A

Three-tank System Simulation

The three-tank system is simulated using MATLAB®/Simulink®. The simulation has been developed using MATLAB® version 6.5.1 (R13SP1), Simulink® version 5.1 (R13SP1), and Virtual Reality Toolbox® version 3.1 (R13SP1). It consists of the modeling part and the animation part. It also works with newer MATLAB® versions such as version 7.3 (R2006b).

A.1 Main Page

The main Simulink® file is *Three_tank.mdl*. Once this file is open, the main page illustrated in Fig. A.1 appears. The reference levels are displayed on the right hand side of this page in addition to the sensors measurement and the real levels in the tank.

It is also possible to test the effect of sensor and actuator faults on the behavior of the system by using the blocks on the left hand side of the main page. Consider for example the block shown in Fig. A.2. This block allows us to simulate bias faults for sensor 1 by adjusting the fault amplitude (here it is set to –0.03) and the fault time occurrence (set to 1500 s). Users can easily test other faults such as drifts or freezing.

Figure A.3 shows the block that allows us to simulate a fault on actuator 1. In this case, the *Loss* block is set to 0.2 which means that a loss of effectiveness of 20% is supposed to occur at 1500 s. A value of 1 means the complete loss of the actuator. A value of 0 means that no fault occurs.

Finally, the main page contains the animation window which shows up automatically once simulation is started. This window will be explained in Sect. A.3. It should be noted that the model is automatically initialized; thus a manual initialization is not needed.

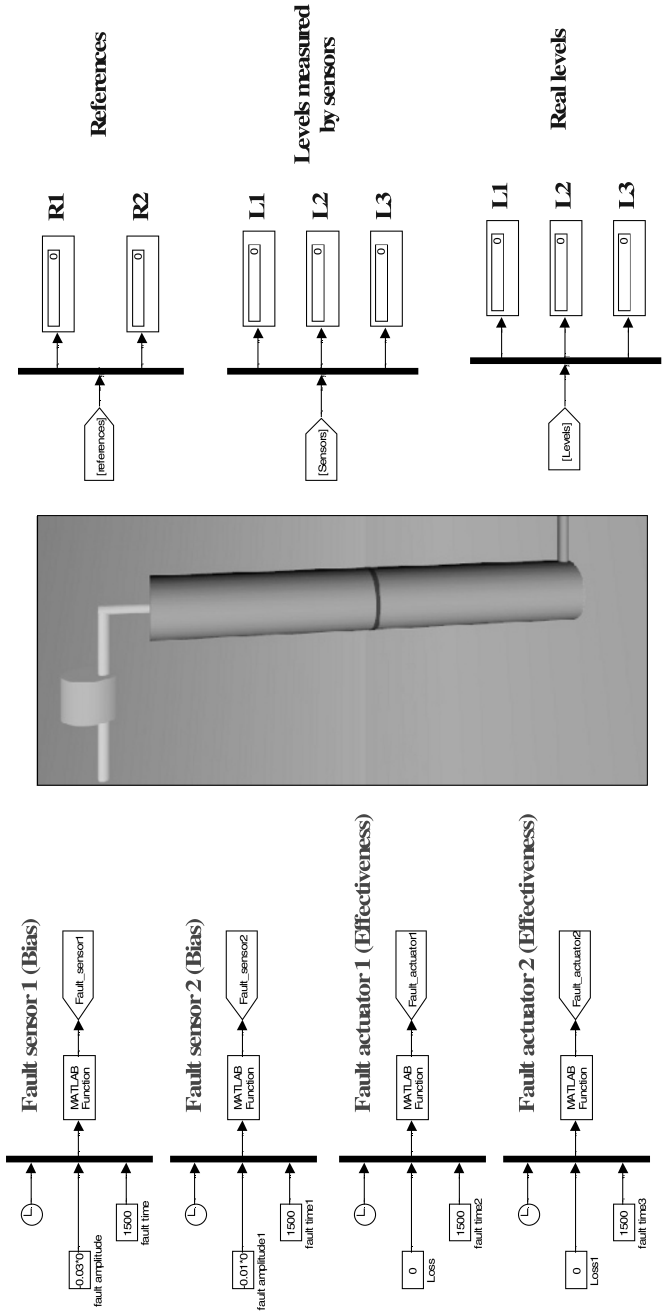

Fig. A.1. Main page of the simulation

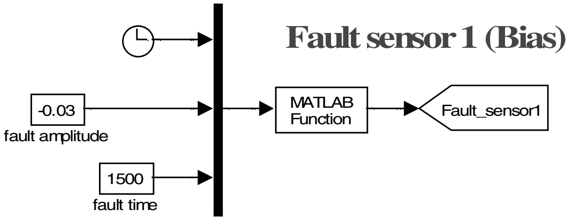

Fig. A.2. Sensor fault block

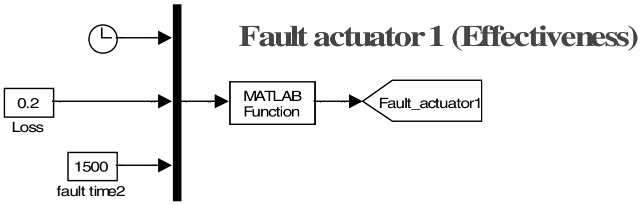

Fig. A.3. Actuator fault block

A.2 Modeling Part

The modeling part shown in Fig. A.4 consists of:

- The nonlinear model of the system (the block *"Three tank system"*)
- The controller
- The reference levels block
- Two blocks to simulate sensor and actuator faults
- Signal routing blocks for the animation purposes

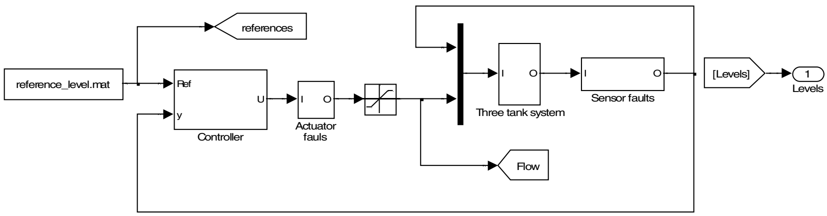

Fig. A.4. The three-tank system

The control law used in this simulation is a state-feedback with integrator where the gains are determined using a linearized model around an operating point (Fig. A.5). Therefore, the controller will give satisfactory performance only around this operating point. Thus, users should pay attention not to drive the system outside the operating region when simulating the nominal behavior of the system. On the other hand, users are invited to apply nonlinear control laws (see for example Chap. 2) for the whole operating range of the system.

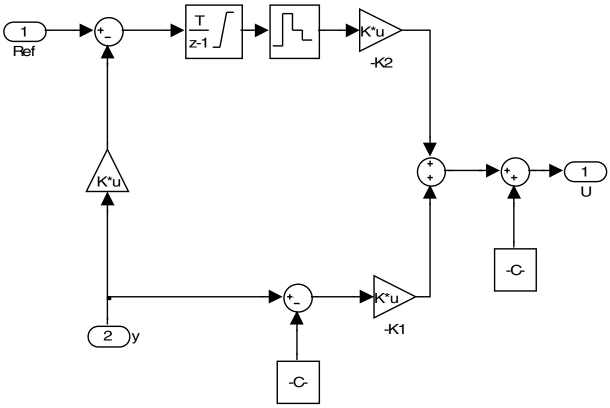

Fig. A.5. State-feedback with integrator controller

Remark A.1. It should be noted that, in this simulation, actuators are assumed to be scalar gains. In addition, no sensor noise is used. These two points can be easily considered in simulation for more consistency.

A.3 Animation Part

The animation window shown in Fig. A.6 allows one to visualize the measurements issued from the modeling part. As stated before, this window shows up automatically when simulation starts, but it can also be forced to show up by clicking the middle block of the main page (Fig. A.1).

This window shows the three interconnected tanks, the two pumps, and two red rings representing the reference levels (set-points). During the simulation, users can note how water levels follow the references and how the different water flow rates vary with time. This animation is not only useful in displaying the measurements, but also in examining what is going on in the real system when faults occur. In the case of a sensor fault (a bias for example), the sensor tells that the reference is followed while this is not the case in reality. This can be easily seen on the animation.

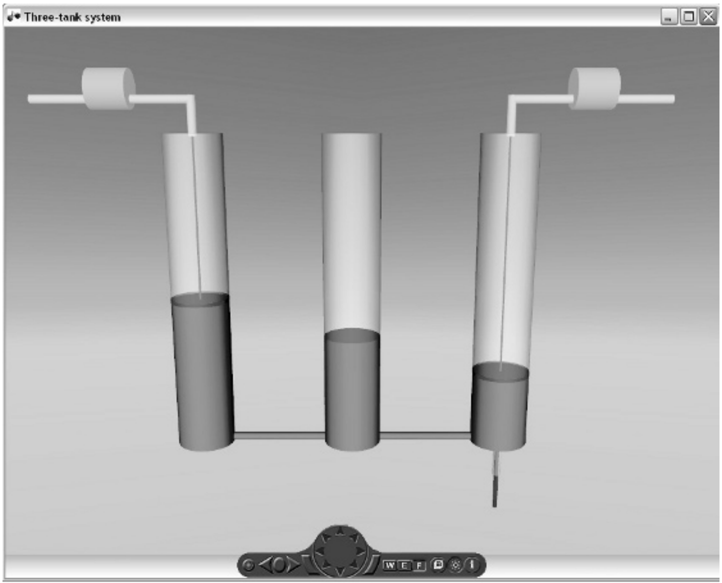

Fig. A.6. The animation window

A.4 Various Files

This simulation comes with a set of files:

- *Three_tank.mdl*: the main simulation file
- *init_para.m*: file containing the different constants initializing the model
- *tank_system.m*: the nonlinear model of the system
- *sensor_fault.m*: used to simulate sensor faults
- *actuator_fault.m*: used to simulate actuator faults
- *reference_level.mat*: a .mat file containing the reference levels
- *3tanks.wrl*: the virtual reality file used for the animation
- *tanks.bmp*: a .bmp figure used for the main page

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