



U.S. DEPARTMENT OF
ENERGY

Nuclear Energy

Office Of Nuclear Energy

Annual Review Meeting

Dynamic Simulation Modeling Tool

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ORNL**

September 16-18, 2014



Work Package SR-14OR130108 – Modeling Tools for Dynamic Behavior Simulations of SMRs



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Project Overview

- **To create a flexible, portable and powerful dynamic system modeling environment**
- **to facilitate investigation of control system strategies for reactor systems in any number of configurations**
 - Facilitate rapid development of models,
 - Ensure consistency among research products,
 - Minimize duplication of effort



Technology Impact

- ***The ORNL ModSim Tool is a development, execution environment and repository for reactor subsystem models and end-to-end reactor system models which allows***
 - *Powerful dynamic simulation in the Modelica environment*
 - *The ability to configure components into new power system arrangements*
 - *The ability to collaborate as a community via the internet*
 - *The ability to export models for analysis within the Excel environment opening affordable collaboration to everyone*

- ***The tool will allow reactor design concepts to be studied***
 - *Without requiring the modeler to develop a unique set of BOP models*
 - *With multiple reactors coupled to shared infrastructure*
 - *With control system implementations modeled separately so that system models do not require modification for different I&C designs*



Modeling Tools for Dynamic Behavior Simulations of SMRs FY14 Achievements

FY14 Achievements

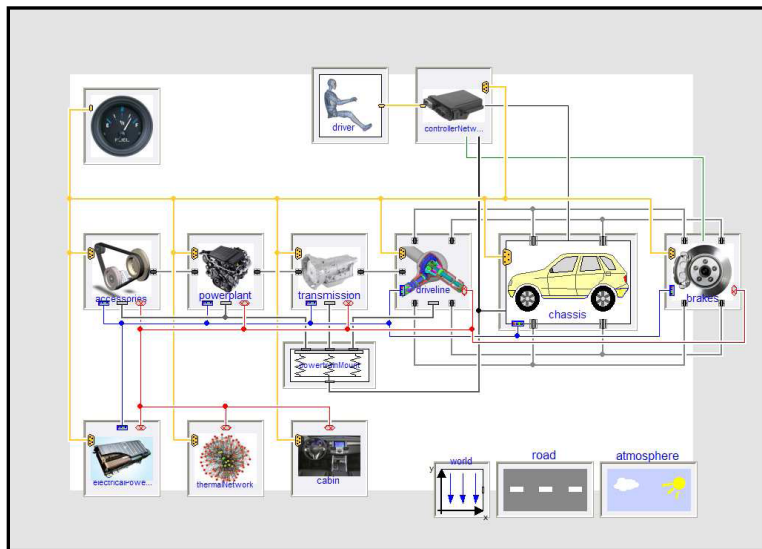
- improved Flexible Model Architecture
- Updated all models to fit within Flexible Model Architecture
- User's Manual
- FHR reactor architecture
- Collaborative efforts initiated
 - Supervisory Control
 - Advanced PRA
 - Universities

FY14 Milestones

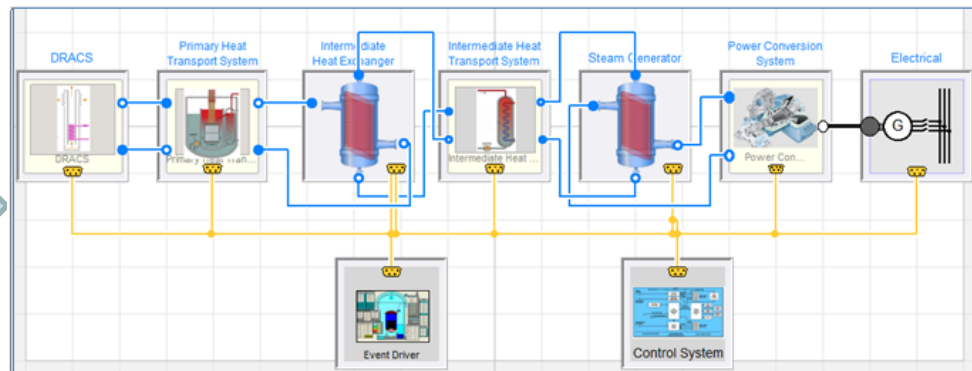
- M3SR-14OR1301086 Level 3 Milestone for Work Package SR-14OR130108, Aug 2014
 - *"Extend Modeling Tool Architecture to Molten Salt Cooled Reactor"*
- M2SR-14OR1301085 Level 2 Milestone for Work Package SR-14OR130108, March 2014
 - *"Update on Small Modular Reactors Dynamic System Modeling Tool"*



Approach Based on Proven Science



Modelica System model for automotive vehicle



Modelica System Model for Advanced Reactors



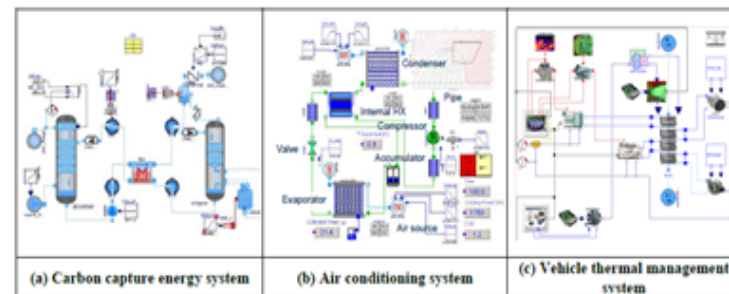
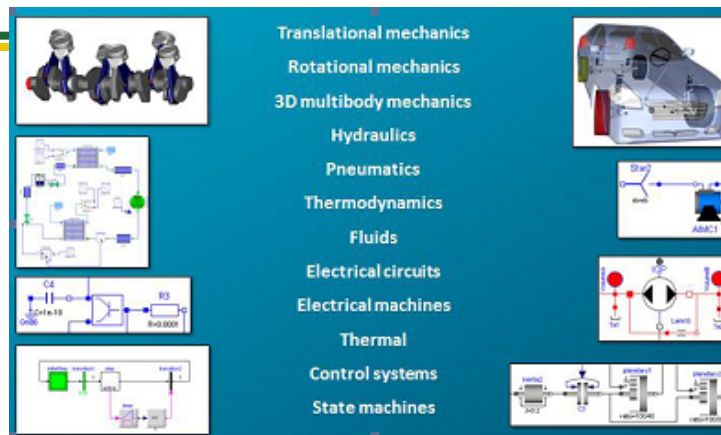
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Modelica: Using the Emerging Open-Source Modeling Standard

- **Modelica is a nonproprietary, object-oriented, equation-based language used to model complex physical systems.**
- **Modelica is free, open source, object oriented and has multi-domain libraries that already exist and can readily be modified**
- **Modelica is a multi-domain modeling language and can handle mechanical, electrical, electronic, fluid, thermal, hydraulic, pneumatic, magnetic, and control systems and their interactions**
- **Been adopted by other industries for fast turnaround design studies (automotive/aerospace)**

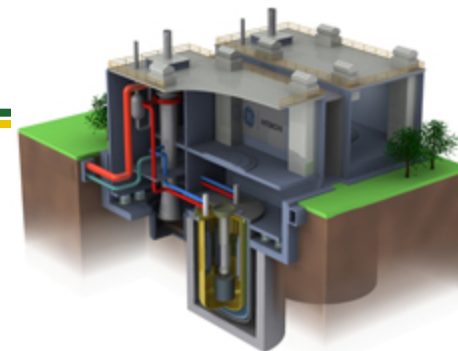




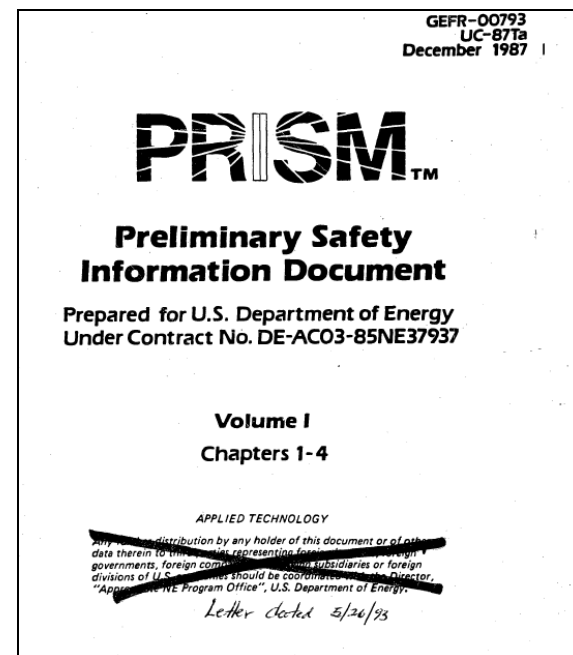
ALMR Concept Modeled

- PRISM¹ ALMR End-to-End System model created from previous models that include:

- *Reactor*
- *Primary System*
- *Intermediate System*
- *Power Conversion*
- *Grid (Generic model)*

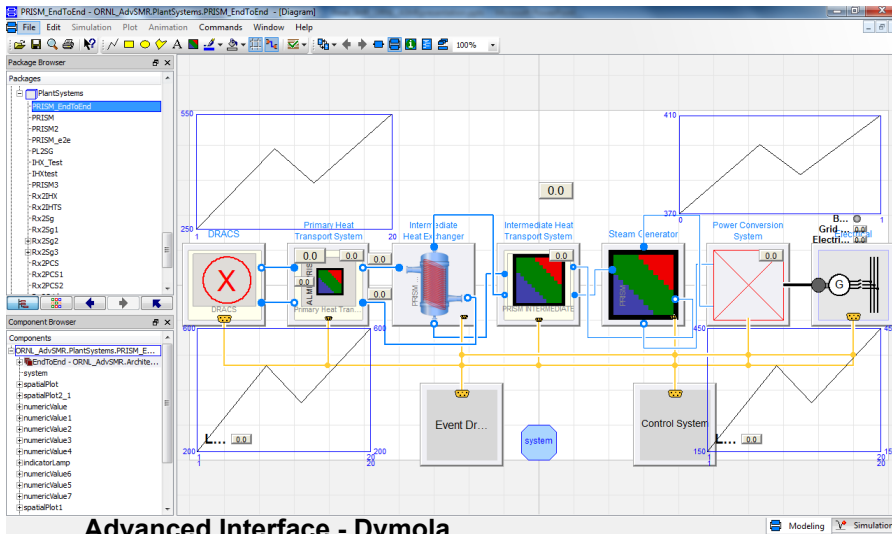


¹The S-PRISM represents GEH's [Generation IV reactor](#) solution to closing the [nuclear fuel cycle](#) and is also part of its Advanced Recycling Center (ARC) proposition^[1] to U.S. Congress to deal with [nuclear waste](#).^[2] It is a [sodium-cooled fast breeder reactor](#), based on the [Experimental Breeder Reactor II](#) (EBR-II) design, scaled up by a factor of ten. [Wikipedia]





User-Tailored Interfaces



Model

Sheet version

Model name

Generation tool

FMU kind

Number of processes

Settings

Start time

Stop time

FMU

Log level

Enable

Output points

Timeout

Indata

Name

reactor_node.T

reactor_Q_coolant

reactor_C_coolant

coolant_loop_radiator.length

coolant_loop_radiator.diameter

coolant_loop_k_heat

coolant_loop_valve_pos

coolant_loop_T_amb

coolant_loop_cooling_factor

controller_mflow_pump

Outdata

Name

reactor_node.Q_flow

reactor_node.T

coolant_loop_tank_level

coolant_loop_coolant_bus_T_rad_in

coolant_loop_coolant_bus_T_rad_out

coolant_loop_coolant_bus_mflow_pump_sensed

coolant_loop_coolant_bus_mflow_pump

controller_coolant_bus_mflow_pump

Message

Default

Case 1

Case 2

Case 3

Case 4

Case 5

Case 6

Case 7

Case 8

Case 9

Case 10

1000

C:\Users\jbatteh\AppData\Local\Temp\VMUD12C.tmp.K158T1U3H6N7.fmu

Info

TRUE

TRUE

TRUE

FALSE

FALSE

FALSE

FALSE

FALSE

FALSE

FALSE

100

0

Variable

Type

Unit

293.15

300

1500

1750

10

10

0.01

1

1000

1

293.15

3

0.01

Real

K

W

J/K

m

m

1

Real

K

Real

kg/s

1499.94

1749.93

486.637

519.181

1.0038

1.00455

336.643

344.188

307.867

310.412

0.01

0.01

0.01

0.01

OK

OK

Disabled

Disabled

Disabled

Disabled

Disabled

Disabled

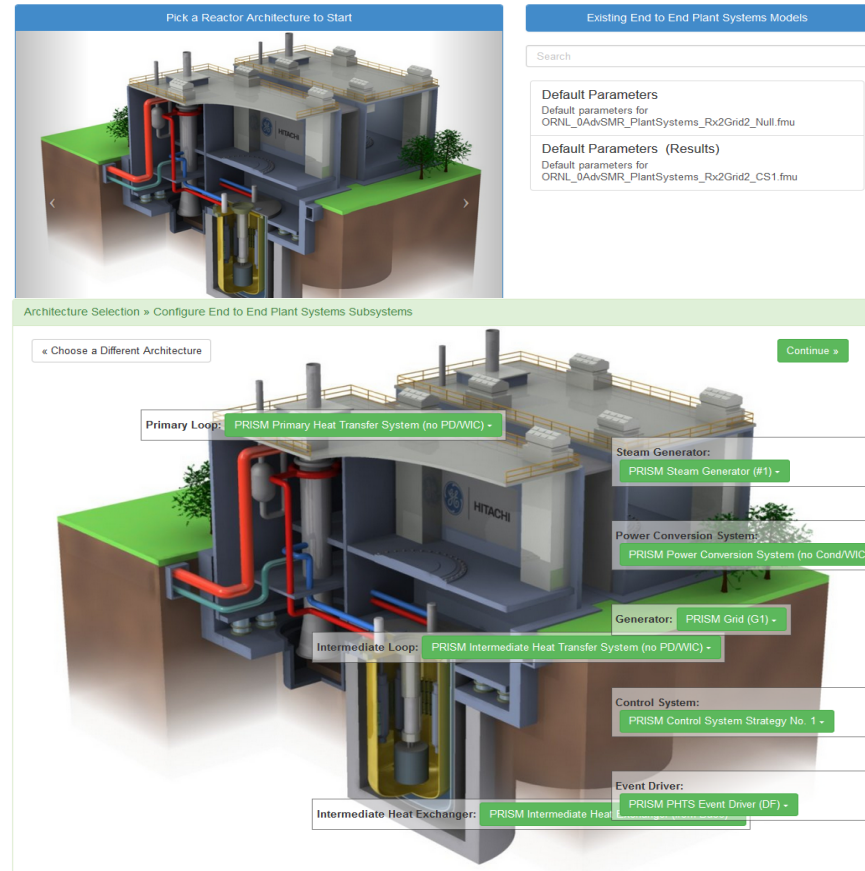
Disabled

Disabled

Disabled

Intermediate Interface - FMIE

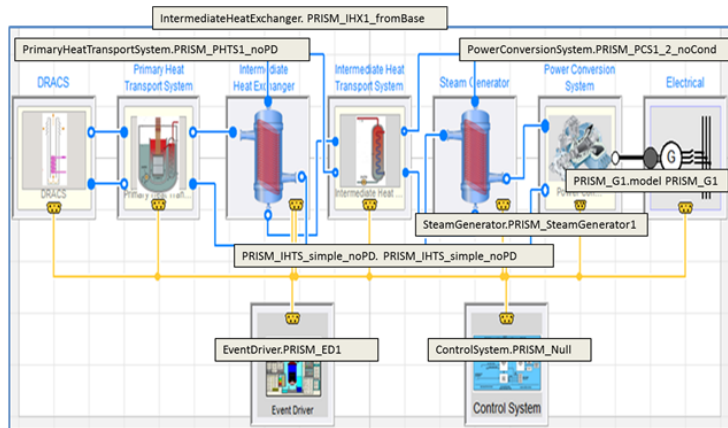
Web-Based Modeling for Small Modular Reactors





Flexible and Powerful Simulation

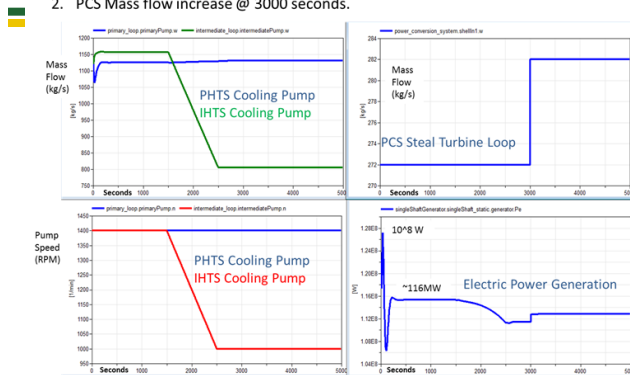
Baseline "Null" Configuration without control
ORNL_AdvSMR.PlantSystems.Rx2Grid2



Baseline "Null" Configuration without control

Two Events:

1. IHTS Intermediate Pump Speed Change @ 1500 seconds.
2. PCS Mass flow increase @ 3000 seconds.

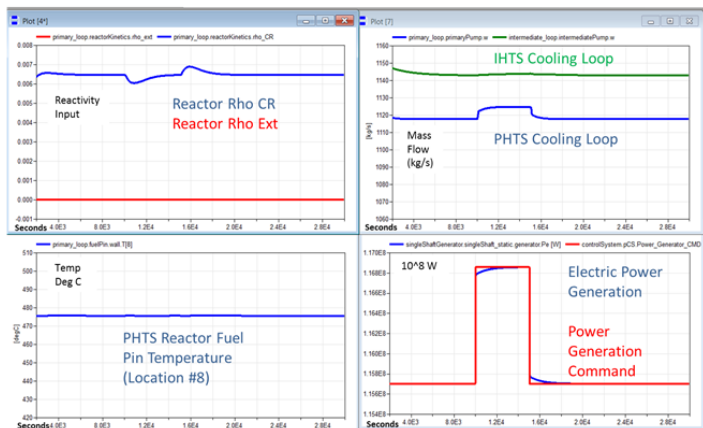


- Two control strategies associated with a single transient

- Transient is simulated step change in reactivity

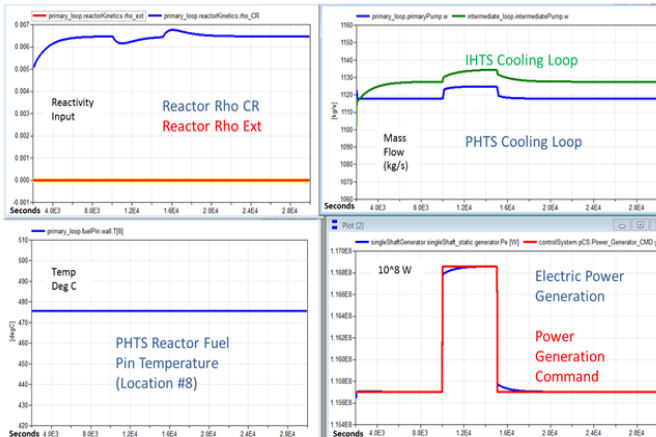
Baseline "Null" Configuration with Control Strategy #1

Trapezoid Power Generation Command Profile – 1.2MW Ramp, Hold, Negative Ramp over 5000 seconds



Baseline "Null" Configuration with Control Strategy #2

Trapezoid Power Generation Command Profile – 1.2MW Ramp, Hold, Negative Ramp over 5000 seconds



- #1 is controlling outlet temperature

- #2 is controlling differential temperature



Modifying and Executing Models Outside of Dymola



- **FMI Excel** Tool Allows sophisticated compiled models to be modified and executed through an Excel Interface, without a Dymola License

Meta Data							
Sheet version				Generated by Modelon FMI Add-In for Excel version 1.0			
Model name				PowerPlantControlTest_0v2			
Generation tool				Dymola Version 2013 (32-bit), 2012-03-28			
FMU kind				CoSimulation_StandAlone			
Settings							
tstart				Default	Case 1	Case 2	Case 3
tstop				-10			
FMU				10	800	800	800
log level				C:\Users\df2\Documents\Dymola\PowerPlantControlTest_0v2.fmu			
enabled				Info			
output points				TRUE			
				100	800	800	800
Indata							
Name	Variability	Type	Unit				
steamPlant_Sim1_1hRSG.drums.HPd_Tmstart	parameter	Real	K	300			
steamPlant_Sim1_1.sourceGas.w0	parameter	Real	kg/s	585.5			
watt_t_Gas.k	parameter	Real		5.4E-06			
ramp.height	parameter	Real		-10			
ramp.duration	parameter	Real	s	50			
ramp.offset	parameter	Real		110			
ramp.startTime	parameter	Real	s	500			
Pl.k	parameter	Real	1	250	250	25	10
Pl.T	parameter	Real	s	100	100	100	200
ramp1.height	parameter	Real		10			
ramp1.duration	parameter	Real	s	10			
ramp1.offset	parameter	Real		0			
ramp1.startTime	parameter	Real	s	700			
Outdata							
Name	Variability	Type	Unit				
steamPlant_Sim1_1hRSG.GasOut.w	continuous	Real	kg/s	-591	-590	-587	
steamPlant_Sim1_1hRSG.HeatExchangersGroup.Ec2_HP_waterI	continuous	Real	kg/s	63.2	63.64	63.77	
steamPlant_Sim1_1hRSG.HeatExchangersGroup.Ec1HP_EcIP.g	continuous	Real	kg/s	590.6	590.3	587.3	
steamPlant_Sim1_1hRSG.HeatExchangersGroup.Ec_LP_gasOut	continuous	Real	kg/s	-591	-590	-587	
steamPlant_Sim1_1hRSG.HeatExchangersGroup.Ec_LP_waterO	continuous	Real	kg/s	-85	-85.7	-85.2	
steamPlant_Sim1_1hRSG.HeatExchangersGroup.mixIP.T	continuous	Real	K	631.7	631.7	632	
steamPlant_Sim1_1.sTG_3LRh.steamTurbines.valveIP.Tin	continuous	Real	K	858.8	859	859.3	
steamPlant_Sim1_1.sTG_3LRh.totalFeedPump.feedWaterPump.	continuous	Real	K	307.4	307.4	307.4	
steamPlant_Sim1_1.sTG_3LRh.totalFeedPump.pumpSpeed_rpm	continuous	Real		1422	1431	1424	

Functional Mockup Interface Add-in for Microsoft Excel® enables steady-state and dynamic simulation of physical models integrated in a spread sheet environment.

- Batch-simulations
- parameter sweeps

Model Configuration/Case Settings

Adjustable Model Inputs

Resulting Model Outputs



Sharing and Collaboration

Web-based model development collaboration through Github with open and secure repositories for proprietary and non-proprietary work



GitHub B A project to build a web-based analysis tool for small, modular nuclear reactors

72 commits 2 branches 0 releases 3 contributors

branch: master ORNL-WebSMR /

Improved layout

mtiller authored a month ago latest commit cd329eb04a

Documentation	incorporating Mike's edits and a few of my own	8 months ago
Examples	minor changes to models	8 months ago
Models	Sample generated HTML.	7 months ago
fms	Pre conference material	a month ago
images	Forgot to add John's reactor image	8 months ago
schemas	Adding optional Title property	8 months ago
util	Another syntactic change to architectures.yaml	8 months ago
.gitignore	Improved .gitignore	8 months ago
README.md	Demonstrating making changes	8 months ago
architectures.yaml	Improved layout	a month ago
fms.yaml	More tweaking based on compiler feedback	a month ago
subsystems.yaml	More tweaking based on compiler feedback	a month ago

Code

Issues 0

Pull Requests 0

Wiki

Pulse

Graphs

Network

HTTPS clone URL

<https://github.com/x>

You can clone with HTTPS, SSH,
or Subversion.

Clone in Desktop

Download ZIP

GitHub is a web-based
hosting service for
software development
projects that use the Git
revision control system.



Conclusion

-
- *The ORNL ModSim Tool creates a set of common tools to investigate advanced reactor concepts and applications*
 - *The tool saves time and money by giving researchers libraries of functioning models to begin with, modify and share*
 - *ModSim facilitates collaboration by*
 - *Using an open-source and emerging simulation environment*
 - *Having access via the internet*
 - *Having the ability to create models that operate within the Excel environment*



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