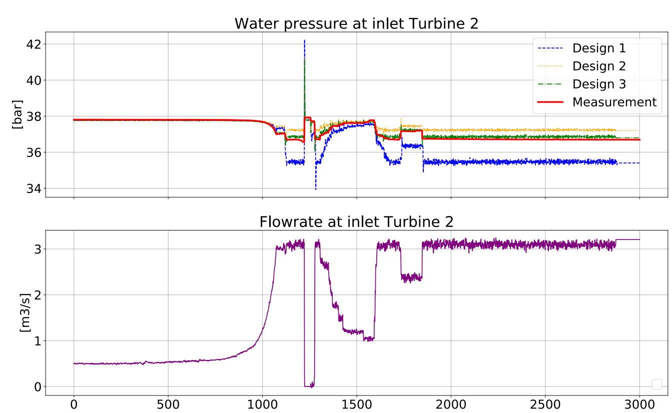
Today, renewable energy plays a major role in the transition towards environment-friendly energy sources. Hydropower is one of the most important renewable energy sources leading to the high interest of research associated with the development of new technologies. These technologies aim to examine and predict the characteristics and behaviour of hydropower plants during different operating conditions and are often associated with simulation models. In the progress of creating accurate simulation models, it is necessary to have an organised and systematic method to verify and optimise the model with the help of available data. This is where the "Design of Experiments" (DoE) principles should be applied.

A simulation model of a reference hydropower plant located in Seljord municipality in the south-east of Norway was implemented using the modelling language Modelica. All parts of this hydropower plant model were tuned according to DoE procedure with the purpose of design verification and optimisation. The results of the experiments are a complete and optimised hydropower plant model that gives reliable simulation results.





Using Multi-Physics Simulation to Estimate Energy Flexibility for Local Demand Response Strategies in a Microgrid

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This work discusses the development of a multi-physics simulated model, in the frame of the decarbonization and energy efficiency objectives of the European Commission. Its central feature is the interconnection, through a microgrid, of a distributed PV installation and of several electric dispatchable loads, thus powering a Collective Self-Consumption network.

The simulator presented within this document aims to serve as a technological enabler for the design and testing of On-Site DR strategies, which actuate directly on the connection status of the loads, before their deployment on the target, real-world systems. The simulator supports the design and validation of such strategies by generating realistic simulated data of certain loads that present monitoring difficulties, taking into account online, real external weather conditions.

All the elements described and modeled in the current work belong to a real-world installation, which is a university campus —ESTIA, Bidart, France— composed by several buildings with DER.

Power System Real-Time Simulation using Modelica and the FMI

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Real-time digital simulation of power systems is incredibly important for the testing of appropriate control and protection strategies in the power system industry. However, the case in which one single model can be used in offline simulations and then for testing in real-time studies is rare, if existing at all. This is due to the lack of adequate standard development in the power industry and the adoption of successful standards elsewhere.

A direct consequence of this lack of portability is the large amount of time and resources spent in re-implementation and validation of models for real-time digital simulation of power grids.

The present study proposes the usage of Modelica and the FMI standard in order to address this issue. To test the proposed approach, two power system models are built in Modelica for offline simulations using the OpenIPSL library and are exported as co-simulation FMUs with source-code.

Real-time simulations of these typical power system models are performed using dSPACE SCALEXIO™, proving that the proposed framework using Modelica and the FMI can greatly contribute to the enhancement of today's current practice in the power industry by providing portability and tractability between offline and real-time power system models.

Figure 1: Three-step workflow adopted for simulation of FMUs in a real-time processing unit.

A Playground for the Modelica Language

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This paper introduces a Modelica playground which allows users to experiment with the Modelica language without having to install any specific Modelica tools. This web-based application also contains content and lessons that provide users with a guided tour of the language and the opportunity for advanced users to create domain specific content built on top of this same infrastructure. This paper will explain the various open source technologies employed in creating this application and discuss potential future work to further enhance the experience for the user as well as the reach for Modelica itself.

To help "onboard" users, many programming languages include a web-based environment that allows users to see working fragments of code in that language. What makes such an environment a playground is that it allows these code fragments to be edited and compiled as well. This enables users to explore the language and understand at least the basics of different syntactic constructs without having to install any of the normal tooling associated with the language.

These playgrounds are not only useful tools for users to "try out" a language before committing to installing all the tooling, they are also very useful as educational tools.

Such playgrounds often include examples of specific features of the languages. In a sense, they are used to help "sell" users on the design of the language or help explain difficult concepts by giving the users running examples (created by language experts) to help users understand the particularly idiomatic ways of accomplishing various tasks in that language.

The goals of this project are as follows. First, the playground should be freely available that anybody can easily find. In addition, it should be possible to visualize the results of simulating a model. Furthermore, the playground content should support linking directly to complete playground examples including both models and visualizations.

Finally, it should be possible for others to create content for the playground without having to having access or changing the source code for the playground itself. All of these goals should be achieved while maintaining the privacy of the users.

Towards an Open Platform for Democratized Model-Based Design and Engineering of Cyber-Physical Systems

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This paper reports on the development of GitWorks, an open platform for democratizated Model-Based Design of cyberphysical systems (CPS). The GitWorks platform is currently under development by Perpetual Labs Ltd in collaboration with the Open Source Modelica Consortium (OSMC)[1] and the OpenCAESAR project[2]. In this paper, we present our vision for the platform, its system architecture (shown in Figure 1) and a prototype implementation.

We also present a case study that demonstrates the use of the proposed platform for enabling the seamless integration of Modelica models into a broader range of systems engineering processes for complex product development.

In the long-term, the platform also aims to enable the integration of Modelica tools with advanced systems engineering processes that rely on other domain specific languages (e.g. SysML v2, BPMN, etc.).

[1] https://openmodelica.org/home/consortium
[2] https://www.opencaesar.io/
[3] All trademarks, logos and brand names are the property of their respective owners.

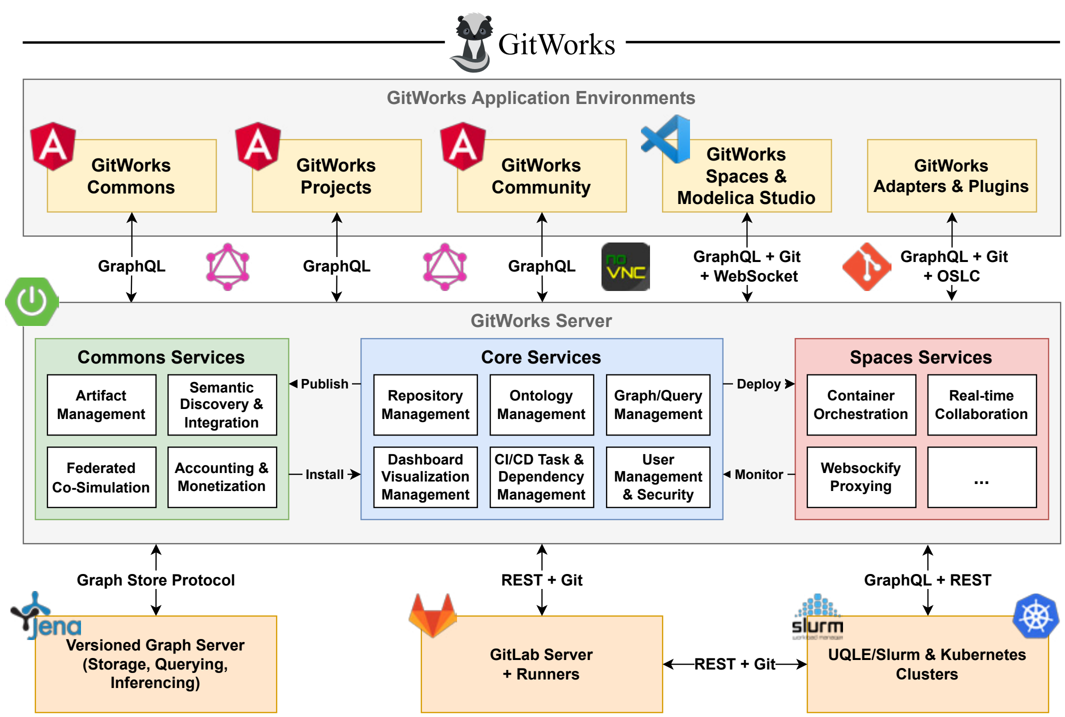

Figure 1. Conceptual software architecture of the GitWorks Platform[3]

Enhancing SSP Creation using sspgen

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The System Structure and Parameterization (SSP) standard is a tool independent standard to define complete systems consisting of one or more components, including its parameterization, that can be transferred between simulation tools. Thus the SSP standard is a natural extension to the Functional Mock-up Interface (FMI) standard, allowing systems of components, rather than just in-dividual components, to be simulated in a growing number of supported tools.

This paper introduces sspgen, a textual Domain Specific Language (DSL) for generating SSP archives. The aim of the DSL is to greatly simplify the creation of SSP compatible simulation systems. ssp-gen is written in the Kotlin programming language, which provide syntax highlighting and static code analysis in selected tools, full access to Java compatible libraries, and more importantly a scripting context so that sspgen definitions can be easily shared and executed on demand.

As the DSL is based on a generic programming language, it enables complex expressions to be evaluated for the purpose of e.g., pre-simulation and initialization of variables. The DSL also performs validation and through integration with the Open Simulation Standard - Interface Specification (OSP-IS) even allows more complex connections to be formed than the single scalar connections that the SSP standard defines, while still retaining compliance. Furthermore, the DSL handles automatic packaging of its referenced content into a ready-to-use SSP archive. As a whole, the introduced package makes it easier to create, modify and share SSP systems.

Development of a Modelica Model for the Texas A&M Smart and Connected Homes Testbed

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As Modelica grows in popularity among the research community, libraries are built and maintained by labs to further develop the software. Researchers at the Lawrence Berkeley National Laboratory (LBNL) have created an open-source library, the Modelica Buildings library, which enables researchers in the building science community to design and operate buildings and district energy and control systems (Wetter at al. 2014). This library contains dynamic simulation models for HVAC systems, energy storage, multi-zone airflow, and so much more. The contributions to this library come from many researchers among different institutions that aid in developing these tools for building research.

Buildings research is a growing field as the electrification of the grid and modern technology advancements enable the use of new smart home technologies. Whether it is smart thermostats, high-efficiency equipment, or even advanced building controls that are being researched, they all require a dependable model of the physical building to develop these complex fields. With the help of Modelica and the Modelica Buildings library, a flexible building model can be constructed while saving time in simulation-based projects.

The Buildings Energy and HVAC&R research group at Texas A&M University has a smart home testbed that will allow for the testing of smart home technologies, smart grid applications, and other residential building research topics. This paper will briefly go over the testbed before walking through the modeling using Modelica and the Modelica Buildings library. The paper will finish with individual model inspection. The future work of this project is to tune and verify the complete Modelica model performance using data taken at the testbed during operation.

Photo 1. The Texas A&M Smart and Connected Homes Testbed (TAM-SCHT)

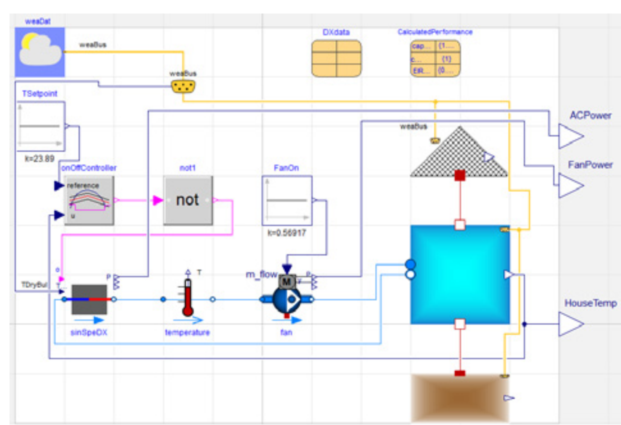

Figure 1. The complete Modelica model of TAM-SCHT, cooling only

Performance Enhancements for Zero-Flow Simulation of Vapor Compression Cycles

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Models that correctly describe the dynamic behavior of vapor compression cycle at low or zero refrigerant mass flow rates are valuable because they can be used to handle low load, on/off cycling and inactive component conditions. However, low- or zero-flow simulation imposes significant computational challenges because of high frequency oscillations in mass flow. We explore techniques that may be used for improving robustness and performance of low- or zero-flow simulation. Comparisons are conducted to demonstrate the efficacy of the proposed techniques. It is shown that these techniques can result in simulations that are more robust and significantly faster than real-time.

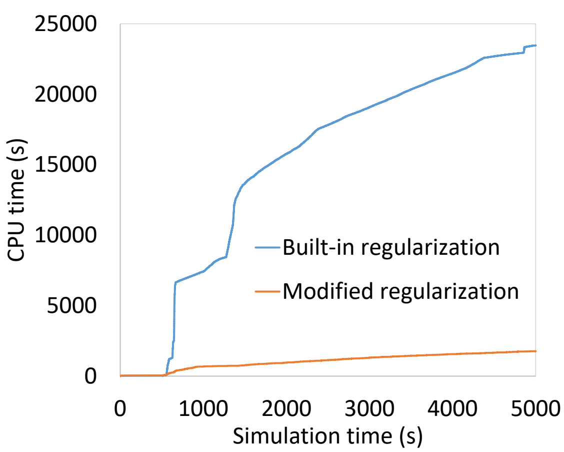

Figure 1. CPU time vs. simulation time with different types of regularization

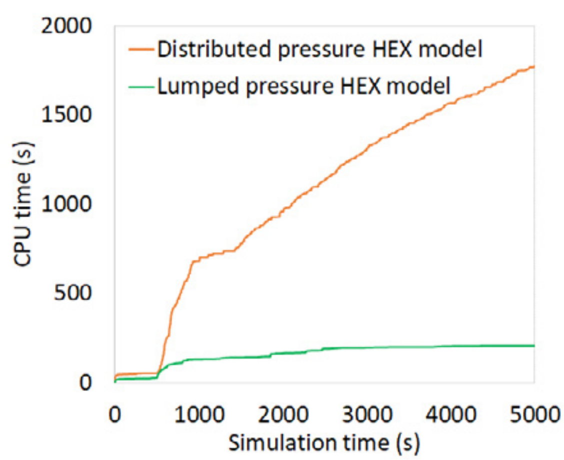

Figure 2. CPU time vs. simulation time with different heat exchanger models

Tradeoffs Between Indoor Air Quality and Sustainability for Indoor Virus Mitigation Strategies in Office Buildings

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The COVID-19 pandemic has motivated building operators to improve indoor air quality (IAQ) through long-term sustainable solutions. This paper develops a modeling capability using the Modelica *Buildings* library to evaluate three indoor virus mitigation strategies: use of MERV 10 or MERV 13 filtration and supply of 100% outdoor air into a building with MERV 10 filtration. New evaluation metrics are created to consider the impact of improving IAQ on financial and environmental costs. The mitigation strategies are studied for medium office buildings in three locations in the United States with differing climates and electricity sources. The results show that use of 100% outdoor air can significantly improve IAQ with limited increases in costs in the milder climate, but leads to very high costs in the hot and humid and very cold climates. MERV 13 filtration can improve IAQ relative to MERV 10 filtration with small increases in costs in all locations.

Guidelines and Use Cases for Power Systems Dynamic Modeling and Model Verification using Modelica and OpenIPSL

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This paper offers systematic guidelines for modeling power systems components in the phasor-domain using the Modelica language and their verification against the *de facto* domain-specific tools trusted by the power industry. It aims to consolidate and share the authors' experience in the development of component models for the Open-Instance Power Systems Library (OpenIPSL)[1] and the approaches used to meet the high expectations of the power industry w.r.t. to the models' response. While the modeling guidelines are generic, the verification procedure includes the validation against a domain-specific commercial software tool called PSS®E, that is the *de facto* "standard" used for power system transmission planning and analysis in North America and Scandinavia.

To formalize the proposed approaches, a schematic description of the processes of model implementation and validation is elicited through flowcharts. Challenging use cases are presented to point out some of the major difficulties that can be faced in the modeling steps because of unclear/missing documentation of the models' dynamics in the reference tool. Finally, unique features of the Modelica language that allow for power system modeling and verification unavailable in traditional tools are illustrated.

An example of the difficulties faced when implementing typical power system model like those of power system stabilizers (PSSs) PSS2A shown in Figure 1. The reference software tool PSS®E comes with several manuals to help understanding the implementation and behavior of the different components present in its libraries. In some cases, like for the aforementioned PSSs models, the documentation is insufficient and not helpful to understand the behavior of one of the blocks of the models, the ramp tracking filter highlighted in Figure 1. After following the proposed guidelines, the model is verified against the PSS®E software, as shown in Figure 2, using two Modelica-tools, Dymola and Modelon's Impact. The paper illustrates the process of following the guidelines for model implementation and verification for the example above and other interesting cases that raised several challenges for their successful verification. The results from this work is a new set of verified power system component models models for the OpenIPSL library[2] that have been included in the latest versions of the library, V2.0.0 and V3.0.X, as well as future version.

[1]https://github.com/OpenIPSL/OpenIPSL

[2]Verification results can be found online at: https://alsetlab.github.io/NYPAModelTransformation/

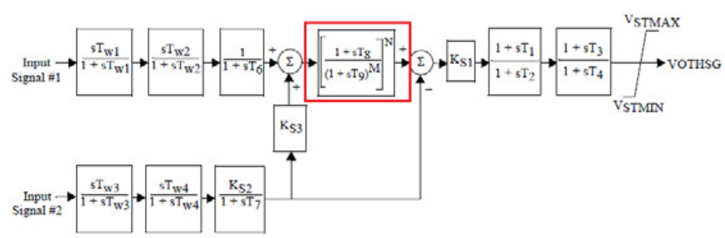

Figure 1. Block diagram of PSS2A from PSS®E manual (Siemens Industry 2013).

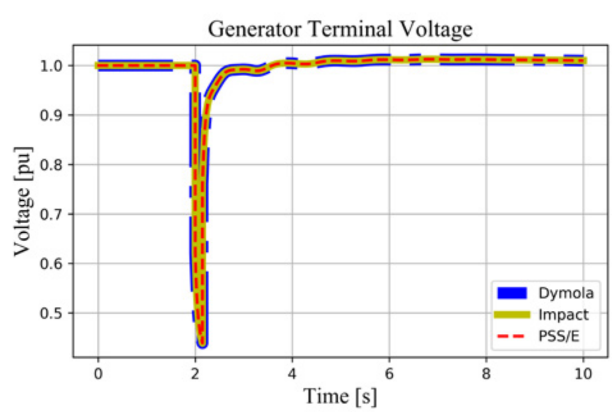

Figure 2. Generator terminal voltage being stabilized by the PSS2A model.

Material Production Process Modeling with Automated Modelica Models from IBM Rational Rhapsody

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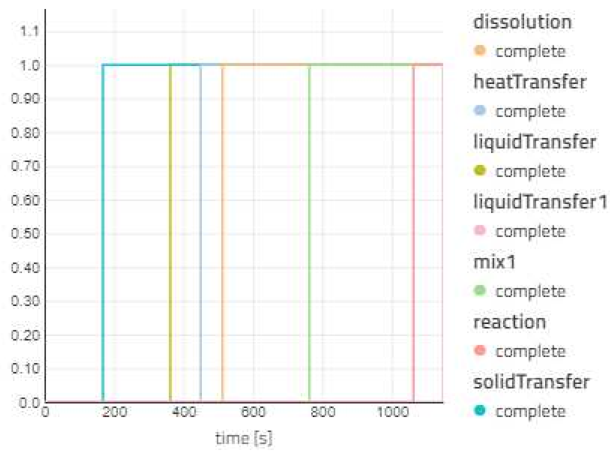
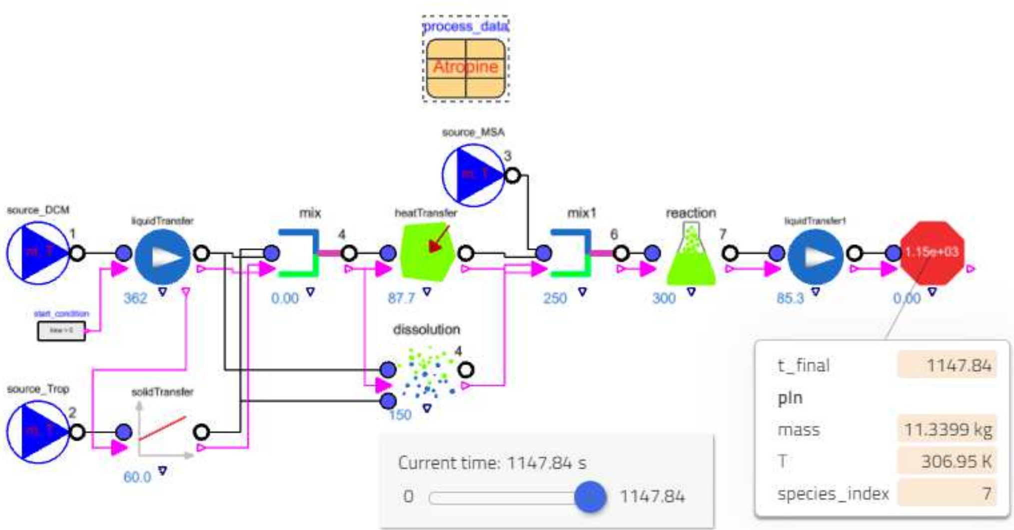
This paper describes a method to author dynamic simulation models in Modelica from a manufacturing architectural model structure in SysML.

Modelica models are generated from IBM Rational Rhapsody and simulated using Modelon Impact.

Following a brief overview of the overall modeling approach and tool coupling, the Modelica modeling is detailed for computing process throughput and processing time.

Following the model overview, a sample application for the production of the pharmaceutical ingredient atropine is demonstrated.





Model-Based Optimization for a Campus District Cooling System

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While equation-based object-oriented modeling language Modelica can evaluate practical energy improvements for district cooling systems, few have adopted Modelica for this type of large-scale thermo-fluid system. Further, to our best knowledge, district cooling modeling studies have yet to include hydraulics in piping networks alongside plant models featuring realistic mechanical systems and controls. These are critical details to include when looking to make energy and control improvements in many physical system installations.

To this study used the newly developed open-source district cooling models at the Modelica Buildings Library for a real-world case study at the University of Colorado Boulder. The site includes six buildings connected to a central chiller plant featuring a waterside economizer. We have developed detailed Modelica models for the entire system. Then the models are calibrated and validated using the measured data.

After that, several energy saving strategies are pursued based on the validated model, including control setpoint optimization, equipment modification, and pump setpoint adjustments. Results indicate that a combination of the studied measures can save the campus annually 84.6 MWh of energy, 8.9% of electricity costs, 58.0 metric tons of carbon dioxide emissions, while the waterside economizer cuts down chillers' run times by 201 days/year, reducing maintenance costs and extending chiller life.

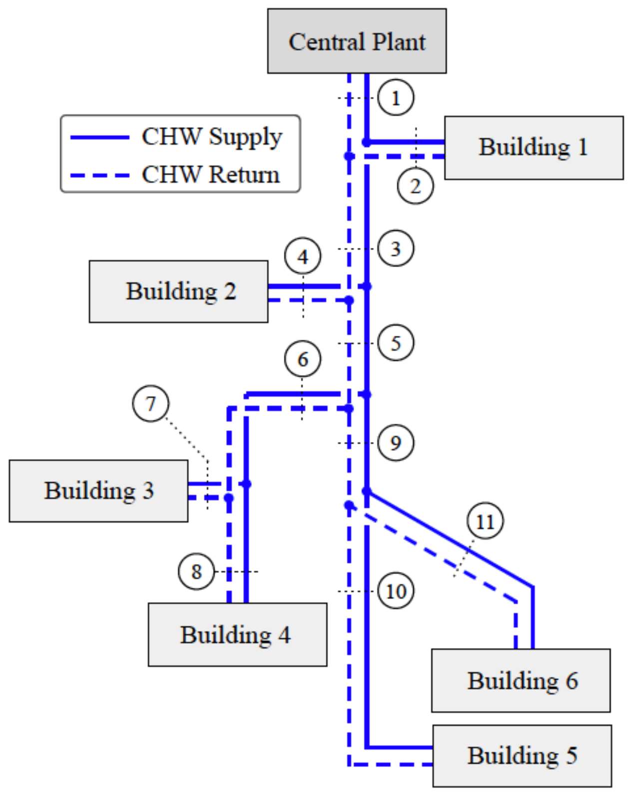

Figure 1. System schematic of the studied district cooling systems

Hybrid Model Predictive Control of Chiller Plant with Thermal Energy Storage Evaluated with Modelica-Python Co-Simulation

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As the heating, ventilation and air conditioning (HVAC) systems dominate the energy consumption of building operation, energy efficiency and power demand management have become important for HVAC system controls to achieve cost reduction and grid support. The system of interest is a chiller plant coupled with chilled-water based thermal energy storage (TES) for air conditioning of commercial buildings (Figure 1).

With day-ahead electricity price profile, a hybrid model predictive control strategy is proposed to optimize the chiller-TES operation based on the weather and load forecast by minimizing the overall energy cost that combines the time-of-use (TOU) and demand charges, with the cooling load satisfied in real time. Such strategy is implemented with a two-level hierarchical structure. At the lower level, two PID control loops are implemented, which regulate the compressor suction refrigerant superheat with EEV opening and the supplied chilled water temperature with compressor speed. At the higher level, the hybrid MPC is designed with mixed-integer nonlinear programming (MINLP) such that the charging and discharging of TES can be optimally scheduled in parallel to the manipulation chiller operation.

As for control-oriented modeling, both first-principle and data-driven modeling approaches are used. A two-layer water temperature dynamic model is built for the TES, where the states include the top- and bottom-layer water temperatures (T_a and T_b). In light of the nonlinearities of the chiller plant characteristics, a data-driven Koopman-operator model is developed, where the states include the cooling-tower return water temperature (T_{cw}), compressor discharge temperature (T_{cd}) and compressor suction pressure (P_{cs}), and the manipulated inputs include the tower fan speed, the condenser water mass flow rate, the evaporator leaving water setpoint, the evaporator water mass flow rate, and a binary control command for TES charging or discharging. The building dynamic is approximated as a first-order model with the building return-water temperature (T_r) as its state. The predictable disturbances include ambient temperature, ambient relative humidity (*RH*) and building cooling rates.

The proposed control strategy is evaluated with Modelica based simulation study. Based on the development a Modelica based dynamic simulation model for a chiller plant with TES, as shown in Figure 2, a Functional Mockup Interface (FMI) based Python-Modelica co-simulation framework is developed, where the hybrid MPC is implemented in Python with the IPOPT solver. While the quality of the co-simulation mechanism has been validated, simulation study for validating the proposed control strategy is being conducted.

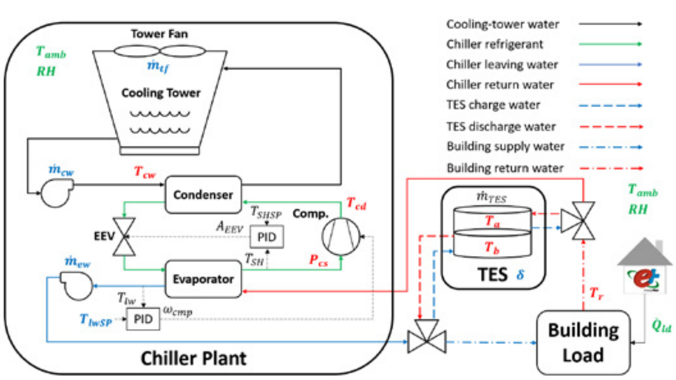

Figure 1. Schematic for Chiller Plan coupled with Thermal Energy Storage (TES)

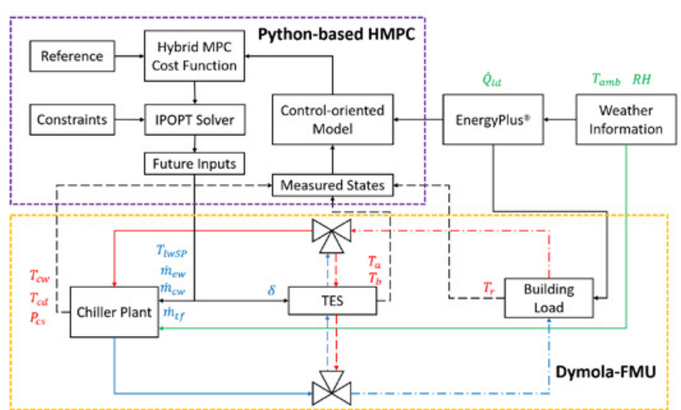

Figure 2. FMI based co-simulation platform for hybrid MPC Energy management of Chiller Plant with TES

The Use of Modelica and the Functional Mockup Interface for the Building Optimization Testing Framework (BOPTEST)

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Needs for advanced and improved control strategies (CS) in building and district energy systems are growing due to requirements for reducing energy use, greenhouse gas emissions, and operating costs, providing flexibility to the electrical grid, as well as ensuring performance of novel hybrid and collective system architectures. Examples of such CS are advanced rule-based control, Model Predictive Control (MPC) [Drg20], and Reinforcement Learning [Wan20]. However, while these and other CS show promise, two challenges slow their widespread adoption:

1. The performance of each CS is typically demonstrated on individualized case studies and quantified using different performance indicators, making it difficult to properly benchmark and compare their performance, identify the most promising approaches, and identify needed further development.

2. Demonstrations in real buildings and district energy systems pose large operational risks and difficult environments for controlled experiments. The building simulation (BS) community can address these challenges by providing suites of publicly available, high-fidelity simulation models, called emulators, to be used for benchmarking CS.

Furthermore, providing a comprehensive framework to deploy, interact with, and generate key performance indicators (KPI) from these emulators would ensure their benchmarking capability and make them readily available to related control and data science fields outside of the BS community. There exists precedent for such an approach in the optimization fields (e.g. Decision Tree for Optimization Software [Mit22]) and data science (e.g. OpenAI Gym [Ope22]). Work is underway on the envisioned framework and emulators, called the Building Optimization Testing Framework (BOPTEST). It has been developed within the IBPSA Project 1 Work Package 1.2 [Wet19], with primary software development occurring open source at https://github.com/ibpsa/project1-boptest. The framework is described in [Blu21] and has been used so far in [Arr20, Arr22, Bun21, Hua18, Wal20, Yan20]. Additional development is making BOPTEST available as a web-service, providing an online dashboard to share and sort results, and creating an OpenAI Gym interface [Arr21]. The Role of Modelica and Functional Mockup Interface Key to the implementation of BOPTEST is the development of high-fidelity building emulators that can represent HVAC system dynamics in a way that can realistically emulate how building controls are implemented and perform in practice. For the implementation of these models, we use Modelica libraries developed under IBPSA Project 1 for the purposes of building and urban energy system simulation. For packaging these models in a shareable format and simulating within the BOPTEST run-time environment, we use the Functional Mockup Interface (FMI). This presentation will present the motivation, design, and example usage of BOPTEST, emphasizing how Modelica and FMI enable its core capabilities.

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Use of TRACE 3D Plus Models with Spawn for Rapid Prototype Development in Modelica Environment

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Spawn was released with Modelica Buildings Library (MBL) in 2021 to support new use cases in HVAC and controls. Spawn reuses the envelope and daylighting modules of EnergyPlus and the interface in MBL (that utilizes Functional Mockup Interface-FMI) allows it to couple them to HVAC and control models developed in Modelica (Wetter et al. 2020). As Spawn uses subset of EnergyPlus modules, the building envelope information is needed in the form of input data file (IDF). Generating these EnergyPlus files could be a tedious task and TRACE 3D Plus (TRACE) simplifies creation of such models.

TRACE is built on EnergyPlus engine with enhanced features that are added based on industry experiences. Due to prebuilt templates, gbXML import and building-wizard module in TRACE we are able to quickly build building envelope models of complex geometry, zone structures and use cases (e.g. mixed use buildings, hospitals etc.) in TRACE. The models developed in TRACE are directly not compatible with EnergyPlus, as the additional TRACE objects, new fields in existing EnergyPlus objects, additional control options create mismatch with EnergyPlus engine and input data dictionary (IDD).

Previously we evaluated Building Controls Virtual Test Bed (BCVTB) to co-simulate models developed in TRACE, however, this solution did not widely get used in projects with co-simulation requirements due to various usability related concerns. EnergyPlusToFMU (Nouidui et al. 2013) was used to co-simulate TRACE models where there is a clear separation of model and controls. As Modelica-based complex two-phase flow models became available, we had co-simulation requirement of building models from TRACE with Modelica-based equipment models. Such modularization involved lot of workarounds with IDFs.

To meet the requirements mentioned above, we adopted a solution that converts TRACE idfs to EnergyPlus idf. A Python conversion script was written that compares the IDD files of TRACE and EnergyPlus, removes additional fields and replaces them with EnergyPlus compatible alternatives. In this conversion the model loses features that are available in TRACE. After the conversion process the script runs the original TRACE model with its executable and converted IDF with EnergyPlus executable and compares the results and report if there are major differences.

Figure 1 explains the steps involved in using the TRACE model with Spawn. As a test, we used Buildings.ThermalZones.EnergyPlus.Examples.SingleFamilyHouse.AirHeating model from MBL and replaced the idf with similar model created in TRACE.

Along with supporting new use cases in HVAC (e.g. use of two phase flow HVAC equipment models) and controls (e.g. demand-response management) this workflow has simplified the FMU export of building models that are developed in TRACE. For such export we have created causal wrappers for Spawn that allows click-of-a-button export of TRACE buildings. These FMUs have been used for model sharing and to test Artificial Intelligence (AI) and Machine Learning (ML) based controls.

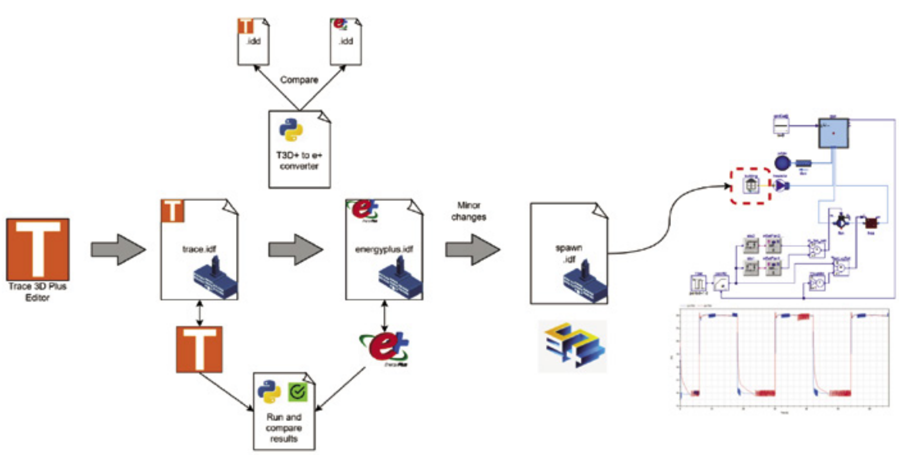

Figure 1. Workflow to use TRACE model in Spawn

Comparative Analysis of Price-based Control Strategies for a High Temperature Thermal Energy Storage System

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The increasing penetration of renewable energy production necessitates the use of thermal energy storage systems (TES) to balance fluctuating renewable energy production with fluctuating energy demand. Implementation of advanced control strategies such as model predictive control (MPC) for TES has been widely investigated to facilitate energy-efficient/cost-effective operations (Tarragona et al. 2021). However, most of the studies focus on water-based TES and MPCs for high temperature thermal energy storage systems (HTTES) are still limited. This work contributes to bridging this research gap in the literature via implementing an MPC for HTTES and evaluating its control performance.

To that end, an emulator for a high temperature thermal storage system was first developed and verified. Figure 1 illustrates the system layout consisting of charging, discharging, and a Rankine cycle process. In the charging loop, the air is heated with electricity from the grid and blown into the energy storage consisting of a rock bed as the storage medium. When discharging, the air is extracted to heat the working fluid in the organic Rankine cycle. The produced electricity will be entirely sold to the grid. The Rankine cycle loop is connected to a district heating network supplying additional heat.

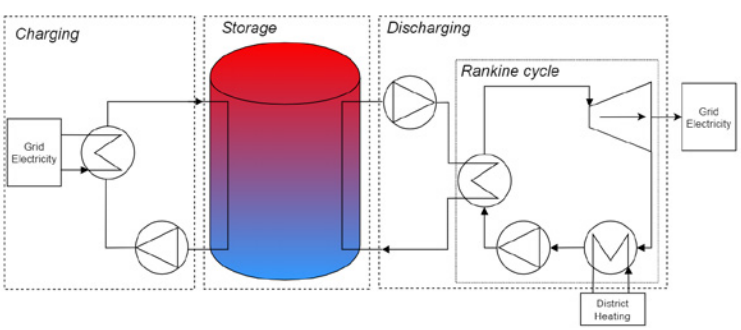

Figure 1. Schematic diagram of the HTTES

Next, a nonlinear MPC for the HTTES was formulated and implemented in Matlab MPC block and Simulink, allowing co-simulation using functional mock-up units (FMU). The objective of the MPC is to maximize the cumulated net revenue of the ssystem, which is calculated as the profits of selling electricity subtracted by the energy cost of electricity consumption in the charging process and the district heating consumption. The manipulated variable of the MPC is the air mass flow rate of the charging/discharging process. It is assumed that simultaneous charging and discharging cannot take place. The storage temperature has to satisfy the constraints of the lower and upper limits (100°C and 600°C). A parameter tuning procedure concerning sampling time, prediction horizon, and control horizon for the MPC was conducted to find the optimal setup.

In order to benchmark MPC control performance, a rule-based control (RBC) strategy was developed in Modelica and compared with MPC. Modelica has previously demonstrated good ability in implementing controls for thermal storage systems enabling dynamic simulation in many studies, which can be exemplified in (Rohde et al. 2021). The control logic of RBC is shown in Figure 2a, where Pricemin and Pricemax are the lower and upper thresholds for electricity price. They are chosen as 258 DKK and 358 DKK, respectively. Likewise, Tmin (100°C) and Tmax (600°C) are the lower and upper limits of the storage temperature (Ts). Based on the electricity price, storage temperature, and charging/discharging process of the previous time step, the RBC divides the system into five operation modes. The MPC and RBC were simulated for 7 days and the comparison of simulation results is shown in Figure 2b. From the top to bottom, the subplots are storage temperature, air mass flow rate, and electricity price respectively. The negative value of air mass flow rate represents discharging process while positive values mean the charging process. As shown in the figure, RBC only supplies maximum air mass flow rate when charging/discharging. However, the nonlinear MPC allows supplying varying air mass flow rates. Besides, a more frequent running of the charging/discharging process is observed in MPC than that in RBC due to MPC being capable of predicting electricity price and system dynamics and optimally choosing operation mode through optimization. The net cumulated revenue was calculated to quantitively evaluate the economic benefits of the two control strategies, resulting in 469.7 DKK for MPC and 170.7 DKK for RBC.

The preliminary results show that MPC outperforms RBC. However, the current RBC performance highly relies on the choice of electricity price threshold. The continuation of the work involves tuning the Modelica-based RBC settings based on price margin including customizing different RBCs under different price scenarios.

Modelica-Based Control of a Delta Robot

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This presentation describes the author's research to develop a delta robot that is useful for precise robotic assembly. A delta robot is a closed-chain, parallel link mechanism, and is used in industry almost exclusively for pick and place operations, because of its low cost and high speed. These applications require simple PID type control, which makes the robot very precise in terms of its position control, but also very stiff. However, the delta robot has mechanical characteristics that make it very attractive for use in more complex assembly operations, involving contact and collision, where high robot stiffness is not desirable. These characteristics include its low mass (because actuators are mounted at the base), high link stiffness, high mechanical precision and low joint friction (all because of its mechanical design), and low capital cost (because of its symmetry, giving a low parts count). Assembly applications require point to point motion control and also feature contact and collision between the robot end effector and objects it seeks to manipulate. Conventional robots move very slowly in these applications, so they do not transfer excessive energy or momentum, implying the dynamics of contact and collision can be neglected. To exploit the delta robot's low mass and high speed, the dynamics of contact and collision need to be considered. In these situations, it is desirable to modulate the robot impedance. This requires more sophisticated multivariable control algorithms.

Modelica is the ideal (and arguably the unique) language capable of modeling and simulating not only the robot dynamics, but also an assembly task including contact and collision, in addition to the control algorithms, ranging from low level feedback to higher level task management. The robot itself is a closed-chain manipulator, which can be represented as a set of high-index set of differential-algebraic equations (DAEs). These are readily expressed in Modelica. Unlike serial-link robotic manipulators, the delta robot has two distinct Jacobians. One of these is useful for simulation of the effects of forces applied to the end effector on robot motion (and vis versa), and the other useful for control. There are good reasons for the distinction, which will be described. Impedance control can be achieved by feedback linearizing the robot dynamics. Unlike serial-link robotic manipulators, the feedback linearization must be computed algorithmically (iteratively). This is because the delta robot forward kinematics cannot be expressed analytically, but can be computed algorithmically. This implies that the control law must be expressed in discrete-time. Modelica's algorithm blocks, support of functions and arrays etc. allow for rapid realization of control algorithms, and its synchronous features allow for correct representation and simulation of the resulting closed-loop sampled data system, which is a feedback interconnection of the continuous-time robot dynamics (a high-index DAE) and a discrete-time controller.

The presentation will also describe efforts to model and simulate object contact and collision using a hybrid DAE modeling framework, which combines a finite state machine and continuous, high-index DAE. Again, the Modelica language, with its hybrid DAE model of computation, is ideal for representing contact and collision, and results in a non-stiff set of DAEs that does not suffer from odd behaviors that are associated with alternative methods of representing contact and collision, such as impulsive methods and those that are based on complementary formulations.

Finally, the presentation will show real-time control of a laboratory delta robot directly from the Modelica development environment. Using the device drivers library, with suitable but relatively straightforward modifications, we may take models of the control used for simulation, disconnect the dynamic model of the robot, plug in the experiment's inputs and outputs, recompile and instantly have a closed-loop laboratory experiment. Although this has some limitations, in part because the Modelica development environment runs as a single process and thread, it is an effective way to move from simulation to experiment without recoding. As such, Modelica should be considered as a platform not only for desktop modeling and simulation, but also for control system represen-tation (as the algorithms are developed throughout the lifecycle of a project) and also laboratory experiment. This may be particularly of interest to similar research laboratories and educational organizations.

Prototyping Composable Simplification Passes for Equation-Oriented Models Using ModelingToolkit.jl

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ModelingToolkit.jl (MTK) is an acausal modeling language for high-performance symbolic-numeric computation in scientific computing and scientific machine learning. Like many Modelica implementations, MTK also performs structural transformation passes on differential-algebraic equations. MTK uses alias elimination, partial state selection, and tearing to simplify general DAEs to index 1 semi-implicit DAEs or ODEs. One design that makes MTK distinct from all the other Modelica implementations is that it tries to work with the rest of the Julia language. Thus, users can not only take advantage of the Julia ecosystem, but also apply MTK transformations seamlessly on ordinary models written in Julia without MTK in mind.

MTK was first developed by following Otter and Elmqvist's 2017 paper "Transformation of Differential Algebraic Array Equations to Index One Form" Since then, we have prototyped alternative alias elimination and partial state selection algorithms in comparison to those described in their paper.

Equation-oriented simulation tools need to lower the index of DAEs so that numerical solvers can perform consistent initialization and integrate them. Index reduction algorithms work by adding differentiated equations to the original system, and then to maintain a balanced model, the partial state selection pass needs to select as many dummy derivatives as the number of added equations. Modia.jl's partial state selection pass relies on tearing to detect dummy derivatives which is an elegant approach that bridges Pantelides' index reduction algorithm and tearing.

However, the drawback of this approach is that it's very computationally expensive to perform tearing optimally. Thus, in practice, only heuristic algorithms are used for performance reasons. Unfortunately, a heuristic tearing approach cannot guarantee partial state selection to produce a balanced model, since we must select a precise number of dummy derivatives to keep the DAE system bal-anced. In addition, tearing is oblivious to the numerical rank of the Jacobian matrix of the transformed system as it only has access to structural information. Hence, Modia's approach could produce numerically singular systems even for linear systems with only integer coefficients. To circumvent the aforementioned difficulties, MTK uses the dummy derivative algorithm proposed by Mattsson and Söderlind, and when the Jacobian is integer valued, we use the Bareiss algorithm to select the spanning columns to ensure that the transformed system is always numerically non-singular for this common case. When the Jacobian is non-integer valued, we use the bipartite matching algorithm to pick dummy derivatives that result in at least structurally fully ranked Jacobian.

MTK's alias elimination is strengthened so that it can simplify equivalent differentiated variables as well. After applying the Bareiss algorithm to the linear subsystem to identify aliasing pairs, we may have structures like

$$
\begin{tikzcd}
 & z \arrow[r] \arrow[dd, equal] & \frac{\mathrm{d}z}{\mathrm{d}t} \arrow[d, equal] & \\
 & & z_t \arrow[r] & \frac{\mathrm{d}z_t}{\mathrm{d}t} \\
x \arrow[r] & \frac{\mathrm{d}x}{\mathrm{d}t} \arrow[r] \arrow[d, equal] & \frac{\mathrm{d}^2x}{\mathrm{d}t^2} \arrow[r] \arrow[dd, equal] & \frac{\mathrm{d}^3x}{\mathrm{d}t^3} \\
k \arrow[r] & \frac{\mathrm{d}k}{\mathrm{d}t} & & \\
 & & \mathrm{dd}x \arrow[d, equal] & \\
 & & y &
\end{tikzcd}
$$

where = denotes alias and → points to the differentiated variable.

To eliminate redundant differentiated variables, MTK picks the least differentiated variables and aliases all other variables to that particular differentiation chain. In this case, if we pick x as the root variable, we would generate the following aliases

$$
\begin{gathered}
z := \frac{\mathrm{d}k}{\mathrm{d}t} := \frac{\mathrm{d}x}{\mathrm{d}t} \\
\frac{\mathrm{d}z}{\mathrm{d}t} := z_t := \mathrm{dd}x := y := \frac{\mathrm{d}^2x}{\mathrm{d}t^2} \\
\frac{\mathrm{d}z_t}{\mathrm{d}t} := \frac{\mathrm{d}^3x}{\mathrm{d}t^3}.
\end{gathered}
$$

In this talk, we will present how MTK achieves an easy-to understand implementation of simplification passes by utilizing high-level features of Julia like multiple dispatch and union splitting. We will first review the role of simplification steps in compiling declarative equation-oriented models to executable simulation code, and then demonstrate how these steps are formulated in MTK. Furthermore, we will provide examples of how these novel approaches enable new applications in optimization systems and stochastic differential algebraic equation systems.

Modeling and Control of Nuclear-Renewable Integrated Energy Systems for Electricity and Hydrogen Production

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The rapid depletion of fossil fuels along with the phenomenon of climate change has intensified the need for green resources to produce various forms of energy for daily consumption. Nuclear and renewable resources are important players in this global effort towards minimizing the carbon footprint. Additionally, energy security and resilience are also critical in a developed society where economy and quality of life rely on energy availability. Diversification of energy resources along with decarbonization is hence the future of sustainable energy. In this context, in an integrated energy system (IES), the different sectors of energy are coupled to exploit the full potential of the clean energy mix. Besides flexibility, energy efficiency is yet another benefit of integrating the different sectors. Physics based modeling and simulation are used to evaluate the behavior and response of the individual units and overall system to varying parameters. Considering the different forms of energy and material transfer within the IES, it is pertinent to utilize a modeling tool which is suitable across different domains and represents the physical system with sufficient fidelity.

The Modelica language is deemed to be suitable for capturing the IES behavior and evaluating the control strategy of the IES to follow the demand while satisfying the safety limits.

In this study, we will present one such IES where the nuclear reactor, particularly the small modular reactor, functions as the primary heat supply system for various end uses, and the renewable generation in the form of wind and solar plants supply variable electricity. The utilities of the IES include electricity supplied to the power grid and an industrial plant producing hydrogen. As is evident, the IES requires modeling of different components in the thermal, hydraulic, and electrical domains. The Dymola environment is utilized for the IES model development using the Modelica language. Further, the control strategy of the overall system and the individual control units is tested for different case studies. The simulation results which provide a close-to-real characterization of the system behavior can be used to analyze the impact of varying parameters (such as electricity demand, renewable generation, and hydrogen demand) on the dynamic performance of the IES.

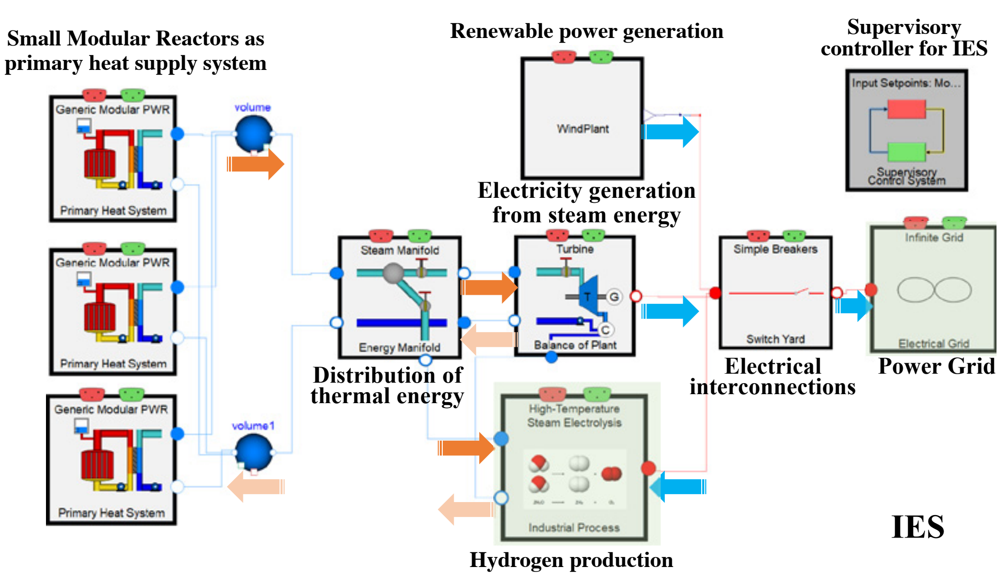

Figure 1. Top level view of the multi-domain IES model architecture in Dymola with component description

Innovative Concepts and Appliation for Large Scale and Multimode Systems: Use Case Study of Heat Networks

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In a global effort to replace fossil fuels in the building sector, many communities in Europe are exploring sustainable alternatives. Thus, the progressive insertion of new energy production systems with high penetration of renewables is leading to more and more decentralization with a large diversity of technologies, actors and consumers, with sometimes divergent points of interests. Since this global setup is expected to play a major role in the future energy mix, there is a strong need for new modeling and simulation means to design and combine such systems for a better definition, control and operation of their targeted performance. Related to ENGIE there are initiatives promoting electrification of space heating and cooling in homes and buildings primarily using heat pumps; on the other hand, there are national and local programs encouraging utility thermal energy networks.

Within this context, ENGIE joined the French consortia industry project ModeliScale supported by the French State, in [2018 , 2021] to create and simulate digital twins, with innovative technological bricks to better analyze larger, more diverse and more complex scenarios for large scale decentralized multi physics energy systems.

The ambition of the project was to develop new scientific concepts for the analysis and resolution of these systems, to prototype technological solutions based on the Modelica and FMI open standards, and to validate them on industrial demonstrators. Thus, the ModeliScale collaborative project addressed several scientific challenges such as: modeling large scale systems (compiling and execution of models with more than 106 equations), multimode modeling (generation of correct simulation code in all modes) and correct and efficient initialization of large Modelica models.

While several case studies dealing with large scale energy grid and heat networks (example in Figure 1) provided by the industrial partners requested the development of Modelica libraries by integrating operational specifications and 'from the field' requirements; ENGIE particularly focused on the modeling and simulation of thermal energy networks, which activity is crucial to develop performing and cost-efficient solutions for customers. To answer to the ENGIE challenges, partners could benefit from enhancements in Dymola prototypes, as well as Modelica library prototypes developed by project partners.

This industrial user presentation will illustrate the ENGIE use case study and the results obtained. The authors will describe the main set of hypothesis (location, characteristics of the existing heat network and its substations, segmentation and architecture, data used for model parameterization, etc.). We will review the different Modelica blocks and physical components that enabled to build the whole model. Consideration about the network tuning, integration and validation will be explained as well. Then an illustration of the Entreprise MBSE engineering scenario example will be given through combination of multiple apps in 3DEXPERIENCE platform, from project management to validation. Finally, the presentation will conclude with summary of benefits and outlook on future work in the domain.

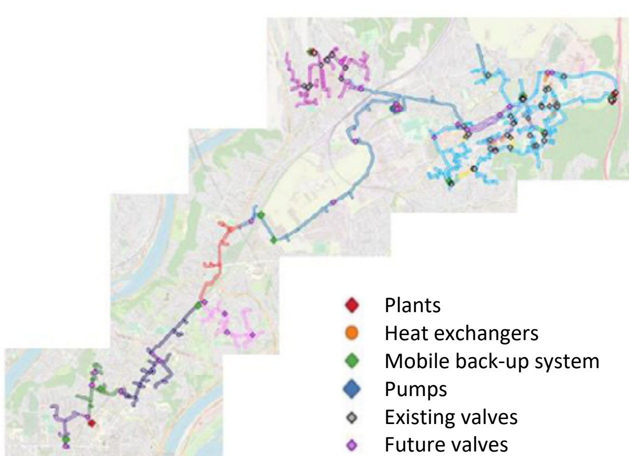

Figure 1. ENGIE Heat network layout in the northern plateau of Lyon, France

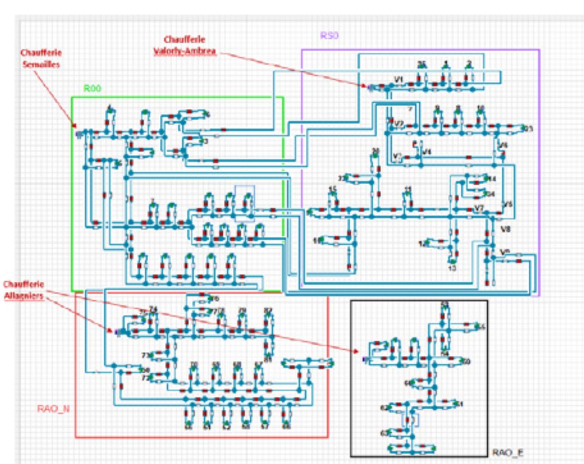

Figure 2. ENGIE global Modelica architecture of the Heat Network

Reinforcement Learning-Based Control of Integrated Energy Systems using ModelicaGym

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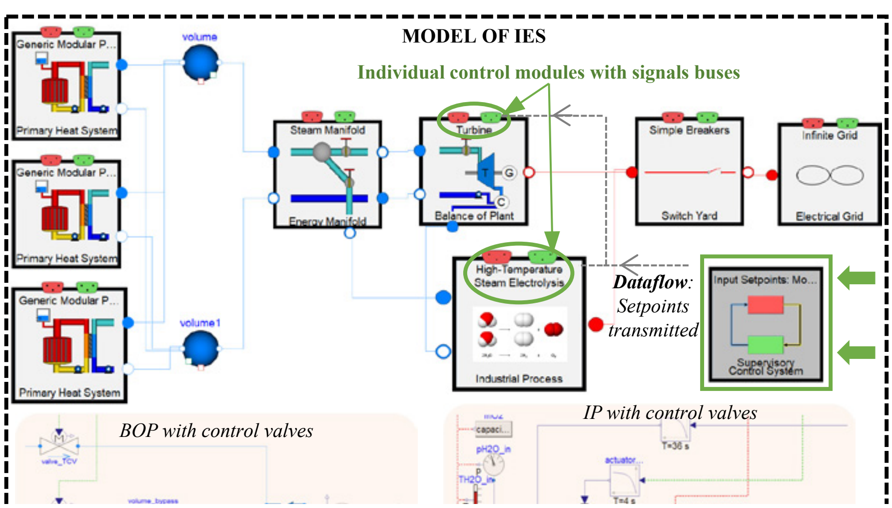
The concept of integrated energy systems (IES) is gaining popularity owing to energy efficiency and security imparted by coupling different forms of energy sources and services. Concurrently, the energy industry has also been transitioning towards green resources such as nuclear, wind, and solar. Traditional nuclear reactors function as base load centralized plants and are not considered as a suitable source for localized energy production. However, with the development of advanced reactor technology such as the small modular reactors (SMRs), the utilization of nuclear for distributed energy production is attaining momentum. Considering the multi-domain interactions in such systems, Modelica language is a suitable tool for model development and designing the control infrastructure. The physical system is driven by suitable control mechanisms on valves and pumps, which is further overseen by a supervisory controller. Conventional PID controllers are used in these models, which are known to be reliable and exhibit simple control strategies. These controllers, however, perform poorly during large perturbations in operating state during disturbances, and in systems with high non-linearity. In view of the complex interactions in the IES, and the uncertainty associated with operating conditions, it may be more suitable to adopt an intelligent control scheme which is adaptive to variations in both plant and environment. Reinforcement learning (RL) based controllers have been garnering attention in this regard, and can be employed for IES control. Additionally, the RL control mechanism is autonomous, and can be deployed online for real-time control of the IES.

In this study, we will implement an RL control for the IES management, by using the open source ModelicaGym toolkit [1] as a bridge between the physics-based model and the artificial intelligence module. The plant here is an IES encompassing nuclear as the energy source, with electricity and hydrogen as end products. The model is developed using the Modelica language in the Dymola platform. The core of the RL framework is developed in python using the OpenAI Gym. The functional mock up interface (FMI) standard is used to derive a compatible representation of the physical model. The proposed control framework will be used for controlling the valves in two specific subsystems, namely the balance of plant and the industrial plant, to meet the power grid and hydrogen plant demands.

Figure 1. The control infrastructure of the IES modeled in Dymola. Individual control modules are assigned for each subsystem and the overall control objective is achieved by the supervisory controller. Lower level PI controllers are used for valve control.



Modeling an Integrated Energy System in OpenModelica to Utilize the Output of a Nuclear Reactor for Producing Energy and Powering a Desalination Plant

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OpenModelica is an open-source modeling and simulation environment intended for industrial and academic usage. OpenModelica has built-in components and models in the Modelica Standard library. Users can develop their own model either using their own components or library components or using a combination of both. In this work OpenModelica has been used to model an Integrated Energy System (IES) where the output of a power source (such as a nuclear reactor) can be utilized to produce steam, electricity and also power a desalination plant; specially in remote areas or regions with lack of freshwater and high salinity of the groundwater.

The model was developed using components of the thermopower and modelica libraries, and by creating the desalination block. Initially, the reactor has been modeled using a generic equilibrium boiler where heat flux is fed from a furnace to boil off the water. The steam from the boiler is then fed to a turbine in the first loop, then to a simple condenser and finally to the equilibrium boiler through the prescribed pressure pump. In the second loop steam is fed to a turbine, then to the desalination plant and finally back to the boiler. Depending on potable water requirements steam will be fed to the desalination plant and the remaining will be sent to consumers for further utilization like district heating.

Initially, the desalination block was modeled using mass and energy balance and utilizing the data published on the amount of energy required to produce per unit desalinated water of the required concentration. Later a more detailed approach was considered; desalination block was modeled as a multi-effect distillation (MED) unit like it was in the Shevchenko nuclear desalination plant. The desalination block and the results are illustrated in the figures below and shows close resemblance to the output of the five-effect commercial desalination plant at Shevchenko.

Future work will be to incorporate a controller in the desalination block that will allow entrance of a certain amount of steam depending on the potable water requirement and limiting criteria of the desalination plant. Finally, the desalination block will be unified in the IES.

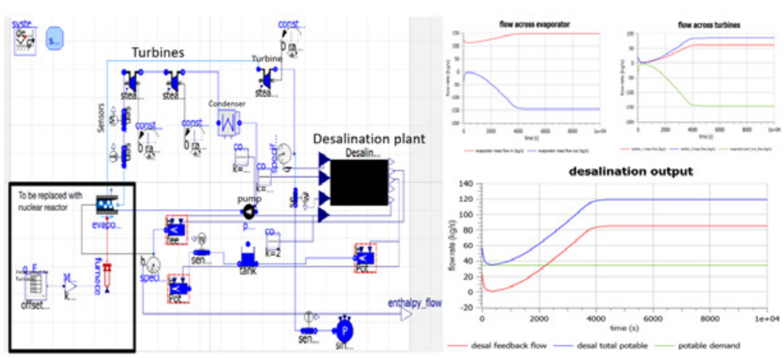

Figure 1. IES block of power source with the initial desalination plant

VENDOR ABSTRACTS

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

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

At this conference, we'll be giving you an insight into unique Modelica editing and system analysis tools integrated into the Visual Studio Code environment. The presentation will demonstrate several key concepts in making model building/editing easy in both graphical and text views, including advanced error reporting. Finally, the presenter will show a postprocessing view interpreting the simulation results live using various templates. 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.

Note : Ricardo Software will be re-branding to Realis Simulation on 1st November 2022 - offering the same suite of tools from the same team of experts in their field.

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.

Modelon Impact

Accurate Simulations.
Better Decisions.

Modelon is revolutionizing the engineering design industry by offering technologies and services that enable customers to leverage system simulation. Modelon's flagship product, Modelon Impact, is a cloud system simulation platform that helps engineers virtually design, analyze, and simulate physical systems.

Our team brings deep industry expertise and is dedicated to guiding our customers in creating innovative technologies at their respective organizations.

Headquartered in Lund, Sweden, Modelon is a global company with offices in Germany, India, Japan, Prague, and the United States. We believe that system simulation should be accessible to every engineer and are dedicated to being an open-standard platform company.

Take your organization to the next level using Modelon Impact for:

- Elevated Productivity
- Better Decision-Making
- Heightened Collaboration
- Increased Flexibility

Modelon

JuliaHub

JuliaSim is a modern SciML powered product for modeling and simulation.

- Acausal modeling in the Julia language.
- Import and chain FMUs in analysis pipelines.
- Fast automatic model calibration to data with differentiable programming.
- Accelerate simulation times with surrogates (Continuous Time Echo State Networks)
- Use JuliaSim's neural network based model autocomplete to hasten the process of model development and construct more accurate simple models.
- Use pre-built models in fields such as HVACs, batteries, and more.
- Autocomplete the missing physics in models by leveraging Universal Differential Equations
- Design, simulate and optimize nonlinear and model predictive controllers.
- Characterize the local minima landscape during the optimization process with JuliaSim's unique robust optimization uncertainty quantification methods.
- Leverage parallelism through cloud and on-prem deployments.

The result? Calibrated digital twins that reduce the need for numerous and iterative lab and field tests, shrinking design time with cost savings that can reach millions. JuliaSim is being used by engineers on a vast variety of problems that include cutting edge applications such as advanced air conditioning simulations, automobile safety, power grid simulation, spacecraft design, carbon sequestration, and systems biology.

The mission of JuliaHub (formerly known as Julia Computing) is to develop products that bring the open source Julia language and its superpowers to its customers. JuliaHub provides the power of a supercomputer at the fingertips of every scientist and engineer. In addition to JuliaSim, JuliaHub also provides access to cutting-edge products such as Pumas for pharmaceutical modeling and simulation and Cedar for electronic circuit simulation, combining traditional simulation with modern SciML approaches.

JuliaHub was founded in 2015 by all the creators of Julia. Julia is the fastest and easiest high productivity language for scientific computing. Julia has been downloaded by over 10,000 companies and over 1,500 universities. Julia's creators have won the prestigious James H. Wilkinson Prize for Numerical Software and the Sidney Fernbach Award.

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.

The Wolfram Language environment is designed to make exploration and analysis as efficient as possible. Combining this with a fully fledged Modelica environment makes it easy to create interactive control panels, design controllers, as well as training and integrating neural nets into your system models, and much more.

During this session version 13.2 of System Modeler, including a new interactive extension to model plots as well as several new Modelica libraries will be presented.

Ansys Twin Builder is a uniquely open solution that allows engineers to create digital twins–connected, virtual replicas of in-service physical assets. Digital twins enable true predictive maintenance, allowing for cost savings, and the proactive optimization of an asset's operation. Ansys Twin Builder lets you build, validate and deploy the twin, potentially cutting the time required to create an accurate product model in half. Once deployed, users can expect a 25% increase in product performance, and maintenance cost savings of up to 20% over the product's lifetime.

To build your system quickly and easily, Twin Builder combines the power of a multidomain system modeler with extensive 0D application-specific libraries, 3D physics solvers, and reduced-order model (ROM) capabilities. When combined with embedded software development tools, Twin Builder allows you to reuse existing components and quickly create a systems model of your product.

To validate your system and ensure expected performance, Twin Builder combines multidomain system simulation capabilities with rapid human-machine interface (HMI) prototyping, systems optimization, and XiL validation tools.

To connect your twin to test or produce real-time data, Twin Builder easily integrates with industrial internet of things (IIoT) platforms and contains runtime deployment options, allowing you to perform predictive maintenance on your physical product. It is the only product that offers a packaged approach for your digital twin strategy.

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Modelon offers technologies and services that enable customers to leverage system simulation.
Our flagship product, Modelon Impact, is a cloud system simulation platform that helps engineers virtually design, analyze, and simulate physical systems.
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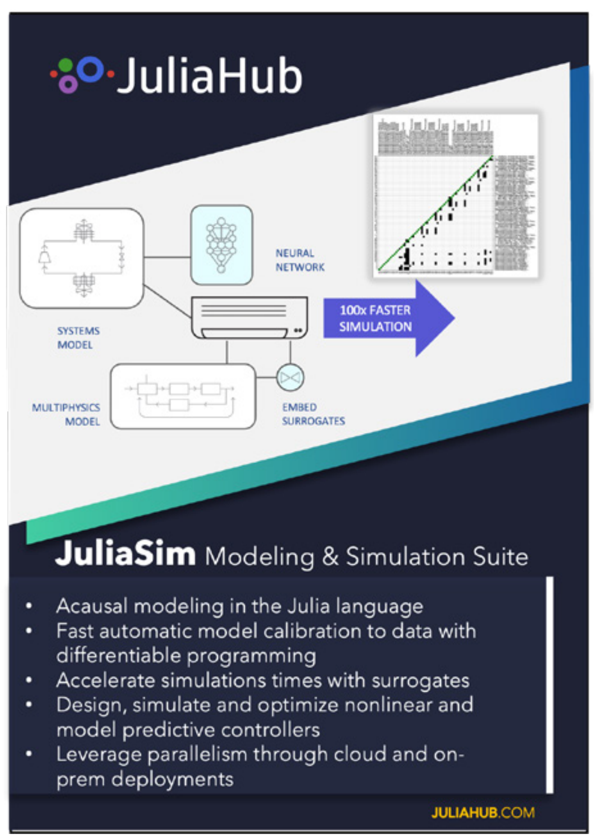
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