PID Aeration Control

December 31, 2016

This example shows how to use a PID control in order to control aeration rate with the purpose of maintaining the DO concentration in a pond constant. The PID controller is assumed to control the aeration rate as governed by K_{La} coefficient. A very simple BOD-DO interaction model is assumed while both BOD and DO limitation effects are considered using Monod kinetics. The processes controlling DO uptake are described using the following simple process:

$$BOD + DO \xrightarrow{r_{max}\frac{BOD}{BOD+K_s}\frac{DO}{DO+K_O}} CO_2 + Biomass + OtherStuff \quad (1)$$

Here we only model BOD and DO explicitly. In the following the steps to build the model has been described:

- Start GIFMod.
- Add a pond using the top tool ribbon by clicking on the pond 
- Set the following properties for the pond:
  - **Bottom Area:** $1m^2$
  - **Initial water depth:** $1m$
- **Adding constituents:** Add two water quality constituents named "BOD" and "DO" by right-clicking on **Project Explorer→Water Quality→Constituents** and selecting **Add constituent**.
- **Adding reaction parameters:** Add the following reaction parameters using **Project Explorer→Water Quality→Reactions→Reaction parameters**.
  - r_{max}, value = 50
  - K_s, value = 10
  - K_O, value = 2
- **Adding the process:** Right-click on **Project Explorer→Water Quality→Reactions→Reaction network** and fill it out as shown in Figure (1).
- **Adding a sensor and controller** In order to simulate PID controller we need to first introduce one sensor and one controller.

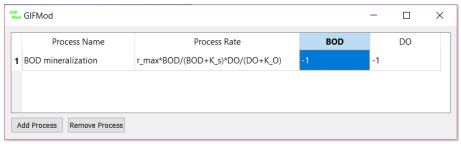

Figure 1: Reaction network for the DO control example

– Add a sensor by right-clicking on **Project Explorer→Control→Sensor** and then selecting **Add sensor** from the drop-down menu.

– Set the following properties for the newly added sensor:
- **Name:** *DO sensor*
- **Sub-type:** *Block*, (This indicates that the quantity that will be measured is at a block and not a connector.)
- **Location:** *Pond(1)* (This indicates the location where the quantity will be measured.)
- **Quantity:** *DO*, (This indicates that the sensor will measure DO concentration
- **Error Distribution:** *Normal-Additive*, (This indicates that the sensor measurement error is normal and additive.)
- **interval** *5 min*, (This indicates that the sensor measures DO concentration with 5 minutes intervals.)
- **Error Standard Deviation:** *0.1*, (This indicates that the error standard deviation of the sensor measurements is 0.1mg/L).

– Add a controller by right-clicking on **Project Explorer→Control→Controller** and then selecting **Add Controller** from the drop-down menu.

– Set the following properties for the newly added controller:
- **Name:** *Aeration Controller*
- **Type:** *PID-Manual*
- **Sensor:** *DO Sensor* (This indicates that this controller will use the measurements from the DO sensor that was previously introduced.)
- **Setpoint:** *3* (This specify the set-point value for DO, i.e. that the controller's goal is to maintain DO level at 3 mg/L).
- *kp -10* (This is the P gain coefficient for the controller.)
For now we will only use P-controller which means that we will leave the *kd* and *ki* properties empty.

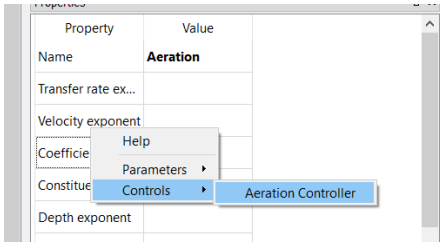

Figure 2: Assigning controller to a model property

Interval: *5 (min)*, (This indicates the time interval at which the control values are updated).
Initial Value: *10*, (This indicates the initial value of K_{La} that the simulation starts with.)
Minimum value: *0*, (This indicates the minimum value of the actuator physically possible.)
Maximum value: *1000*, (This indicates the maximum value of the actuator physically possible.)

- **Adding Aeration:** Add an "external flux object" by right-clicking on **Project Explorer**→**Water Quality**→**External Flux** and then selecting **Add External Flux** from the drop-down menu.

- Attribute the following properties to the added external flux object:
-**Name:** *Aeration*
-**Constituent:** *DO*
-**Model:** *Constant Rate*
Also right-click on the name of the property labeled as **Coefficient** and from the drop-down menu that appears select **Controls**→*Aeration Controller* (Figure 2).
Saturation: 8.5 , (This specifies a saturation DO concentration of 8.5mg/L)

- To apply the external flux item to the pond. Choose the pond and select "Aeration" for the property labeled as **External flux**.

- **Adding BOD loading to the system** Here we add an inflow of BOD to the pond. Create a text file as shown in figure (3). The value of the flow is intentionally kept low to minimize the effect of dilution.

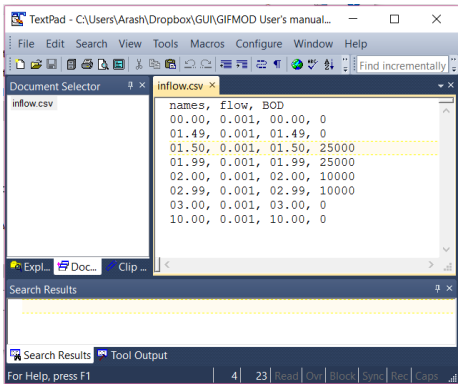

Figure 3: Inflow input file for the PID control example

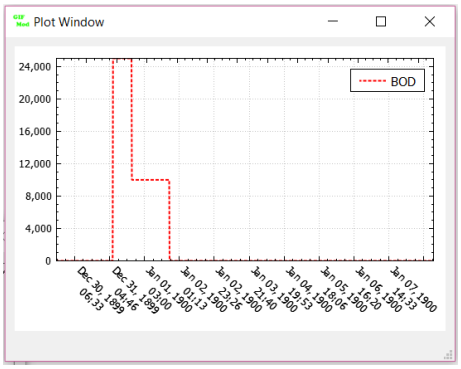

Figure 4: BOD concentration variation in the inflow

- Choose the file that was created as the value for the **Inflow time-series** property of the pond block. To visualize the BOD concentration in the inflow, right click on the file name that was selected and then click on *BOD*. The graph that will appear look like figure 4.
- **Changing the simulation period to 10 days** From the **Settings** menu change duration of the simulation by choosing **Input number** for the **Simulation End Time** and entering *10* in the input box that appears.
- **Save the project.**
- **Running the simulation:** Run the simulation by clicking on the run button  and wait until the simulation ends.

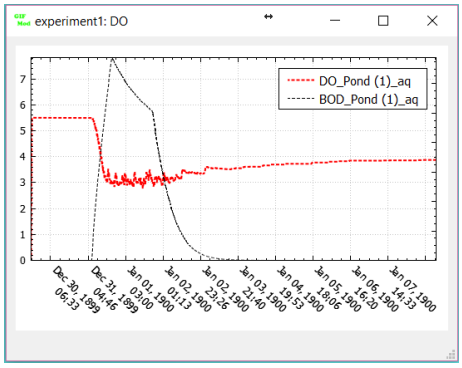

Figure 5: Temporal variation of DO and BOD in the DO control example

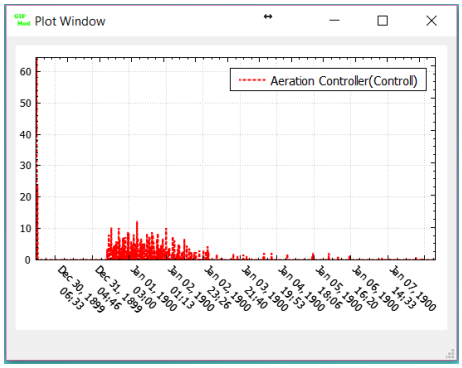

Figure 6: Temporal variation of DO and BOD in the DO control example

- **Inspecting the results:** - Right click on the pond block and from the drop-down menu select **Plot Water Quality Results→DO**. This shows the DO concentration variation with time. Do the same thing for BOD and copy and past onto the *DO* plot. The results should look like figure (5).

  - Right-click on the *Aeration Controller* object in the **Project Explorer→Control→Controller** and select **Plot Control Data**. This will show a graph representing the variation of K_{La} parameter by the controller during the course of simulation. The result should look like figure (6).

  As it can be seen there are oscillations in the actuator value. This is due partly to the noise added to the sensor reading as well as the fact that a simple P controller was used. Let's now reduce the noise and

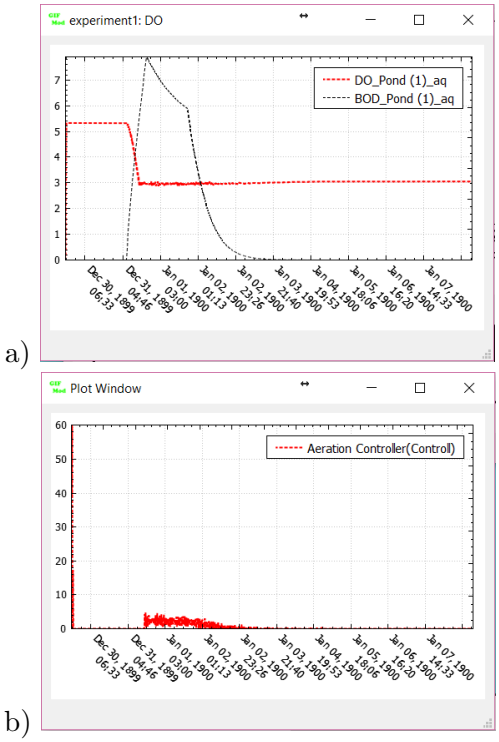

Figure 7: Temporal variation of a) DO and BOD in the DO control example and b) actuator value

change the control scheme to PID.

- Select the *DO Sensor* from the **Project Explorer→Control→Sensor** and change the value for **Error Standard Deviation** to 0.01.

- Select the *Aeration Controller Object* and type a value of 0.01 for **ki** and 0.001 for **kd**.

- Rerun the program and check DO and BOD concentration and the actuator value. They should look like Figure (7).