Hall 9

сниста



Fast product development with virtual prototyping and HiL-testing Dr.-Ing. Franz Lanzerath, TLK Energy GmbH

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WHY USE MODEL-BASED CONTROLLER DESIGN?

Classic approach to design a controller:



Picture source: © eakrinr / 123RF.com



WHAT IS MODEL-BASED CONTROLLER DESIGN?

Design process, where different **design steps of a controller** are tested with a **model of the plant**:



Model-in-the-Loop (MiL)



Software-in-the-Loop (SiL)



Hardware-in-the-Loop (HiL)



EVAPORATOR FROSTING OF AN AIR-WATER-HEAT PUMP



Evaporator frosting lowers the COP and can make the heat pump cycle collapse

Picture source: © eutoch / 123RF.com



EVAPORATOR DEFROSTING USING THE 4-WAY-VALVE

To defrost the evaporator, the heat pump cycle is turned around:



Normal Operation

Evaporator Defrosting

Model-based controller design to develop a defrosting trigger



MODEL OF PLANT: MODELICA AND TIL-SUITE



- Dynamic system ۲
- Flow reversal ٠
- ヹ
- $\dot{m} = 0$ Zero mass flow rate •



exv

DEFROSTING-TRIGGER: TIME-BASED APPROACH

Time-Based Defrosting: Defrosting is triggered every 20 minutes





DEFROSTING-TRIGGER: EVAPORATOR CAPACITY PER TEMPERATURE DIFFERENCE





MIL IN MODELCIA: SUCCESSFULLY DEVELOPED A PROTOTYPICAL DEFROSTING TRIGGER



MiL in Modelica:

- Prototypical implementation of controller
- Defrosting trigger that can react to different ambient conditions





MiL in Simulink:

- Established tool to develop controller code
- Great support for code generation



WORKFLOW TO USE PLANT MODEL IN SIMULINK

Modelica is very well suited to model dynamic systems. Therefore:



Plant model

Build in support for FMU-import in Simulink



MIL IN SIMULINK: TEST OF DEFROSTING TRIGGER



Explanation:

Increased return temperature lowers \dot{Q}_{cond} and $\dot{Q}_{evap} \rightarrow \Psi$ drops below threshold \rightarrow Defrosting is triggered too early



MIL: UNEXPECTED BEHAVIOR WAS FOUND IN AN EARLY DESIGN STAGE



of defrosting trigger

Without MiL, the unexpected behavior would haven been noticed...



... at the test bench.



... at the customer.



Messed up development schedule

or

Picture source: © eakrinr / 123RF.com



NEXT STEP: FURTHER TESTS OF CONTROLLER ON HIL-SYSTEMS

Modelica model can be used on HiL-Systems:



Plant model





HiL systems, for example by Speedgoat, dSpace or National Instruments

- Test of I/O communication
- Test of compiled code



MODEL-BASED CONTROLLER DESIGN SAVES DEVELOPMENT TIME

- Controller is designed with a model of the plant
- With MiL, SiL and HiL, the controller can be tested in different development stages
- FMI standard allows...
 - ... to develop the plant model in the ideal environment
 - ... a consistent use of the same plant model





HARDWARE

TESTING FOR THERMAL SYSTEMS

Hall 4 Booth 4-508a

THANK YOU FOR YOUR ATTENTION

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