BENCHMARK PID 2018

APPENDIX: The MATLAB & Simulink files to approach the Refrigeration System Control Problem

1. INTRODUCTION

This document is an appendix to the main document entitled *Benchmark for PID control of Refrigeration Systems based on Vapour Compression*. It contains a brief description of the MATLAB & Simulink files provided in the Benchmark PID 2018. They have been developed with MATLAB 2013a (Version 8.1.0.604) and Simulink (Version 8.1) for Microsoft Windows 8.1. Furthermore, they have been checked in MATLAB 2014b (Version 8.4.0.150421) and Simulink (Version 8.4), and MATLAB 2016a (Version 9.0.0.341360) and Simulink (Version 8.7) for Microsoft Windows 7 and 8.1 (64 bits O.S.).

The most important files are placed in the main folder, where *RS_simulation_comparison.m*, *RS_simulation_management.m*, *RSBenchmark.slx*, and two simulation data files (**.mat* files) can be found. The initialization files and the compiled files required to simulate the refrigeration system are placed in the folder *Benchmark_files*, as well as the files related to the *CoolProp* tool to compute thermodynamic properties.

2. FILES TO APPROACH THE REFRIGERATION SYSTEM CONTROL PROBLEM

The Benchmark PID 2018 provides the following 5 files in the main folder and one subfolder, explained below, in order to approach the multivariable refrigeration system control problem:

Benchmark_files folder
RS_simulation_comparison.m
RS_simulation_management.m
RSBenchmark.slx
RSBenchmark_20170524_13_48.mat
RSBenchmark_20170528_22_34.mat

RSBenchmark.slx This Simulink model is ready to test the refrigeration system using, for example, a PID controller operating at a certain point. The default controller is a 11x2 Simulink block where the first two inputs are the references, next the values of the output variables to be controlled, and the remaining ones are the disturbances. This block can be modified, as well as the user can create another block. The *Reference and Disturbance Generator* is a 0x9 block that produces the reference and disturbance profile proposed in the Benchmark PID 2018. The only requirement is that all experiments should use this block, since the operating point is initially set. Therefore, all elements in the model are properly initialized before

the simulation. The initialization is carried out using the suitable tab of the Mask Editor, and the simulations can be done by running *RS_simulation_management.m*. The solver method selected is the variable-step ode23tb (*stiff/TR-BDF2*). At the end of the simulation, the variables gathered in Table 1 are automatically sent to the MATLAB Workspace.

RS_simulation_management.m It is an editable file that provides an example of how to run a simulation and save data when finished. It also plots the most relevant variables.

RS_simulation_comparison.m This MATLAB program is designed to show a comparative evaluation of two multivariable controllers, as explained in Section 4 of the main document. One of them plays the role of controller of reference and the other one plays the role of controller to evaluate. The suggested procedure is always the same: first a **.mat* file with the simulation results of reference is loaded, secondly a **.mat* file with the simulation results to evaluate is loaded, and thirdly the comparative evaluation is done. Eventually, as explained in Section 4 of the main document, some comparative pictures are generated and some individual performance indices are shown in the MATLAB Command Window. The file provided in the Benchmark PID 2018 is ready to load the simulation results from the files *RSBenchmark_20170524_13_48.mat* and *RSBenchmark_20170528_22_34.mat*.

RSBenchmark_20170524_13_48.mat This is a data file provided as an example of the performance of a multivariable discrete controller. This data file corresponds to the simulation results of the default controller explained in Section 2 of the main document and labelled as *Controller 1* in Section 4 of the main document.

RSBenchmark_20170528_22_34.mat This is a data file provided as an example of the performance of a multivariable PID controller. This data file corresponds to that labelled as *Controller 2* in Section 4 of the main document.

The *Benchmark_files* folder provides several files required to approach the refrigeration system initial conditions, the simulation, and some auxiliary files:

****.p files*** Some files are used to initialize the system. They are called from the *Refrigeration System* Mask Editor, thus there is no need to manipulate these files. A few files are used for plotting and index calculation.

CoolProp.dll,* Coolprops *folder These files are required to compute all fluid thermodynamic properties. The *CoolProp.dll* file is used within the S-functions, while the *Coolprops* folder is used to compute the initial conditions.

****.mexw64 compiled files*** These files are used within the S-function blocks hidden in the *Refrigeration System* block, playing the role of each element of the refrigeration system explained in Section 2 of the main document: Compressor, Condenser, Expansion Valve, and Evaporator.

Variable	MATLAB variable	Variable	Description
Manipulated variables	Av	A_v	Valve opening
	N	N	Compressor speed
Disturbances	Tsec_condens_in	$T_{c,sec,in}$	Inlet temperature of the condenser secondary flux
	msec_condens	$\dot{m}_{c,sec}$	Mass flow of the condenser secondary flux
	Psec_condens	$P_{c,sec,in}$	Pressure of the condenser secondary flux
	Tsec_evap_in	$T_{e,sec,in}$	Inlet temperature of the evaporator secondary flux
	msec_evap	$\dot{m}_{e,sec}$	Mass flow of the evaporator secondary flux
	Psec_evap_in	$P_{e,sec,in}$	Pressure of the evaporator secondary flux
	Tsurr	T_{surr}	Compressor surroundings temperature
Refrigeration Cycle output variables	Tsec_evap_out	$T_{e,sec,out}$	Outlet temperature of the evaporator secondary flux
	TSH	T_{SH}	Degree of superheating
	TSC	T_{SC}	Degree of subcooling
	m	$\dot{m}$	Refrigerant mass flow
	Qcondens	$\dot{Q}_c$	Thermal power transferred at the condenser
	Qevap	$\dot{Q}_e$	Cooling power
	Qcomp	Q_{comp}	Thermal power provided at the compressor
	Wcomp	W_{comp}	Mechanical power provided by the compressor
	Pcondens_in	$P_{c,in}$	Refrigerant pressure at the condenser inlet
	Pcondens_out	$P_{c,out}$	Refrigerant pressure at the condenser outlet
	Pevap	P_e	Refrigerant pressure at the evaporator
	hcondens_in	$h_{c,in}$	Refrigerant specific enthalpy at the condenser inlet
	hcondens_out	$h_{c,out}$	Refrigerant specific enthalpy at the condenser outlet
	hevap_out	$h_{e,out}$	Refrigerant specific enthalpy at the evaporator outlet
	COP	COP	Coefficient of Performance
References	Ref_TSH	Reference on T_{SH}	Reference on the degree of superheating
	Ref_Tsec_evap_out	Reference on $T_{e,sec,out}$	Reference on the outlet temperature of the evaporator secondary flux
MATLAB variables	name	File name	Name of the data file
	code	File code	Code of the data file
	Tsim	Simulation time	Duration of the Simulink simulation
	sim_t	Time vector	Simulation time vector
	Tm	Sample time	Simulink sample time

Table 4. Variables on MATLAB Workspace after simulation.

Diagrama_ph.mat, Ciclo_1C1R.png These are auxiliary files. The data file is used to represent pressure-specific enthalpy charts, while the *Ciclo_1C1R.png* file enhances the Simulink visualization.

3. ADVICES FOR A PROPER OPERATION

It is very important to follow some advices in order to use properly the Benchmark PID 2018.

1) The user must place the *Benchmark_files* folder and *RSBenchmark.slx* in the same folder or in MATLAB path. Moreover, the *Benchmark_files* folder must be added to the MATLAB path.

2) All files required by *RSBenchmark.slx* are included in the *Benchmark_files* folder. Moreover, it is important not to change the folder name, nor any other file name.

3) The main Simulink model, *RSBenchmark.slx*, is fully modifiable, with the exception of the *Refrigeration System* and the *Reference and Disturbance Generator* blocks. Please do not modify any sub-block, nor code line in these blocks.

4) Some problems related to the solver and element layout in the Simulink model have been found out when changing from a recent MATLAB version to an older one. The block layout in the Simulink model appears disorganized but they are correctly connected. However, the solver might be changed. This inconvenience is critical. The authors suggest that once a MATLAB version is chosen, it is desirable to work always in this version.

4. LIST OF FILES WITHIN THE *BENCHMARK_FILES* FOLDER

***.p MATLAB programs:**

1. *controller_parameters.p*
2. *data_representation.p*
3. *disturbance_profiles.p*
4. *Initial_conditions.p*
5. *Initialization_commands.p*
6. *output_data_clustering.p*
7. *representation.p*
8. *RS_qualitative_comparison.p*
9. *RS_quantitative_comparison.p*

****.mexw64 compiled files:***

10. *Compressor.mexw64*
11. *Condenser.mex64*
12. *Evaporator.mexw64*
13. *Expansion_valve.mexw64*

Files related to the *CoolProp* tool:

14. *CoolProps.dll*
15. CoolProps *folder*

Auxiliary files:

16. *Diagrama_ph.mat*
17. *Ciclo_1C1R.png*