6 Hardware in the Loop

Folder 6 contains all files needed to do hardware in the loop testing: the local supervisors with mutex locks and the hardware mappings.

6.1 Folder *definitions*

The communication between PLCs, from components to PLCs, and from PLCs to components, consists of boolean variables. In the created supervisors, however, communication mostly concerns events. For example, if a sensor turns on, one of the input booleans of a PLC is set to 1. In the supervisor, this corresponds with the event u_on for that sensor. A hardware mapping is needed to link these boolean variables used for PLCs to events.

In the folder *definitions*, a number of hardware components are defined in the files: *HWActuator.cif*, *HWButton.cif*, *HWMode.cif*, *HWPumpDirection.cif*, *HWSensor.cif*, and *HWToken.cif*. These definition files are used in the hardware mapping. The hardware mapping for an actuator will be discussed as an example, other components are treated in a similar fashion.

The hardware mapping for a actuator consists of an automaton with 1 location. A boolean ON is defined. This boolean is linked to an output variable on the PLC. Upon event c_on boolean ON is set to true, upon event c_off boolean ON is set to false.

```
1  group def HWActuator(controllable c_on, c_off):
2    plant actuator:
3      disc bool ON = false;
4        location:
5          initial; marked;
6          edge c_on do ON := true;
7          edge c_off do ON := false;
8    end
9  end
```

6.2 Folders *Loc1* and *Loc2*

The local supervisors are again given in the folders *Loc1* and *Loc2*. The hardware mappings are given in the files *HWmap1.cif* and *HWmap2.cif*. The files *Merge_codegen.tooldef2* are used to merge local supervisors with their hardware mappings, creating hardware supervisors *HWLocal1.cif* and *HWLocal2.cif*. These hardware supervisors are then used to generate PLC code.

The PLC code is imported in TIA Portal, the software package used for Siemens PLCs. A simulation of the plant is run using the Ignition software package, which interacts with the PLCs. A set of 80 test cases is defined to validate the behavior of the system in the hardware in the loop setup. A test case is for example: push button manual of head pumpcellar 1, next push button store of head pumpcellar 1. The expected result is that head pumpcellar 1 changes its regime to store. The result matches the expected result for all test cases.

The GUI and simulation visualization are shown in Ignition as the interface in Figure 6.1. The simulation is visualized at the bottom of the figure and the GUI is visualized at the top. The amount of rain in the simulation can be controlled by using the slider, the amount of water in each pump-cellar is visualized by the three rectangles at the bottom of the figure. The state of all sensors, pumps, and other automata are visualized in the GUI. The GUI also contains buttons which can be clicked to change input variables of the PLC.
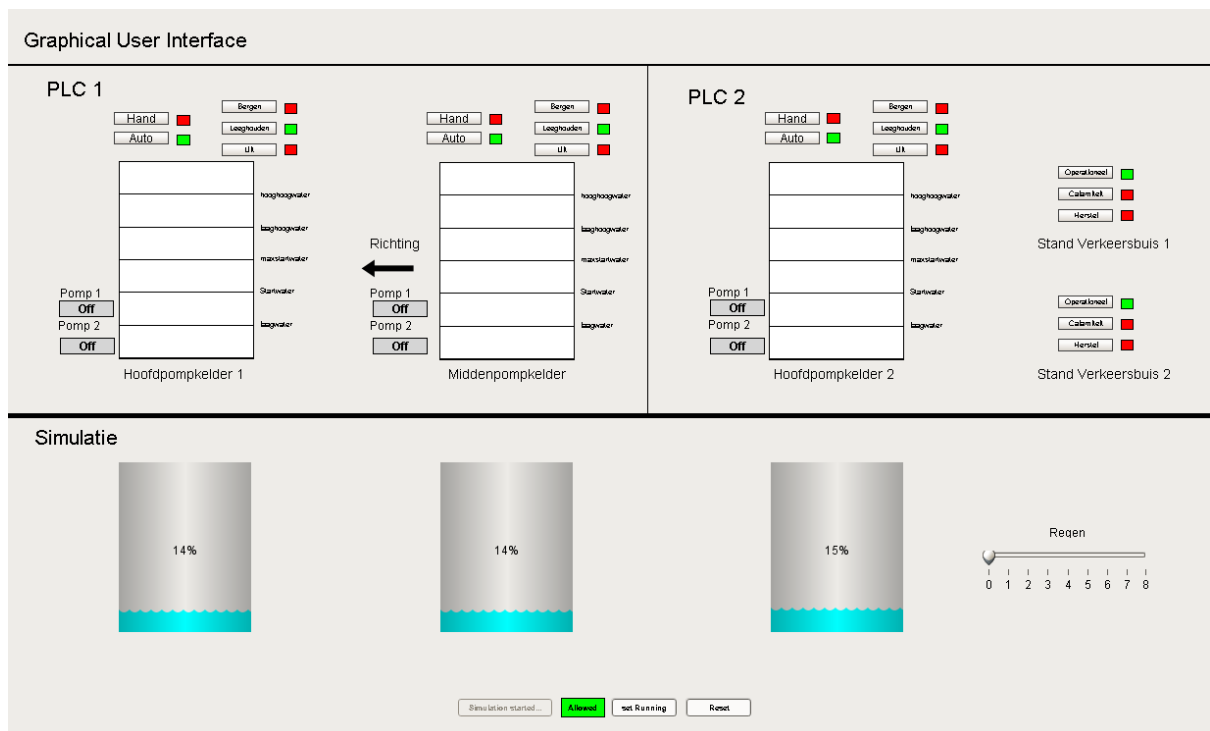
Figure 6.1: Ignition interface