

“HRS-Modell” Manual

The “HRS-Modell” was programmed within MATLAB/Simulink. The usage of the tool requires MATLAB and Simulink including following toolboxes:

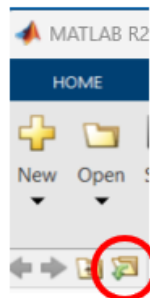
- MATLAB Report Generator
- Simulink Report Generator
- MATLAB Coder
- Simulink Coder
- Optimization Toolbox
- MATLAB Support for MinGW-w64 C/C++/Fortran Compiler

These should be installed according to the manufacturer’s installation guide. Basic knowledge of MATLAB and Simulink are advantageous but no required for the use of the tool.

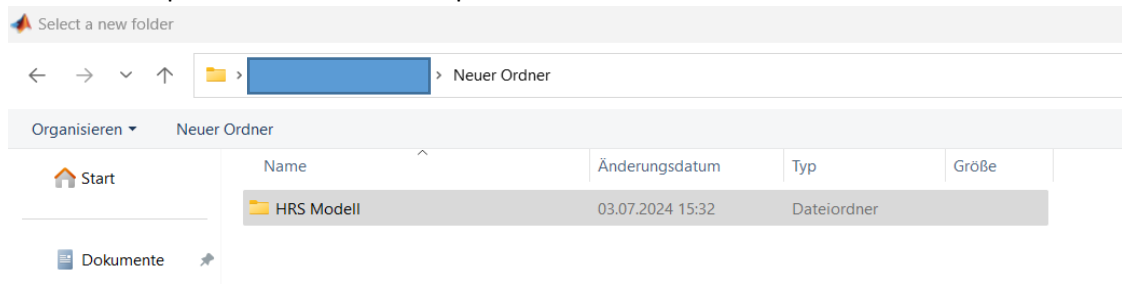
Initial Use

For the initial use, the downloaded “HRS-Library” needs to be integrated into the Simulink Library Browser. This is done within the MATLAB Editor:

1. Load the File: **“slblocks.m”** from the extracted folder → **“Library”** in MATLAB. The file can be opened from the folder or from within MATLAB.
 - 1.1. Using MATLAB the filepath need to be opened. This is achieved by clicking the following button to the left in the MATLAB-window:



- 1.2. Within the opened Window find the path to the extracted Folder **“HRS Modell”**



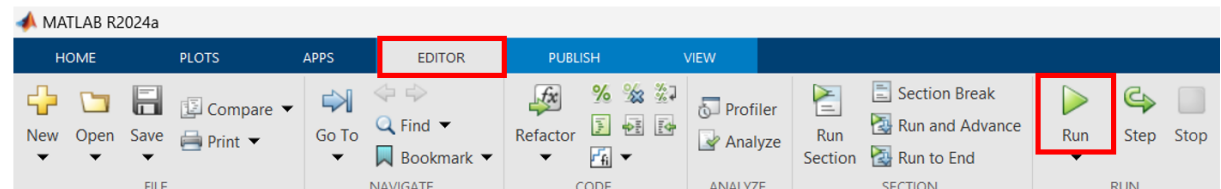
- 1.3. Select the folder and open via the button on the bottom right. The left-hand side of the MATLAB-Workspace should display the selected folder in the **“Current Folder”** window. Select the file **“slblocks.m”** and open with a double-click or right-click → **“open”**

The MATLAB-Editor should display following code:

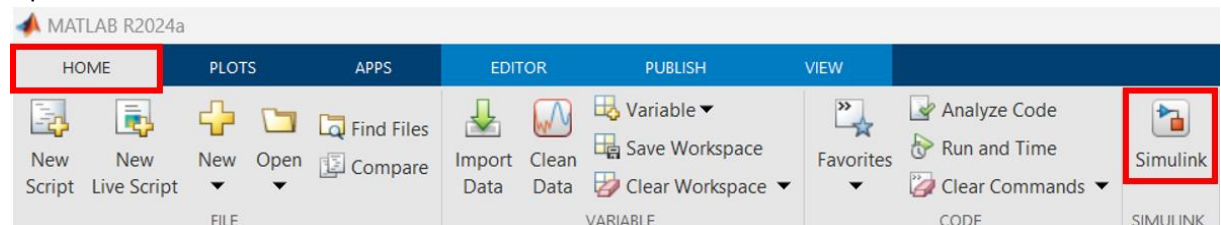


```
1 function blkStruct = slblocks
2
3     Browser.Library = 'HRS_Library';
4
5     Browser.Name = 'HRS Library';
6
7     blkStruct.Browser = Browser;
8 end
```

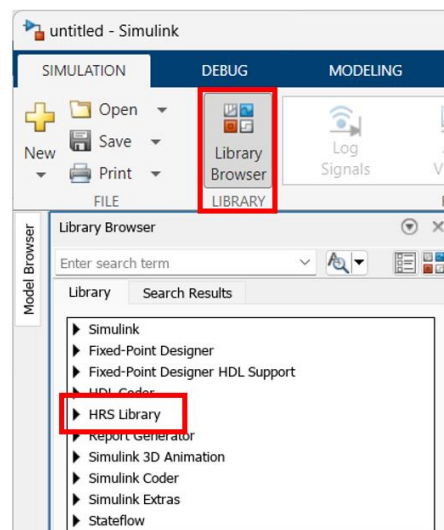
2. Run the script once via “Editor” → “Run”



3. Open Simulink via “Home” → “Simulink”



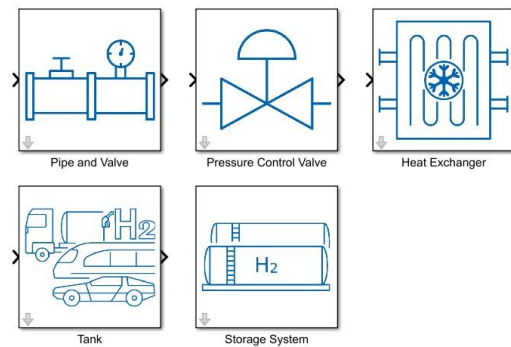
4. In Simulink select “Blank Model” → “Create Model” and check “Library Browser” for “HRS Library”:



Application

The simulation is conducted in the programming space of Simulink. The Library consists of five blocks, which represent the components of an HRS:

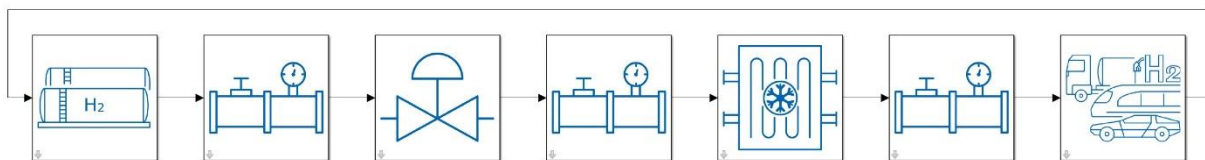
- Heat Exchanger
- Pipe and Valve
- Pressure Control Valve
- Storage System
- Tank



In the current version following rules need to be followed when creating a configuration:

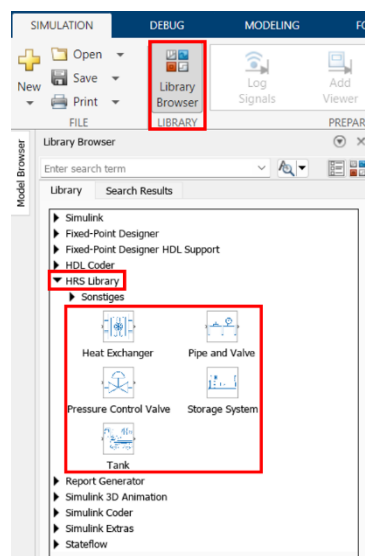
1. Every component needs to be used once.
2. Within a single fueling strand the components **“Pressure Control Valve”**, **“Tank”** and **“Storage System”** can only be used once.
3. A Configuration has to start with the component **“Storage System”**, which needs to be initialized according to 3.1.
4. A Configuration ends with the Component **“Tank”**.
5. The output of **“Tank”** has to be connected with the input of the **“Storage System”**.

The basic principles for creating the configurations will explained in the following chapter. Following configuration is recommended for simulation:



1. Inserting Components

Within Simulink the components can be accessed via **“Simulation”** → **“Library Browser”** → **“HRS Library”**

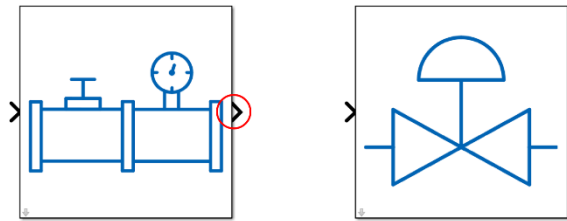


The components can be inserted into the Simulink-Workspace per drag and drop. Alternatively, a search window can be opened by double-clicking an empty spot on the workspace. Using the search window, the required component can be looked up and inserted.

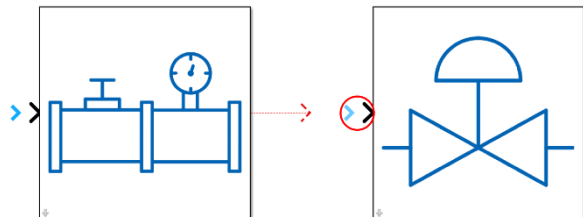


2. Connecting Components

2.1. Left-Click the outgoing arrow and either hold or let go:



2.1.1. When holding the left-button a striped red arrow appears, which can be dragged across the workspace. Connect by dragging to the input of the desired block. A connection exists, when there is a solid, black arrow between the components.



2.1.2. When just clicking the output, blue arrows appear in front of all available component inputs. By clicking the arrow at the desired block a connection is created between the two components.

3. Component settings

All components, except for the pressure control valve include basic parameters that can be set to a desired value. By double-clicking the component, a user interface can be opened.

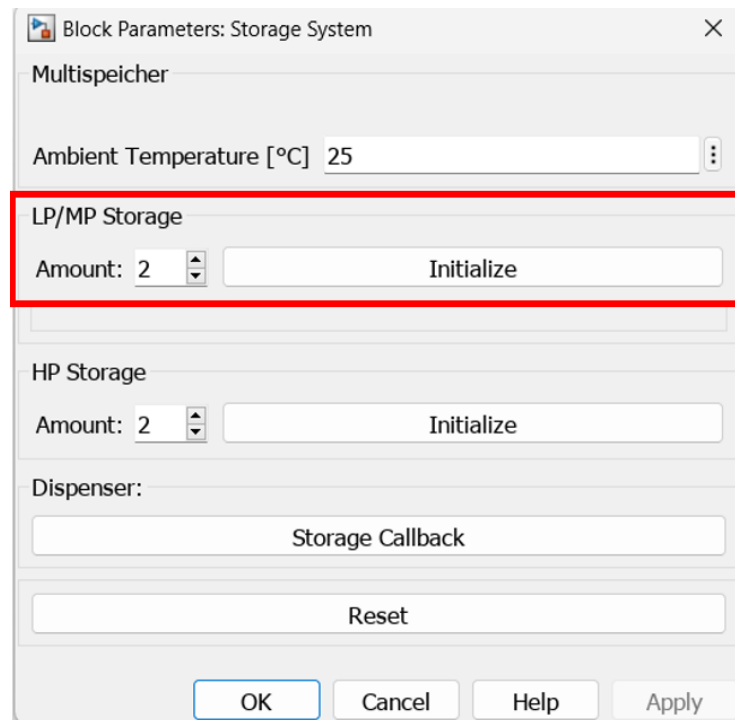
3.1. Storage System

The „Storage System“ block allows the customization of the amount of storage banks, and their initial condition. When inserted into the workspace, the block has no in- or outports. A separate activation process is required. In the current iteration there needs to be at least one “Tank” block in the workspace to start the following steps. Furthermore, the storage system needs to consist of at least:

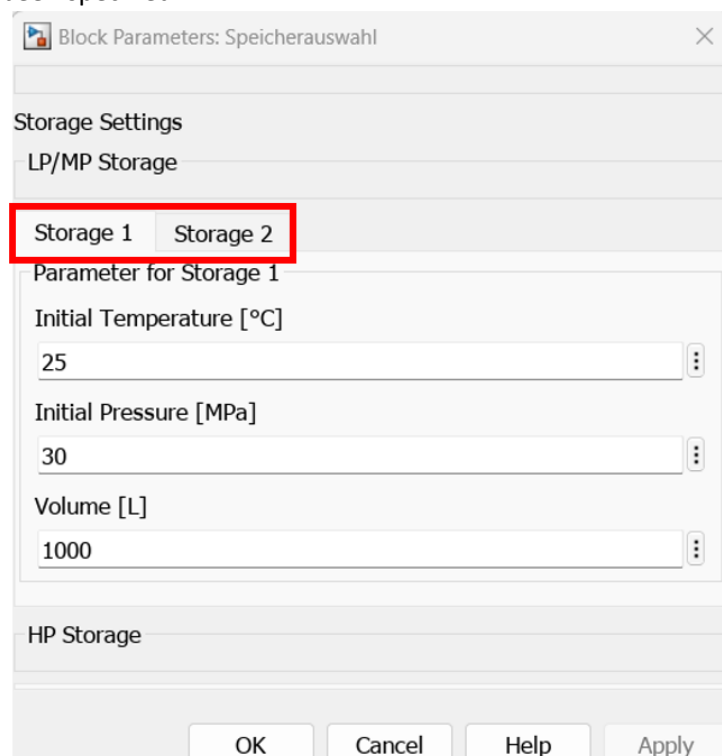
- one low- or medium-pressure-storage
- one high-pressure-storage

Following steps need to be followed to activate the “Storage System” block

1. Set the amount of “**LP/MP Storages**” and click on the corresponding “**Initialize**”-Button.



2. A new window will appear, in which the initial storage parameters can be specified. With multiple storages, additional tabs will appear for the individual storages. The window can be closed after the settings have been specified.



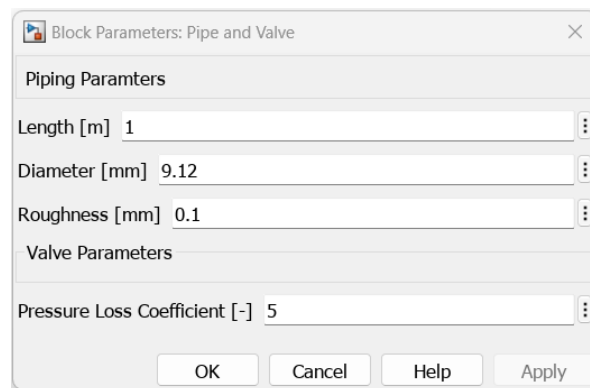
3. Set the amount of **“HP-Storages”** and click on the corresponding **“Initialize”**-Button. The previous window will appear with addition setting options. The window can be closed after the settings have been specified. The storage settings windows can be reached with the **“Storage Callback”**-button to adjust the settings.
4. After step 3 the **“Storage System”**-block will have in- and outputs according to the number of **“Tanks”** in the configuration. Hereby, the output of the **“Tanks”** need to be connected to one of

new inports. The outputs of the **“Storage System”** can be connected to the other components of the HRS. The user interface can be closed via **“OK”** or with **“X”** at the top right of the windows.

If there is a need to adjust the amount of storages, the block needs to be reset with the **“Reset”** - Button. After resetting, repeat steps 1-4.

3.2. Pipe and Valve

The user interface for the **“Pipe and Valve”**-block include the pipe geometry settings length and diameter as well as the wall roughness. For the valve settings, only the **“Pressure Loss Coefficient”** can be adjusted, this parameter can also be adjusted for other potential fixtures.



Block Parameters: Pipe and Valve

Piping Parameters

Length [m] 1

Diameter [mm] 9.12

Roughness [mm] 0.1

Valve Parameters

Pressure Loss Coefficient [-] 5

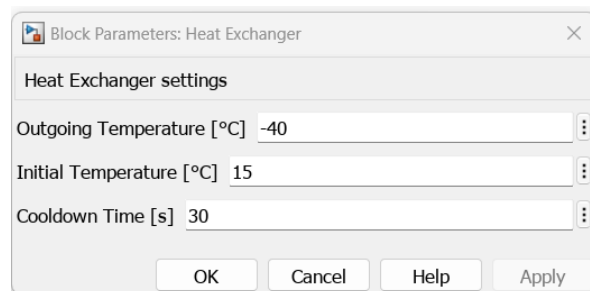
OK Cancel Help Apply

3.3. Pressure Control Valve

In the current version no adjustments are available for the pressure control valve.

3.4. Heat Exchanger

The heat exchanger cools the incoming hydrogen. The **“Cooldown Time”** defines the time it takes for the system to cool down from the **“Initial Temperature”** to a given **“Outgoing Temperature”**.



Block Parameters: Heat Exchanger

Heat Exchanger settings

Outgoing Temperature [°C] -40

Initial Temperature [°C] 15

Cooldown Time [s] 30

OK Cancel Help Apply

3.5. Tank

The Tank block describes the vehicle storage and also includes the setting for the fueling process. Besides the volume and the initial state, the nominal pressure must also be indicated.

In the current version the simulation performs the fueling process using a user defined average pressure ramp rate (APRR). The **“SOC-Goal”** is the SOC at which the process is halted. For back-to-back fueling, the **“Resettime”** is the time between two fueling procedures.

A pressure pulse can also be implemented, by defining the **“Total Mass”** and **“Duration”** of the desired pulse.

Block Parameters: Tank

Parameters

Initial Temperatur [°C] 25

Initial Pressure [MPa] 5

Volume [l] 200

Nominal Pressure [MPa] 70

Ambient Temperature [°C] 15

Pressure Control

Average Pressure Ramp Rate [MPa/min] 19.9

SOC-Goal [%] 100

Resetime [s] 600

Pressure Pulse

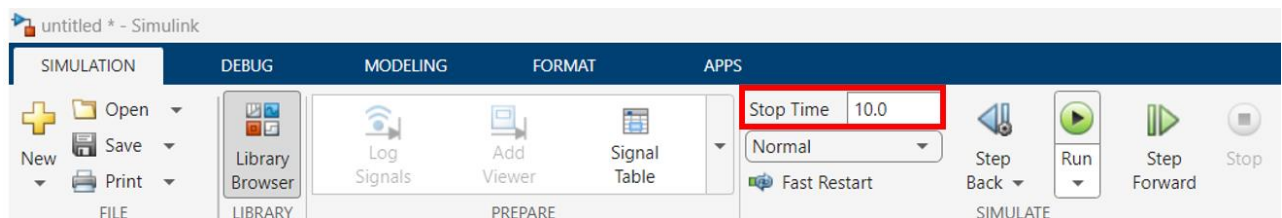
Total Mass [g] 200

Duration [s] 6

OK Cancel Help Apply

4. Last steps

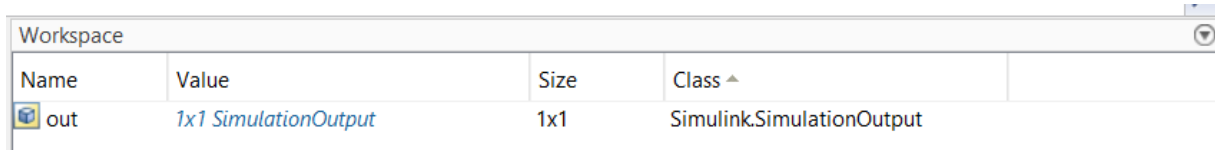
Before the simulation is started, the **“Stop Time”** should be adjusted. In the **“Simulation”** tab adjust the stop time to desire simulation time in seconds.



Start the simulation using **“Run”**.

Simulation Results

At the end of the simulation, the results will be saved in the **MATLAB-Workspace**, at the right-hand side of the **MATLAB-Window**.

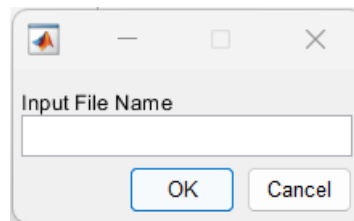


The image shows the MATLAB Workspace window. It has a title bar 'Workspace' and a table with four columns: Name, Value, Size, and Class. There is one row of data.

Name	Value	Size	Class
out	1x1 SimulationOutput	1x1	Simulink.SimulationOutput

These results can be processed directly in MATLAB or converted to a “.xlsx”-file. For the conversion use the script **“Simulation_Excel_Transfer.m”**, which is included in the downloaded folder.

After opening the script, start it in the **“Editor”** tab and clicking **“Run”**. First, a the save path will be requested, followed by a query for the file name.



After confirming the file name with **„OK“**, the file should appear in the chosen folder after the script finished.