



Temperature control with DeltaV using MPC

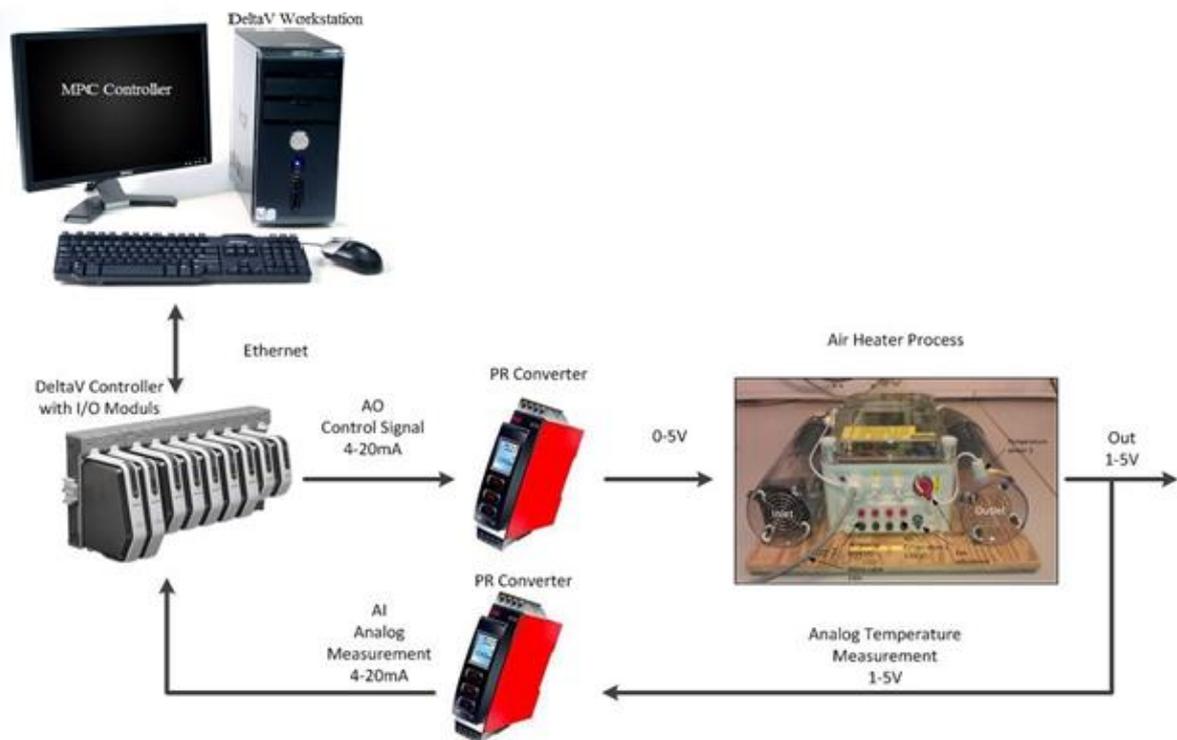


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1 INTRODUCTION

In this tutorial you will learn how to:

- Create a program to control temperature for an Air Heater using DeltaV Database Administration, -Explorer, -Control Studio and -I/O Configuration.
- Create a MPC model for an Air Heater and do validation using DeltaV Predict, -MPC Operate and -MPC Simulate.
- Create a HMI for an Air Heater using DeltaV Operate Configure.
- Control and tune the temperature performance of an Air Heater system using the MPC controller in DeltaV Operate Run.

Figure 1.1 shows the Air Heater system and describes the different components.

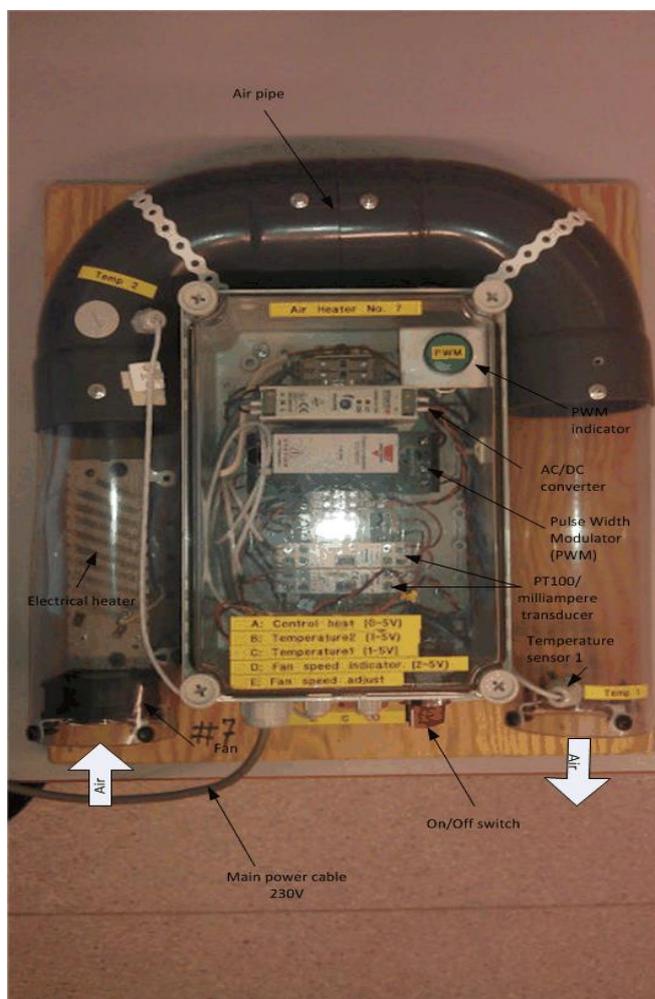


Figure 1.1 Air Heater system

Equation (1-1) is the mathematical model to the Air Heater system.

$$T_{out} \dot{=} \frac{1}{\theta_t} \{-T_{out} + [K_h u(t - \theta_d) + T_{env}]\} \quad (1-1)$$

Where:

- T_{out} is the air temperature at the tube outlet
- $u[\text{V}]$ is the control signal to the heater
- $\theta_t[\text{s}]$ is the time-constant
- $K_h[\text{deg C/V}]$ is the heater gain
- $\theta_d[\text{s}]$ is the time-delay representing air transportation and sluggishness in the heater
- T_{env} is the environmental (room) temperature

2 CREATING THE PROGRAM

In this section you will learn how to create the program used to control the temperature in the Air Heater model using DeltaV Database Administration, -Explorer, -Control Studio and -I/O Configuration.

2.1 Step 1: Creating a new database

Before we start to program in DeltaV we would like to start on an empty program where no inputs or outputs are assigned to the hardware controller. This is easily done with the use of database. To avoid adding all the hardware configurations each time there has been premade a database that is empty, but contains the hardware configurations we need.

The first thing you need to do is log on to the DeltaV station with username: **Administrator** and password: **deltav**. When this is done choose DeltaV Desktop. Click on the start-menu and Database Administration. Double click on the icon Copy Database, choose Student1 and write your name in the Copy to field. Figure 2.1 is showing you how it should look like.

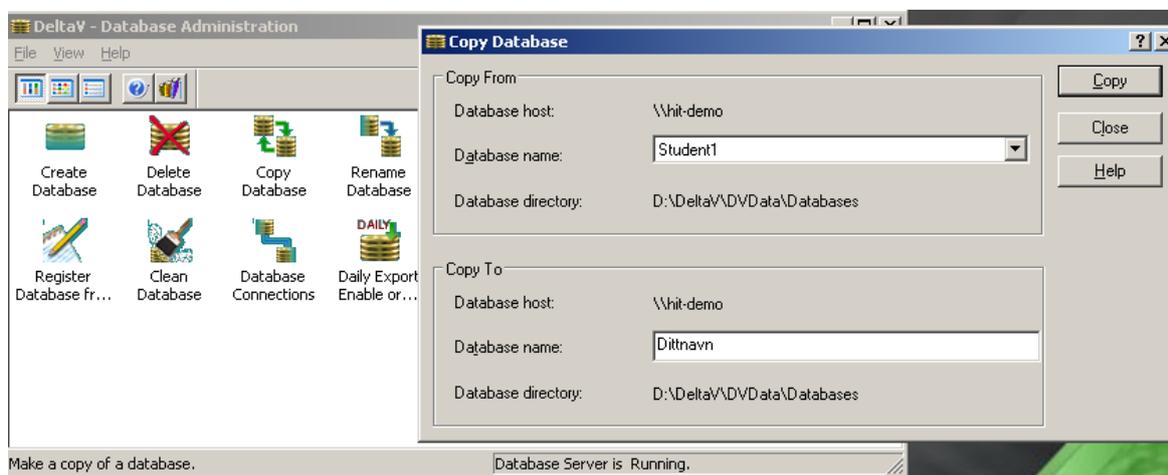


Figure 2.1 How to set up your database using Database Administration.

Now set the database you just made active with the Set Active Database button. This button is found in the Database Administration window. Select the database you just made and press ok. Your database is now created and active.

2.2 Step 2: Creating a MPC control module in an area

Go back to the start menu and run DeltaV Explorer.

Right click on “Control Strategies” and select “New Area”. Name your new Area AIRHEATER.

We now have a new area called AIRHEATER. Now we just need to configure a control module.

Grab a MPC module from the library by choosing Library → Module Templates → Analog Control. Select the MPC_LOOP and drag and drop it down to your Area called AIRHEATER, see Figure 2.2.

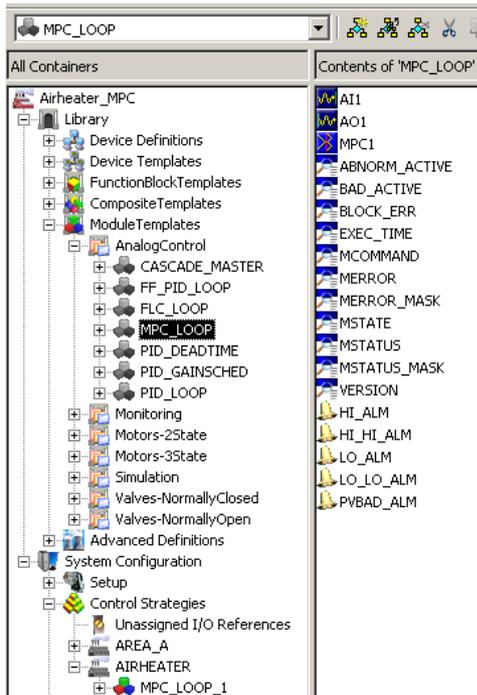


Figure 2.2 Control module MPC_LOOP from library.

You will find the MPC loop you just added in your AIRHEATER area.

2.3 Step 3: Connecting I/O to the MPC_LOOP

Right click the MPC_LOOP and choose open with Control Studio, see Figure 2.3.

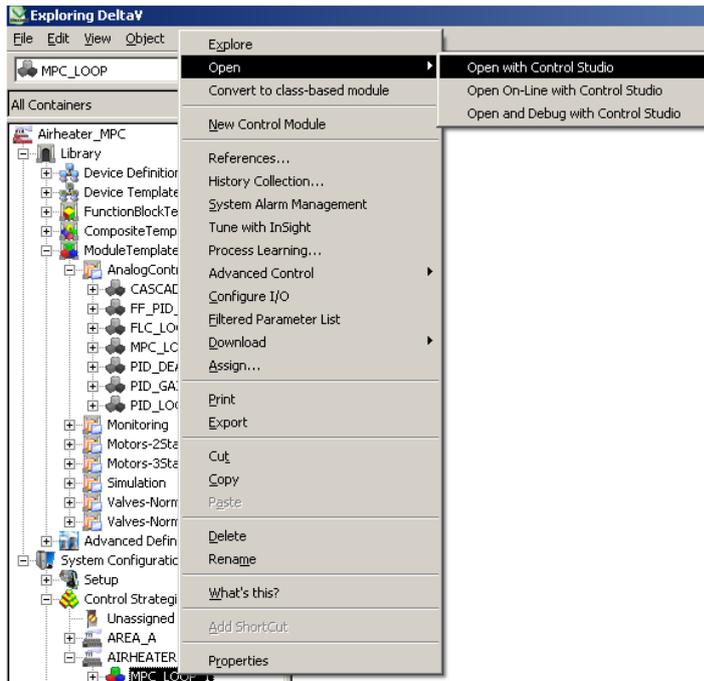


Figure 2.3 Open control module in Control Studio.

From Control Studio we see that we have a MPC block. In addition we have one analog in block and one analog out block, for our case being the controlled variable (CV) for the temperature and manipulated variable (MV) to the heater respectively. These IO's need to be assigned to the hardware controller and IO modules.

Right click the AI block and choose Assign I/O → To Signal Tag. An IO_IN Properties window will then appear, see Figure 2.4.

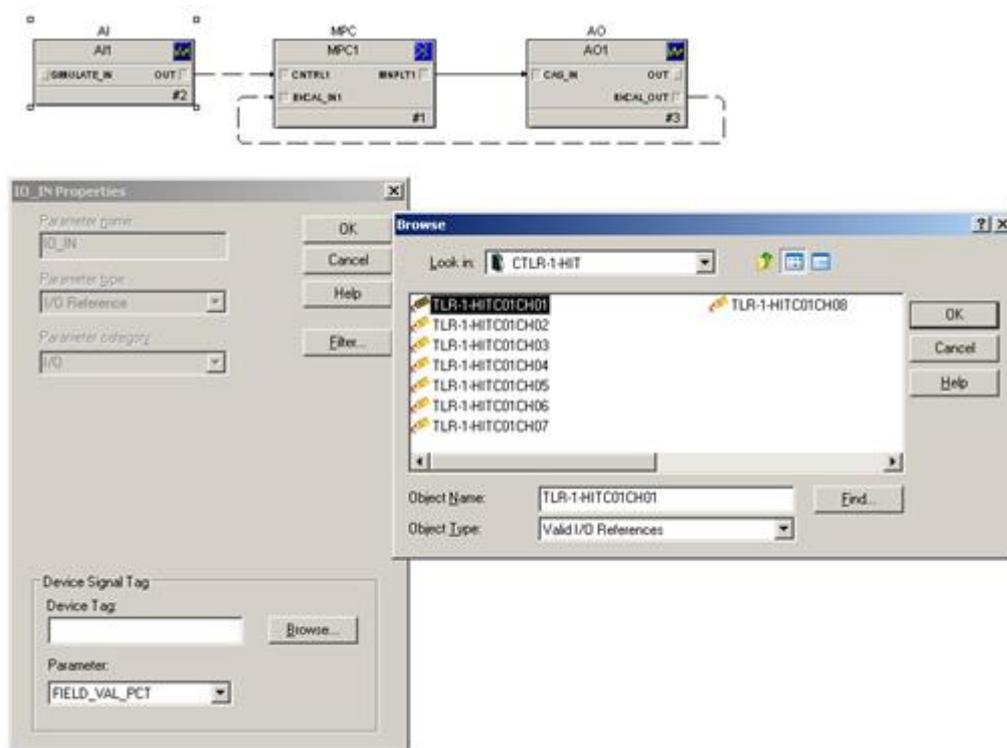


Figure 2.4 Assign I/O to Signal Tag.

Browse Device Tag, double click on CTRL and choose TLR-1-HITC01CH01. This is the first IN on the analog input module (CH01). Press ok until you are back to the MPC loop.

Now right click the AO block and choose Assign I/O → To Signal Tag, and double click IO_OUT. Browse Device Tag, double click on CTRL and choose TLR-1-HITC02CH01. This is the first OUT on the analog out module (CH01). Press OK and then close. We have now connected the I/O to the MPC controller.

In addition, for MPC training purposes, we will also include constraints (AV) on the temperature and disturbance (DV), e.g. the environment temperature. These are typical variables in a process and often affect the performance. To include them we need to add these parameters to the MPC block.

Right click the MPC block and choose Extensible Parameters. Then double click on NOF_DSTRB and add 1 to the Modify Extensible Parameter - NOF_DSTRB, see Figure 2.5. Click OK and add 1 to the NOF_CONSTR. Again click OK and Yes until you are back to the MPC loop.

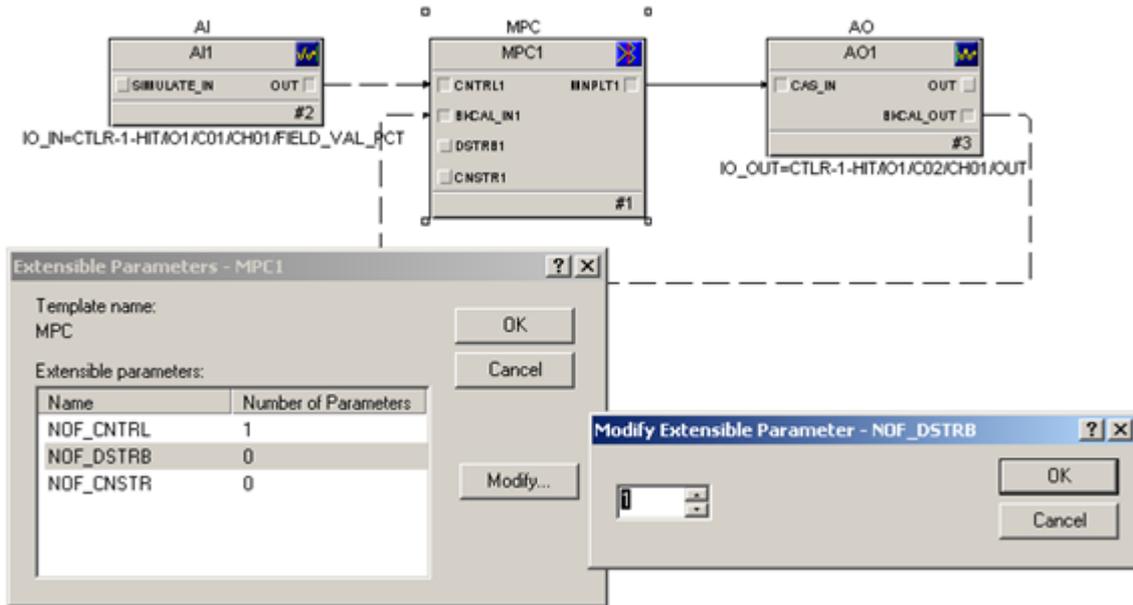


Figure 2.5 Adding disturbance and constraint variables.

Next step is to set the properties for the parameters.

Right click the MPC block and choose properties. A MPC1 Properties window appears for all the parameters. Double click the first row under the Controlled tab and type e.g. a tag-name in the Description field, see Figure 2.6. Then press OK.

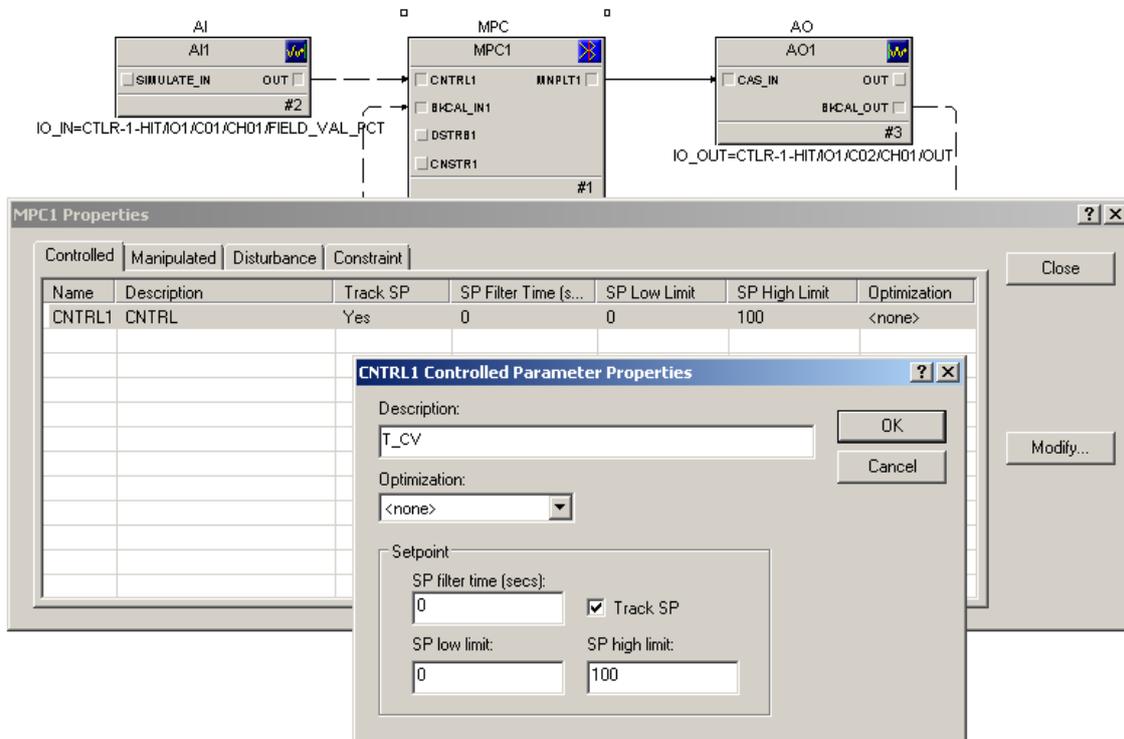


Figure 2.6 Set parameter properties for the MPC variables.

Do the same with the other parameters. For the Constraint parameter, also include CNTRL1 under Related CV, and add a Low limit and High Limit being 20°- and 40° Celsius respectively. When finished close the property window.

Since the temperature is the constrained parameter then we need to connect the AI block OUT to the CNSTR1 input on the MPC block, see Figure 2.7.

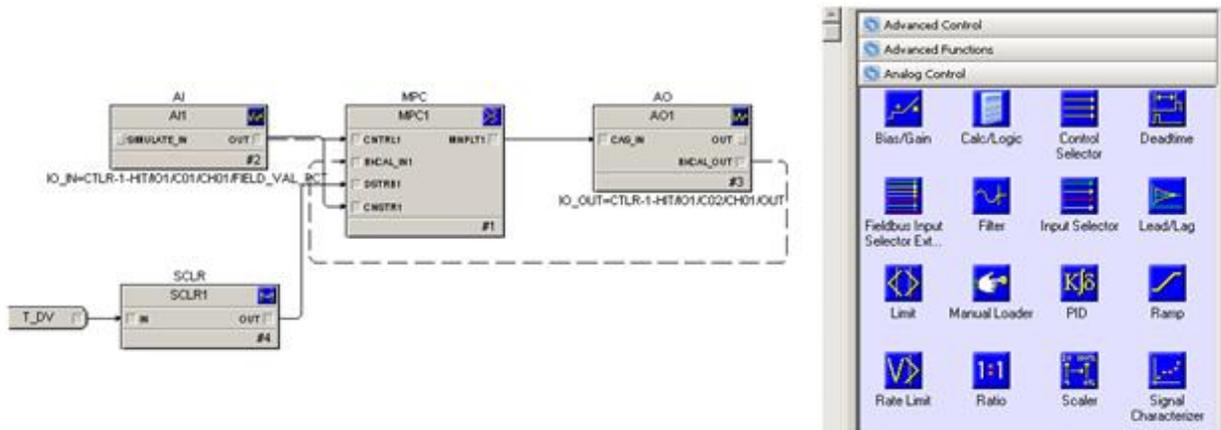


Figure 2.7 Connecting the constraint and disturbance to the MPC block.

Since we don't have any measured disturbance we only add a constant value using an Internal Read Parameter found under Special Items tab. Drag and drop this into the MPC loop, double click it and provide it a Parameter name and Value, e.g. 20 ° Celsius.

Since the MPC block requires an OUT_SCALE as an input then we also need to add a Scaler block found under the Analog Control tab. Connect the Read Parameter and Scaler block to the MPC block as seen in Figure 2.7.

2.4 Step 4: Activate I/O configuration

Now we need to activate the I/O. This is done in Exploring DeltaV. Choose applications → I/O Configuration, see Figure 2.8.

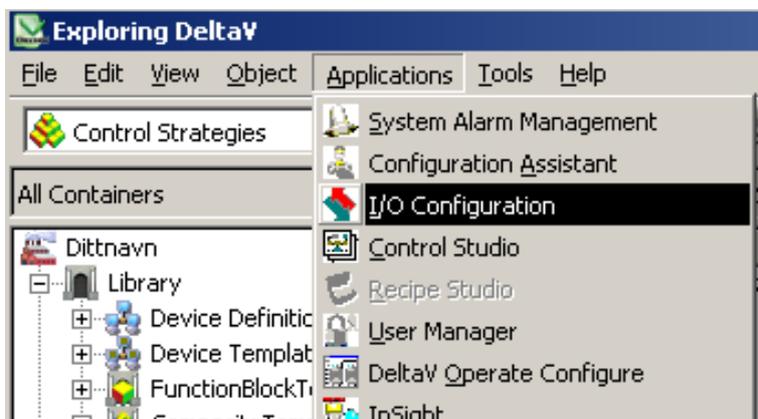


Figure 2.8 I/O Configuration from Exploring DeltaV.

Here we can see all the modules that are connected to the station, see Figure 2.9. Choose C01 and right click the CH01 and enable it. Do the same with C02 → CH01. CH01 under C01 and C02 should now be activated.

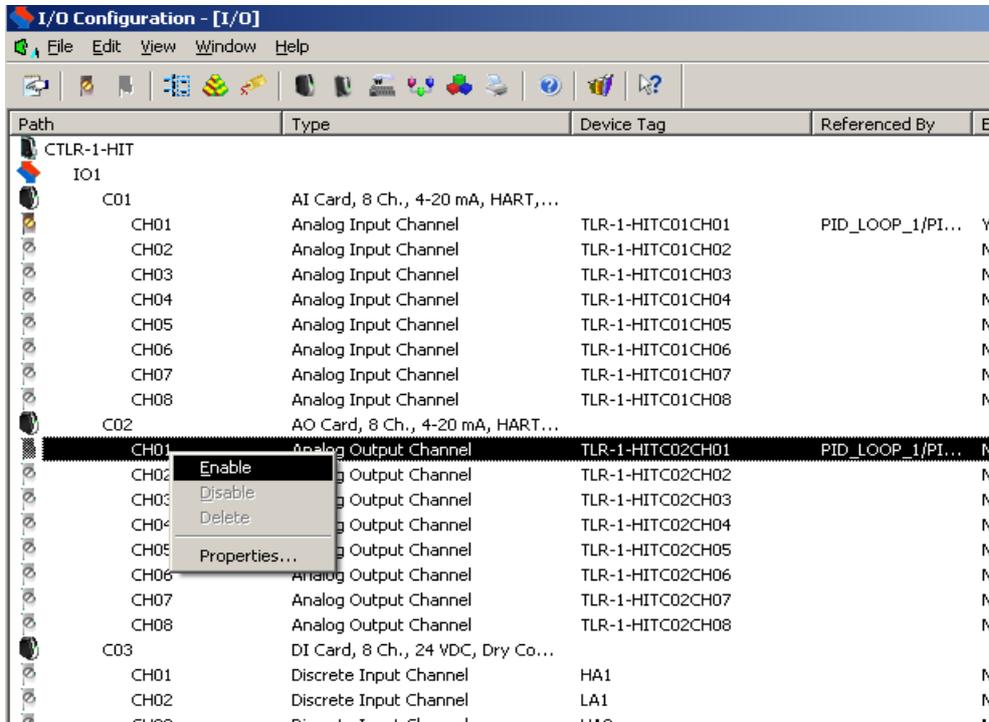


Figure 2.9 Activating I/O configuration.

2.5 Step 5: Assigning area to alarm and events and continuous historian

Now we need to return to Control Studio and download our program. This is done by pressing the arrow called Download, see Figure 2.10. You will then get a question box that asks if you want to assign the module. Press yes, choose CTLR-1-HIT, press Ok, and yes on the Control Studio box. After that, press ok and yes on everything until you have downloaded. If you get any error messages just press Ok and proceed.

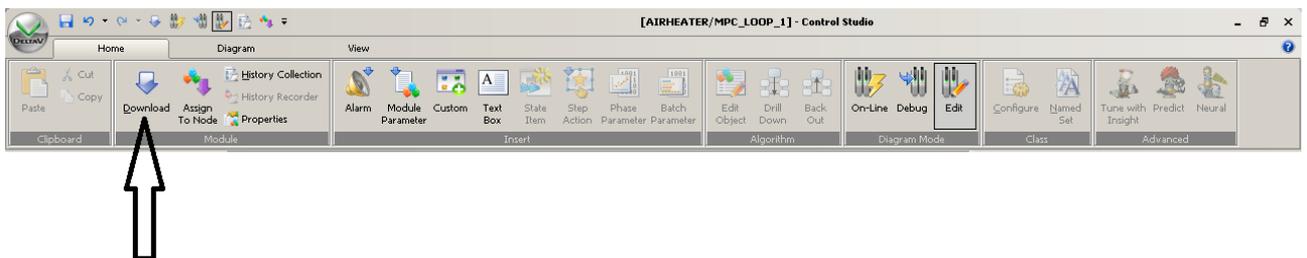


Figure 2.10 Downloading the program in Control Studio.

The control module and I/O is now connected to the hardware module. For alarms and events and data collecting to work we need to connect this to the history module that's pre-made in DeltaV.

Go to Exploring DeltaV, choose your area AIRHEATER under Control Strategies and drag and drop it down to Alarms And Events, see Figure 2.11. Also, since we need to collect input/output data to create a model as in section 3, then drag and drop the area to Continuous Historian as well.

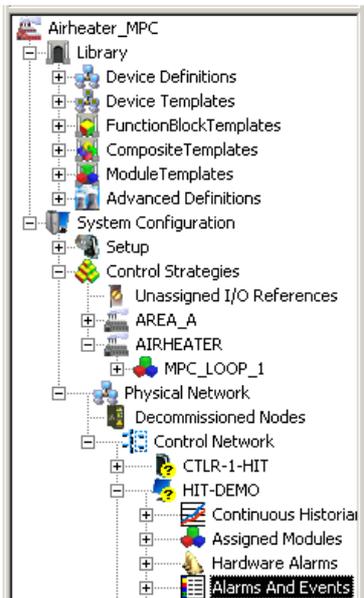


Figure 2.11 Assigning area to Alarms and Events and Continuous Historian.

2.6 Step 6: Downloading the program

The last thing that needs to be done before we start making the model is to make sure everything is downloaded. Right click on Physical network and choose Download physical network. Whenever there has accrued changes in the physical network this need to be downloaded again. If minor changes, e.g. setup data, then instead of downloading the whole physical network there could be more appropriate to right click the physical network and download Setup Data, see Figure 2.12.

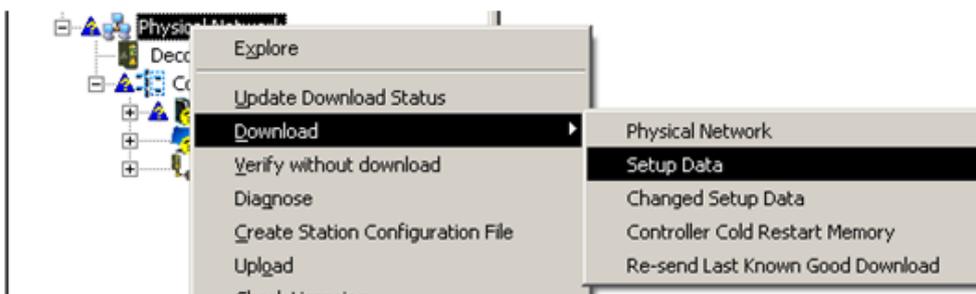


Figure 2.12 Downloading the program in Explorer.

Also, every time you make a change to the program in Control Studio this need to be saved and downloaded again as well, see Figure 2.10.

After the downloading, the program should now be ready.

3 MODELLING AND VALIDATION

In this section we will learn how to create a MPC model for the MPC controller and do validation of the model, using DeltaV Predict, -MPC Operate and MPC Simulate.

3.1 Step 1: Connecting the Air Heater process

Since the MPC block has an inbuilt feature making a model from input/output system identification, we first need to physically connect the Air Heater to DeltaV. Figure 3.1 shows a sketch of how the model is to be wired.

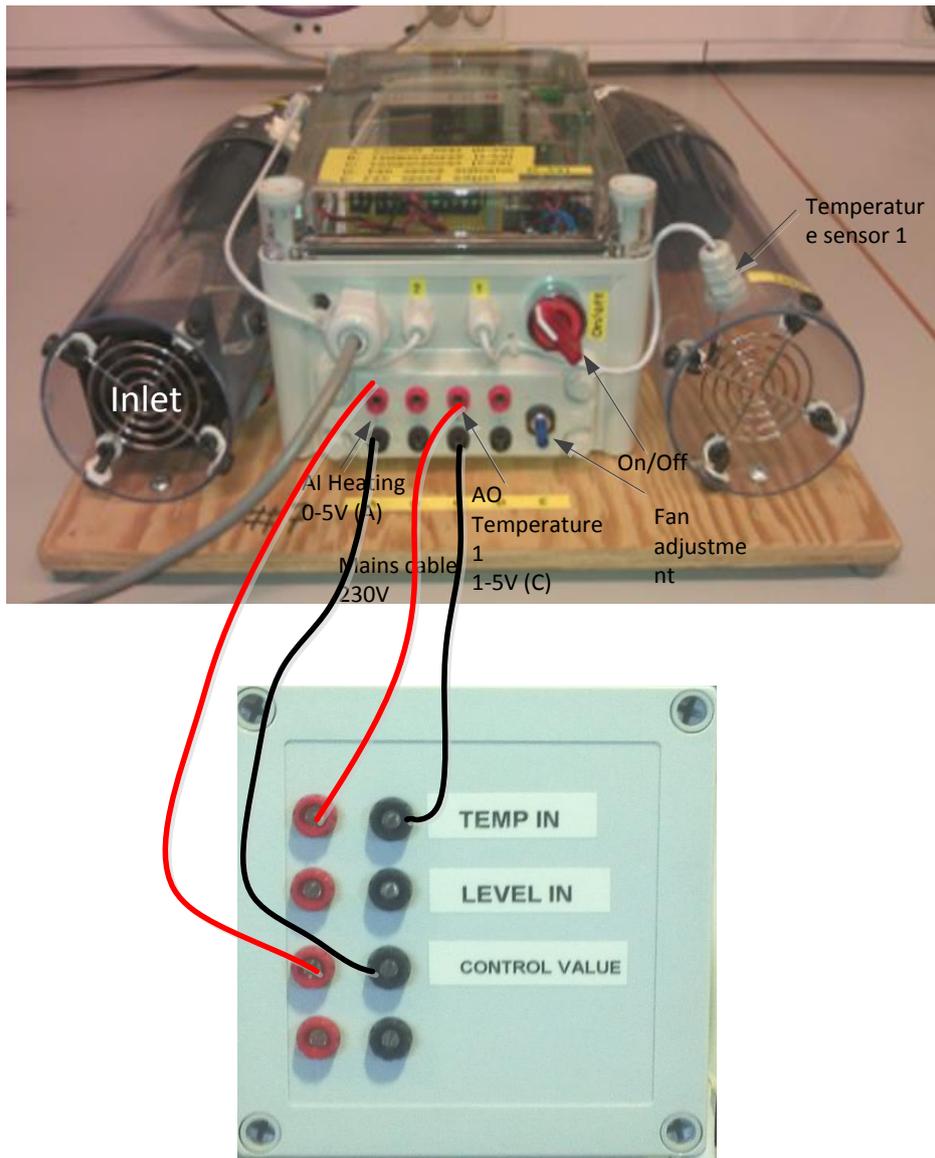


Figure 3.1 Connecting the Air Heater model to the DeltaV system.

3.2 Step 2: Creating the MPC model

The application where we create the model is called DeltaV Predict. Go to the MPC_LOOP_1 in Control Studio and right click the MPC block and choose Advanced Control → Predict, see Figure 3.2.

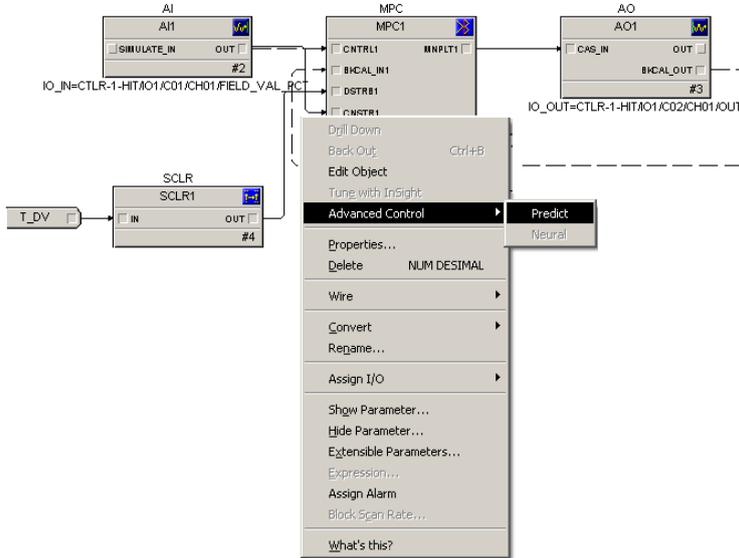


Figure 3.2 Opening DeltaV Predict application.

The application then appears similar to as seen in Figure 3.3.

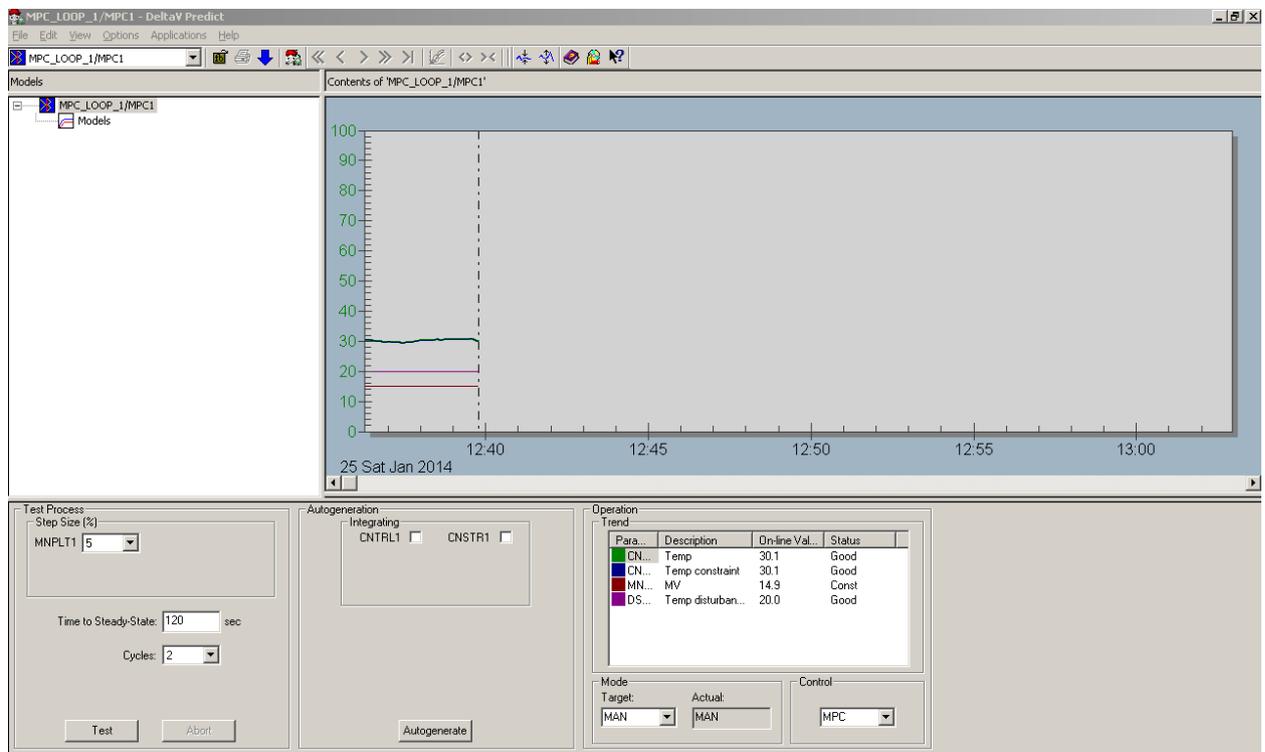


Figure 3.3 DeltaV Predict application.

Start by going to Options in the application menu and chose Expert. This gives additional features which we want to use.

From the figure, the upper left part is where the model hierarchy is found. On the upper right is a trending picture which shows the MPC parameters configured, and chosen by double-clicking the respective parameter under Operation and Trend. The lower left part is for modelling configuration and the lower middle is for model generation.

Before we start modelling we want to find a preferred operational point, e.g. around 30° Celsius. Click Application in the application menu and choose MPC Operate.

A new application appears, and with the physical process connected we have the choice to run the MPC control either in manual or in auto mode. Since we do not have a model yet only the manual mode will work.

On the bottom in the MPC Operate application all the MPC parameters are shown.

Start by marking all the parameter check boxes in the bottom of the figure. Click on the manipulated variable (MV). At the left side a slide-bar for the parameter is then shown. Adjust the slide-bar so that the temperature gets steady and about 30° Celsius, as seen in Figure 3.4.

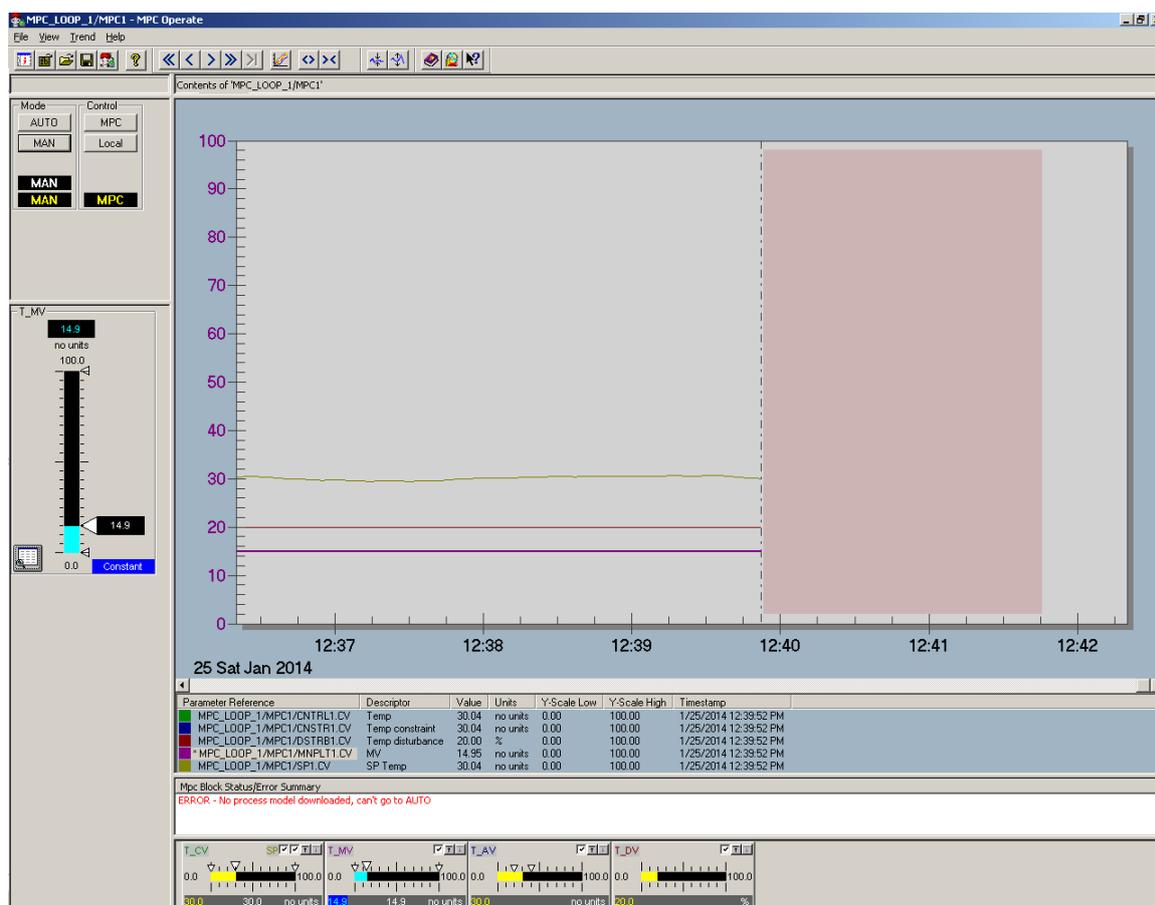


Figure 3.4 Adjusting temperature manually in MPC Operate.

When you have the operational point steady around 30° Celcius, go back to the DeltaV Predict application and set the Test Process parameters Step Size to 5 %, Time to Steady-State to 120 s and Cycles to 2, as seen in Figure 3.5. Then press the Test button.

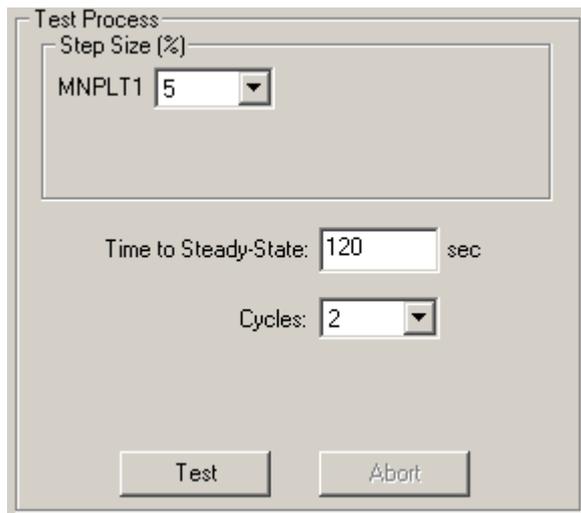


Figure 3.5 Test Process parameters.

The application is now starting to collect input/output data to create the model. For the above Test Process settings it will take some time to finish this test process. This will be indicated by a blue progression bar under Test Process.

When the test process is finished this is indicated by the green area layered on the period of data collection seen on the trend picture and as in Figure 3.6.

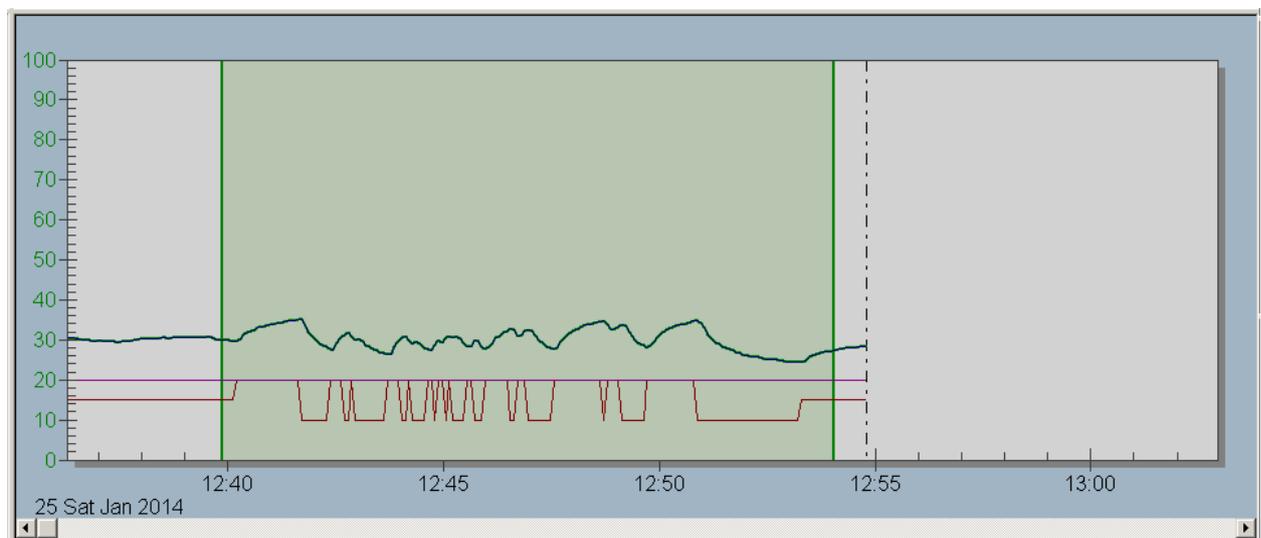


Figure 3.6 Period of data collection.

Click the Autogenerate button to generate the model.

The model will then be generated and all step responses for the inputs and outputs can be seen as in Figure 3.7. The step responses may be investigated in further details by choosing the different input/output relations in the model hierarchy under Models.

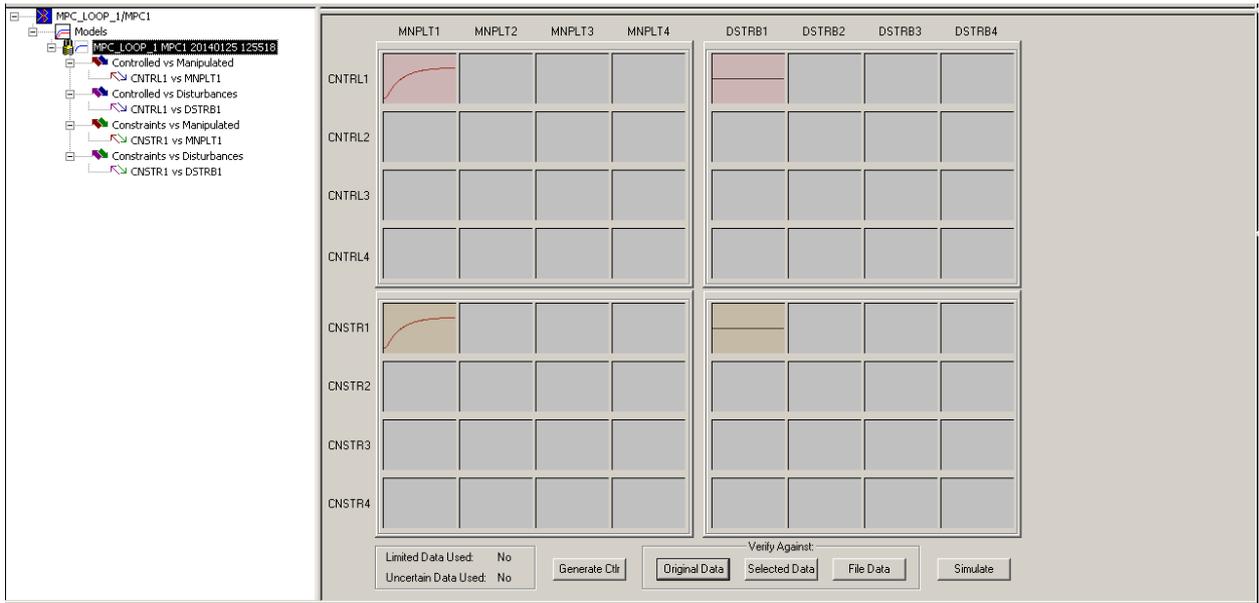


Figure 3.7 Generated model and step responses.

3.3 Step 3: Verification of the MPC model

To verify the model we first want to e.g. check the actual measurement vs the predicted. Click the Original Data button seen in Figure 3.7 (be sure to have chosen Expert under Options to get these buttons available). A Model Verification window, as in Figure 3.8, will then appear. This may give a good indication of how the model is, preferable having smallest possible deviation, and smallest possible Squared Error and R-Squared. The graph in Figure 3.8 seem to show a fairly good model. By choosing Actual vs. Predicted the corresponding best fit line can also be investigated.

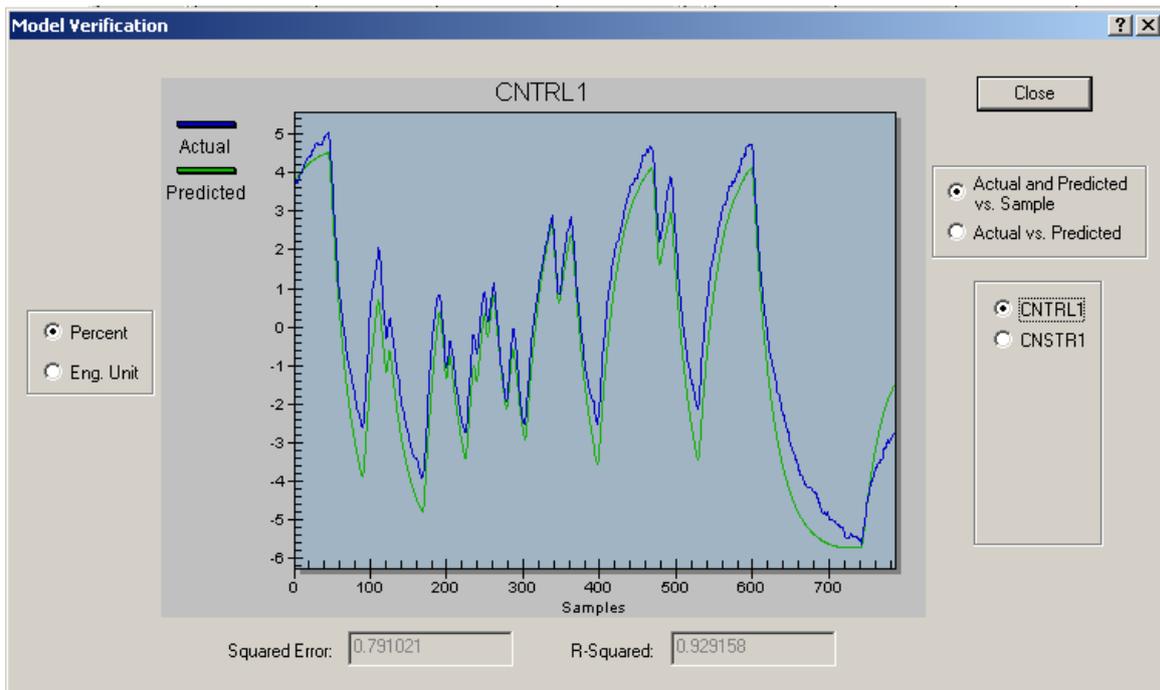


Figure 3.8 Model verification of the actual measurement vs the predicted.

To possibly improve the model, e.g. remove uncertain data, we may adjust the period of data collection. However, note that doing this may also worsen your model, and should be done with cautiousness.

If you want to adjust the period of data collection, then click on and adjust the edges of the green layered area, see Figure 3.6. For more information about doing this, see f.ex. the “Level control with DeltaV using MPC” tutorial.

Once you are satisfied that the model fairly reflects the process dynamics, select Generate Ctrlr to update the MPC configuration for the new model.

When the control is generated from a selected model, control parameters used to generate the control are displayed and shown in Figure 3.9. Here we can somewhat tune the controller. Normally only the Penalty On Move (PM) and Penalty On Error (PE) should be adjusted. In short:

- Increase the PM value (in fifty percent increments) for any manipulated variables that are moving more than the acceptable limits.
- Decrease the PM for manipulated variables that are not responsive. It is recommended that they do not go below the default minimum PM values (the PM min = 3).
- Increase or decrease the PE, depending on process control requirements.

We might want to wait to do this kind of tuning since we have not tested the controller yet. However, normally the default values give a good performance.

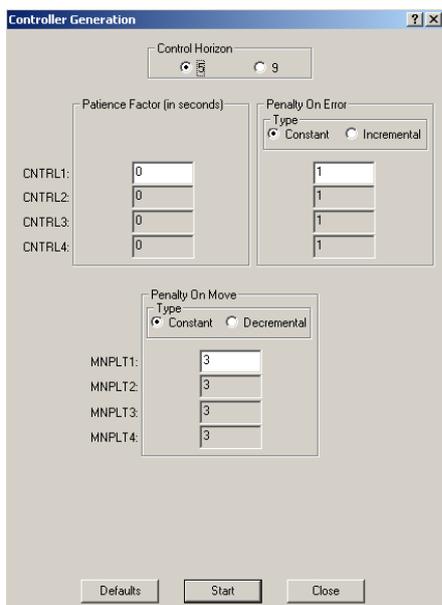


Figure 3.9 Controller generation and tuning parameters.

Now, press Start to continue, and then Close after the progression bar has finished.

To download the MPC controller click the blue arrow in the DeltaV Predict application as seen in Figure 3.10.



Figure 3.10 Downloading the MPC controller.

3.4 Step 4: Validation of the MPC controller

Next step is to simulate the performance of the generated controller. This can be done in the MPC Simulate application.

Press the Simulate button, seen in Figure 3.7, to open the application. Figure 3.11 shows the simulation environment.

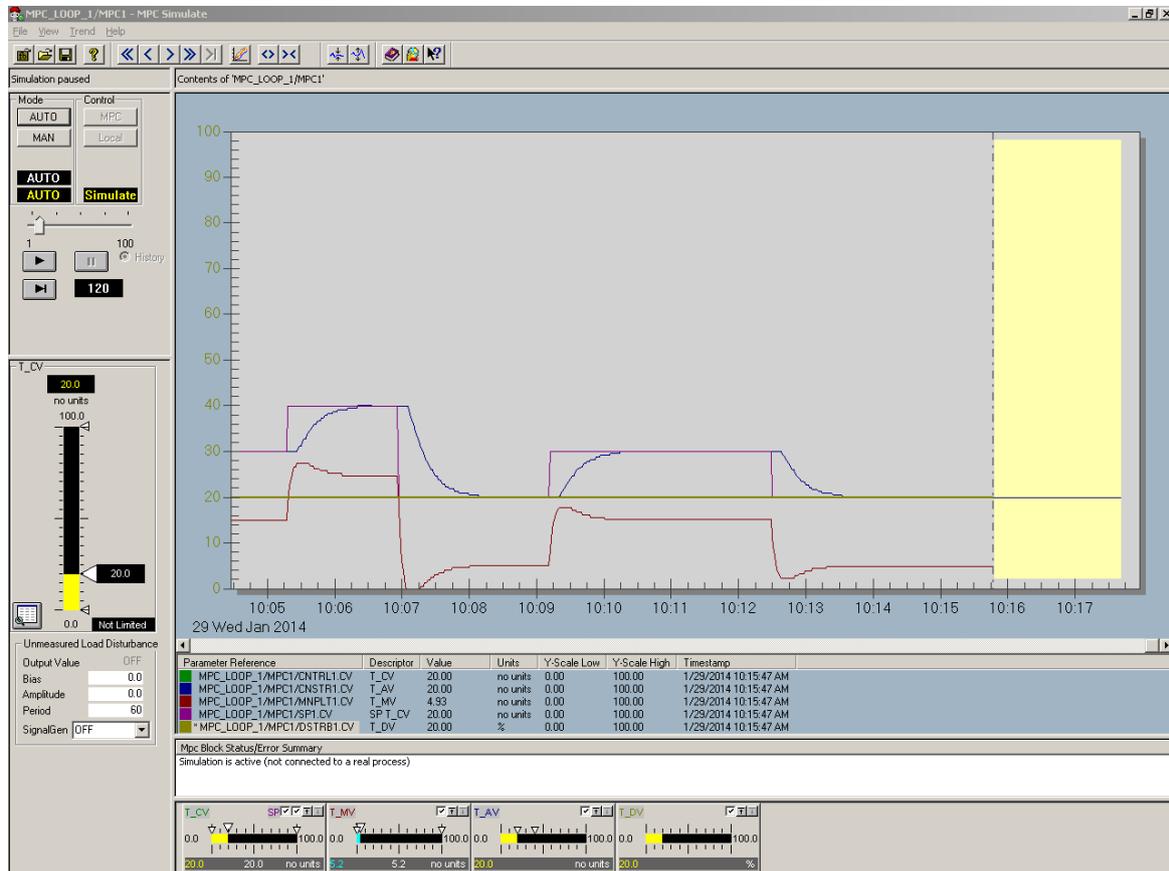


Figure 3.11 Simulation in MPC Simulate.

Start by marking all the parameter check boxes in the bottom of the figure.

Then select AUTO under Mode, and start the simulation by clicking the play button.

Now you can adjust the controlled variable using the slide-bar to the left and see the simulation performance of the MPC controller. If you want the simulation to go faster you can do so by adjusting the horizontal slide-bar above the play button.

If the performance is satisfactory then you can test it on the Air Heater, e.g. using the MPC Operate application in the same manner as in the simulation environment, and see if the response is similar. Figure 3.11 and Figure 3.12 shows that the response is fairly similar.

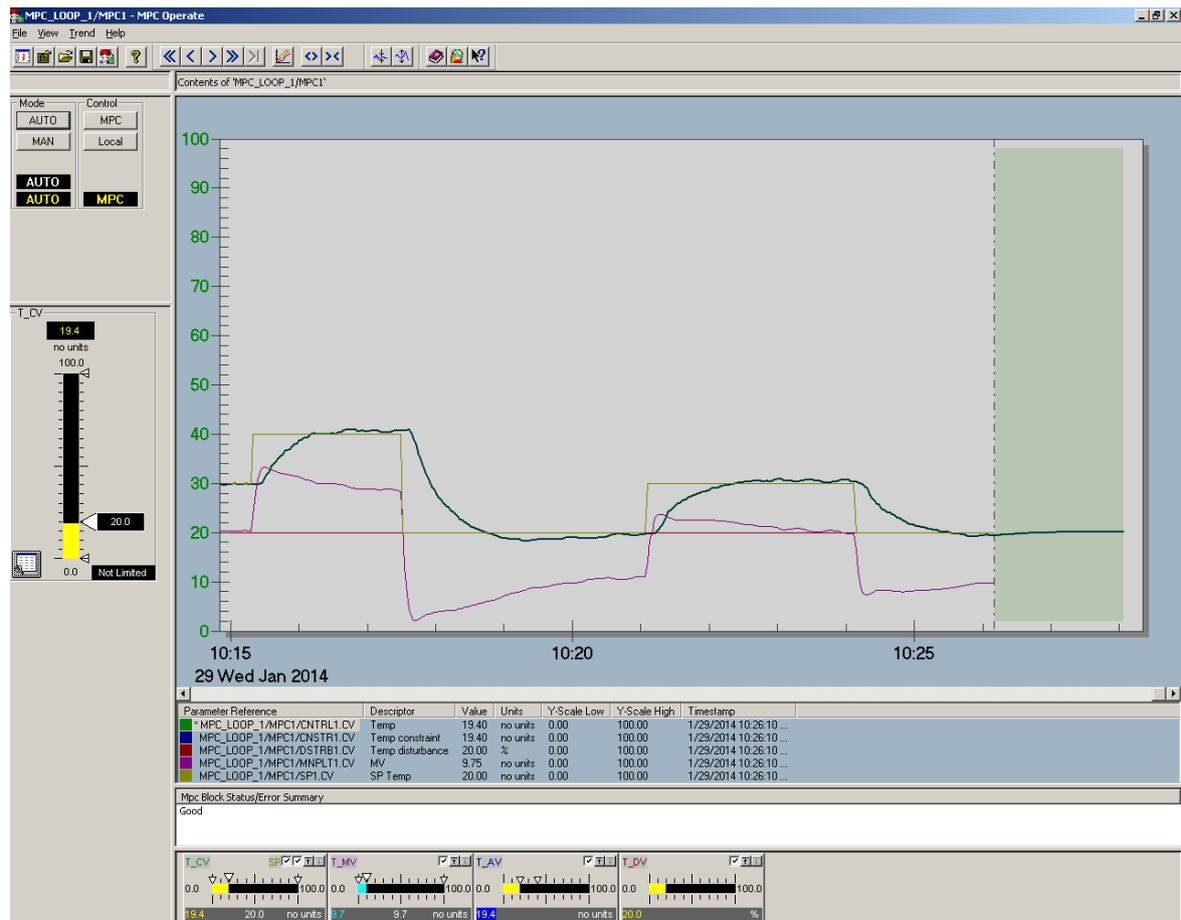


Figure 3.12 Testing the MPC controller in MPC Operate.

Note! If your model or simulations doesn't look to good it could be a good idea doing the test process again and possible change the test process parameters, e.g. try to extend the period of testing to get more samples.

Mark and delete all the text on the picture so you get a blank picture like as seen in Figure 4.3.

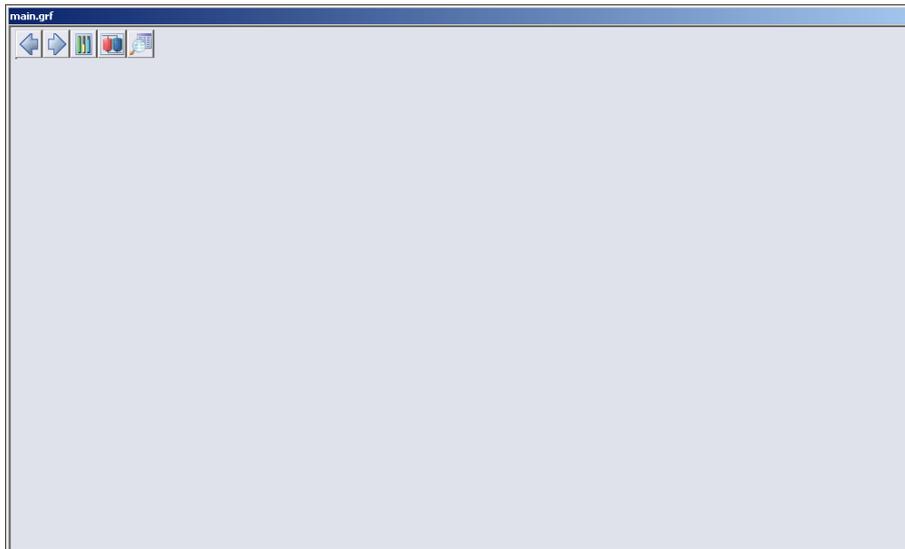


Figure 4.3 Creating blank picture.

Next, go to File in the menu and choose Save As. Save the picture with yourname.grf.

4.2 Step 2: Creating picture interface using dynamos

Now we can begin creating our interface. In the left column you can find many premade dynamo components. We need a pipe, a fan, a temperature measure and a heating element.

Choose Dynamo Sets → Blowers. Drag and drop a suitable fan onto the drawing board, see Figure 4.4.

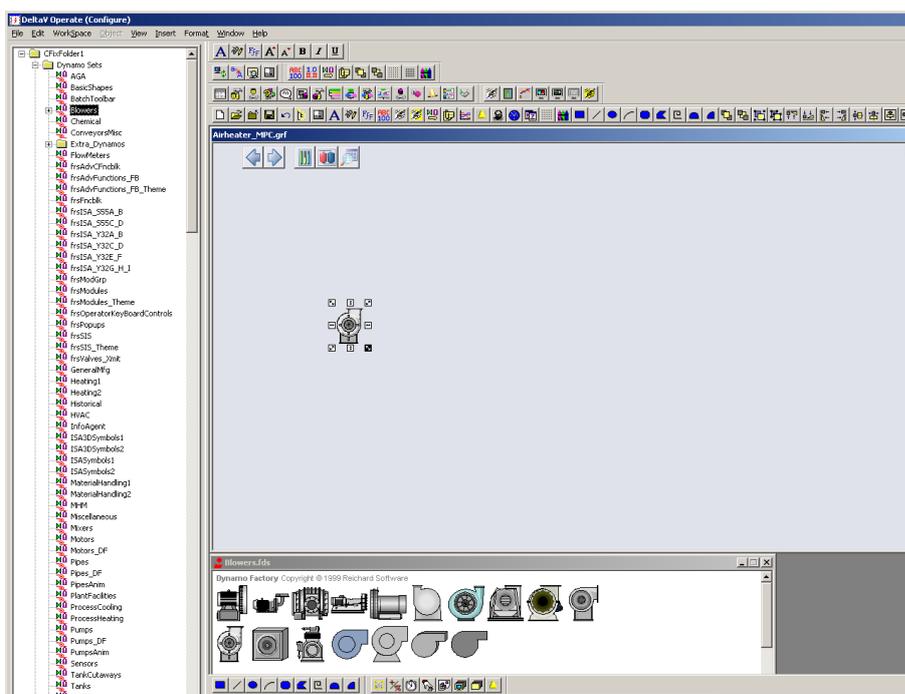


Figure 4.4 Adding a fan to the picture interface.

Then we choose Pipes_DF from the Dynamo Sets. Drag and drop suitable pipes and adjust them so that it looks similar to the Air Heater model, see Figure 4.5.

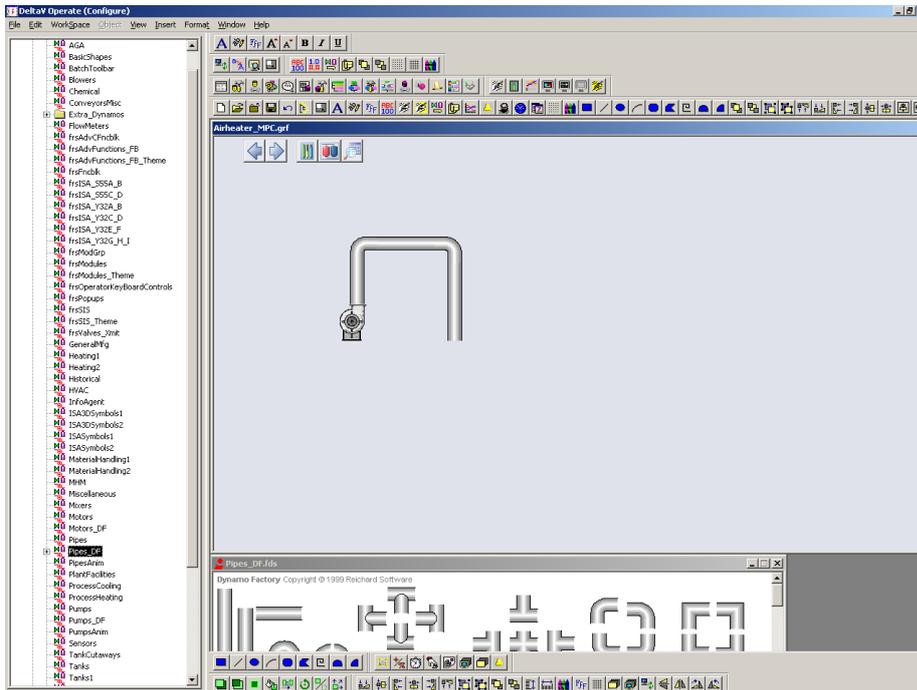


Figure 4.5 Adding pipes to the picture interface.

Now, drag and drop a sensor to show where the temperature measurement is located. This can be found under Sensors in the Dynamo Sets, see Figure 4.6.

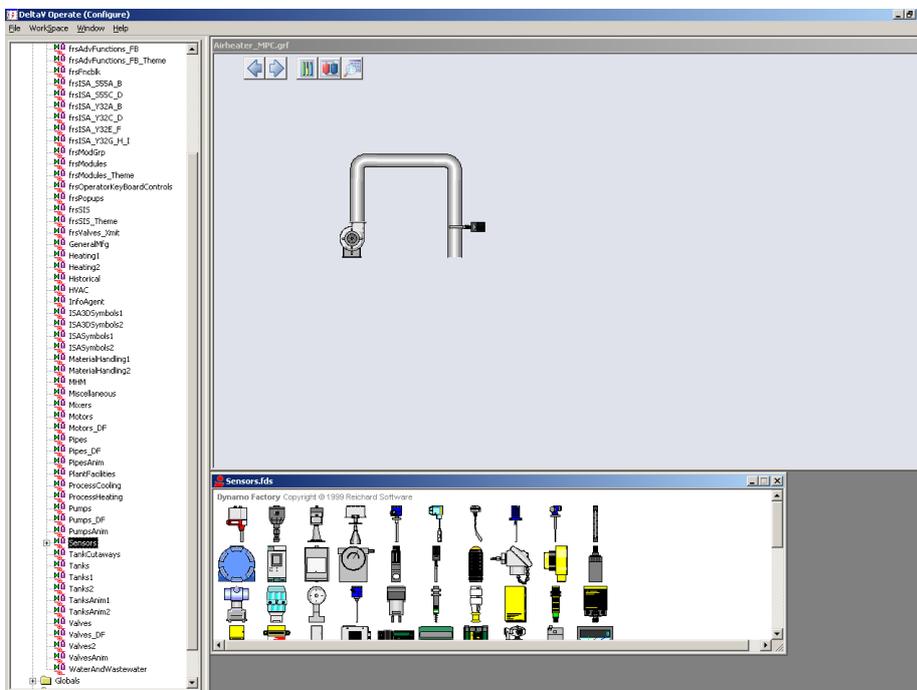


Figure 4.6 Adding temperature sensor to the picture interface.

Finally, use a heating element from GeneralMfg in the Dynamo Sets, see Figure 4.6.

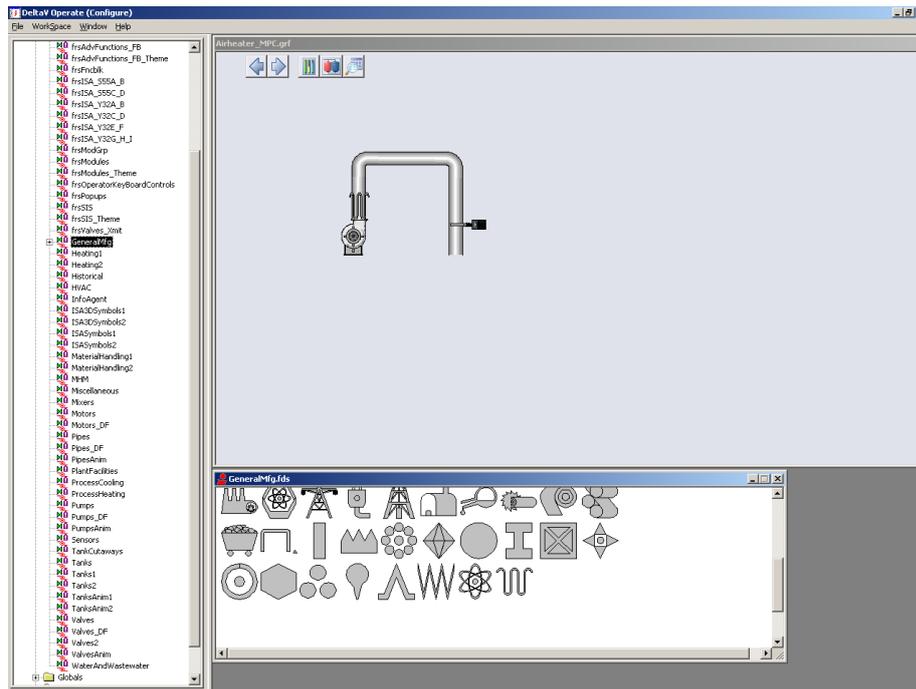


Figure 4.7 Adding a heating element to the picture interface.

4.3 Step 3: Creating names and datalinks

Now we need to create datalinks for some variables. Let's make one for the CV, SP and MV. Here we use the tool bar above the picture. Press the big A and write the different variable names we need, see Figure 4.8. These variables need to be connected to our MPC controller.

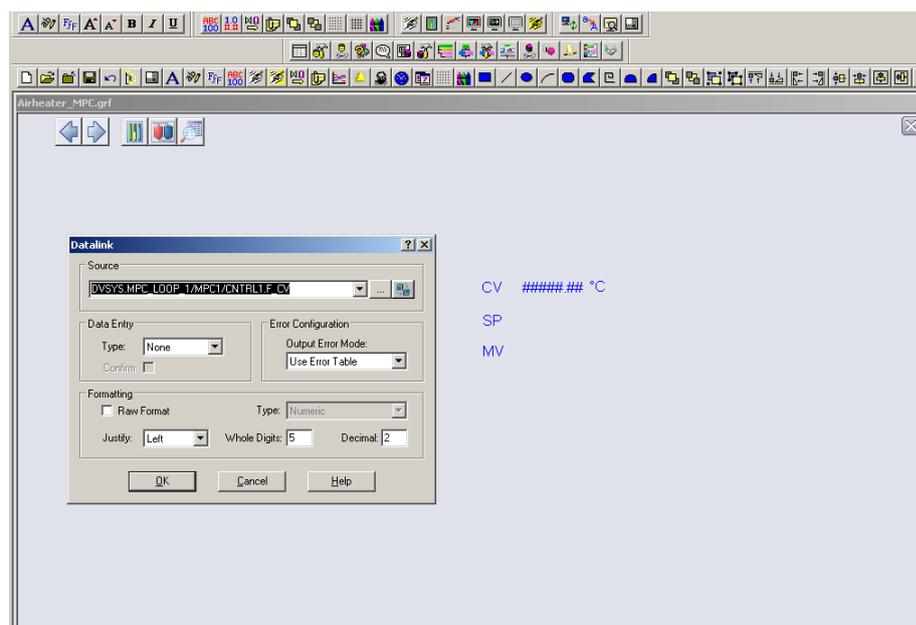


Figure 4.8 Creating names and datalinks for the variables.

Let's start with the datalink for the CV. Press "ABC100" that you also can find in the tool bar. Then press the  button. Browse DeltaV Control Parameters → AIRHEATER → MPC_LOOP_1 → MPC1 → CNTRL1 → CV. Then press ok until you get back the Datalink box. Here, change Type to Numeric and press ok. Place the variable next to CV, see Figure 4.8.

Do exactly the same for SP, but choose SP1 instead of CNTRL1, and in Datalink box we need to choose in-place on the data entry to be allowed to change the variable. Place it next to SP.

The only datalink left is the MV. Do exactly the same procedure as we did with SP, except that we choose MNPLT1. Place the variable next to MV.

4.4 Step 4: Creating faceplate- and MPC operator interface buttons

First we will make a button to open a faceplate to our controller when the program is running. First create the text Open Faceplate, then choose a circle from the toolbox and place it next to the text, see Figure 4.9.

Double click the circle. Under command make sure to activate click.

Double click on DeltaV Open Faceplate, press the  button and choose Browse DeltaV Control Parameters. Then choose AIRHEATER → MPC_LOOP_1 → MPC1 → CNTRL1 → CV and press OK until you are back to your picture.

Figure 4.9 is showing you how to configure the button to open the faceplate.

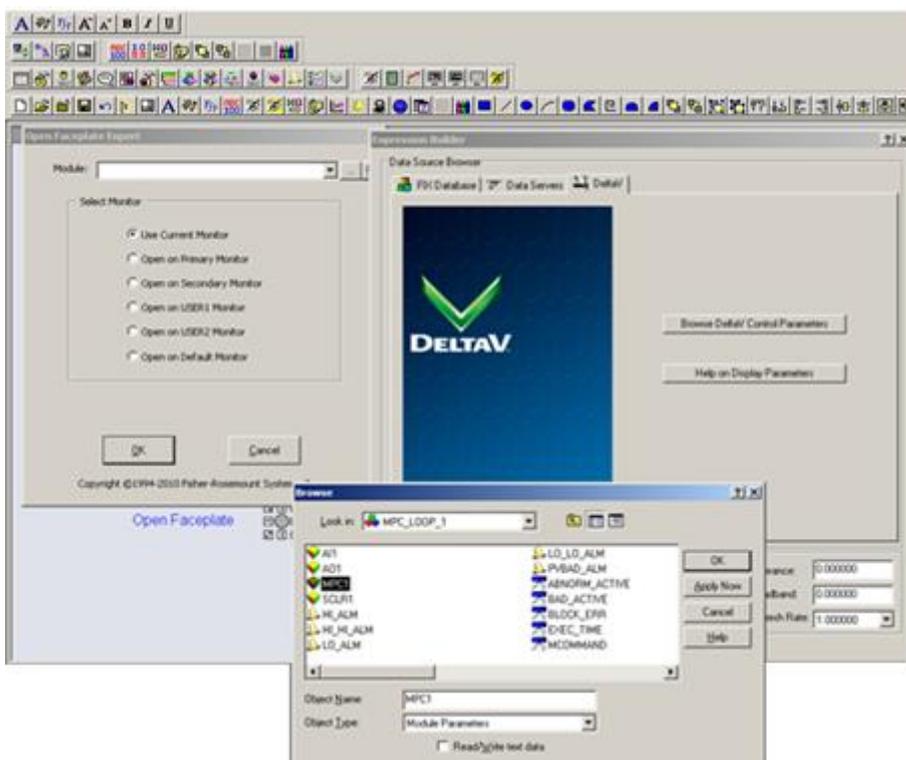


Figure 4.9 Creating a button to open the MPC-controller faceplate.

We have now made it possible to open a faceplate to our controller. Also, we want to create a button that opens the MPC Operate interface. Choose Dynamo Sets and double click frsAdvCFncblk. Then drag and drop MPCOperMode into the picture, see Figure 4.10.

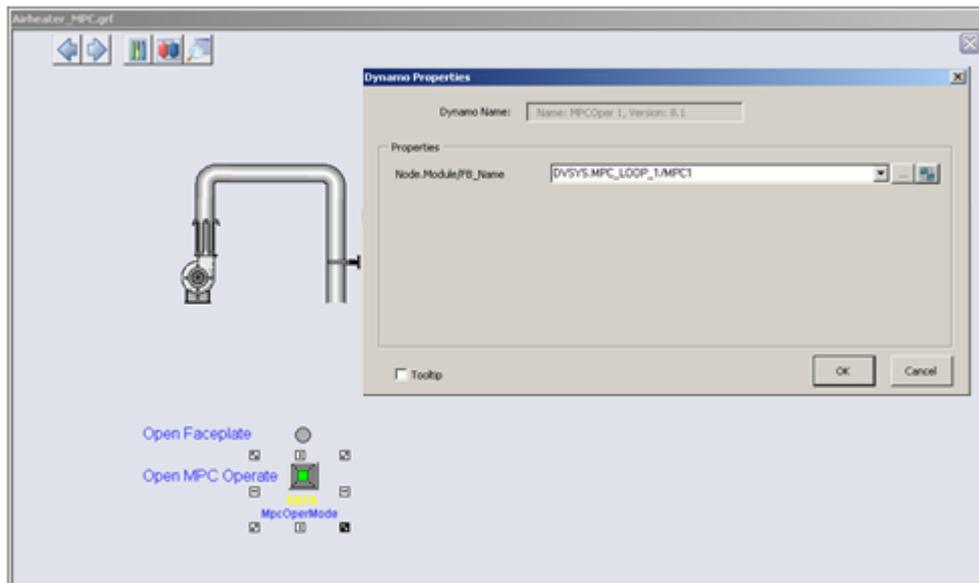


Figure 4.10 Button to open the MPC Operate interface.

A Dynamo Properties window appears. As for the faceplate press the  button and choose Browse DeltaV Control Parameters. Then choose AIRHEATER → MPC_LOOP_1 → MPC1 → CNTRL1 → CV and press OK until you are back to your picture.

You have now made the interface that can be used to control the temperature for the Air Heater. If you haven't already saved your picture then do this now by choosing Save As under File. Save the picture with yourname.grf.

5 OPERATING THE AIR HEATER SYSTEM

To operate the Air Heater system we need to physically connect it to DeltaV. Wire up the model as shown in section 3.1.

When the model is connected press Ctrl + w in the previous HMI picture you created to enable the run mode, DeltaV Operate Run. The model is now ready to be controlled.

The running application can be seen in Figure 5.1.

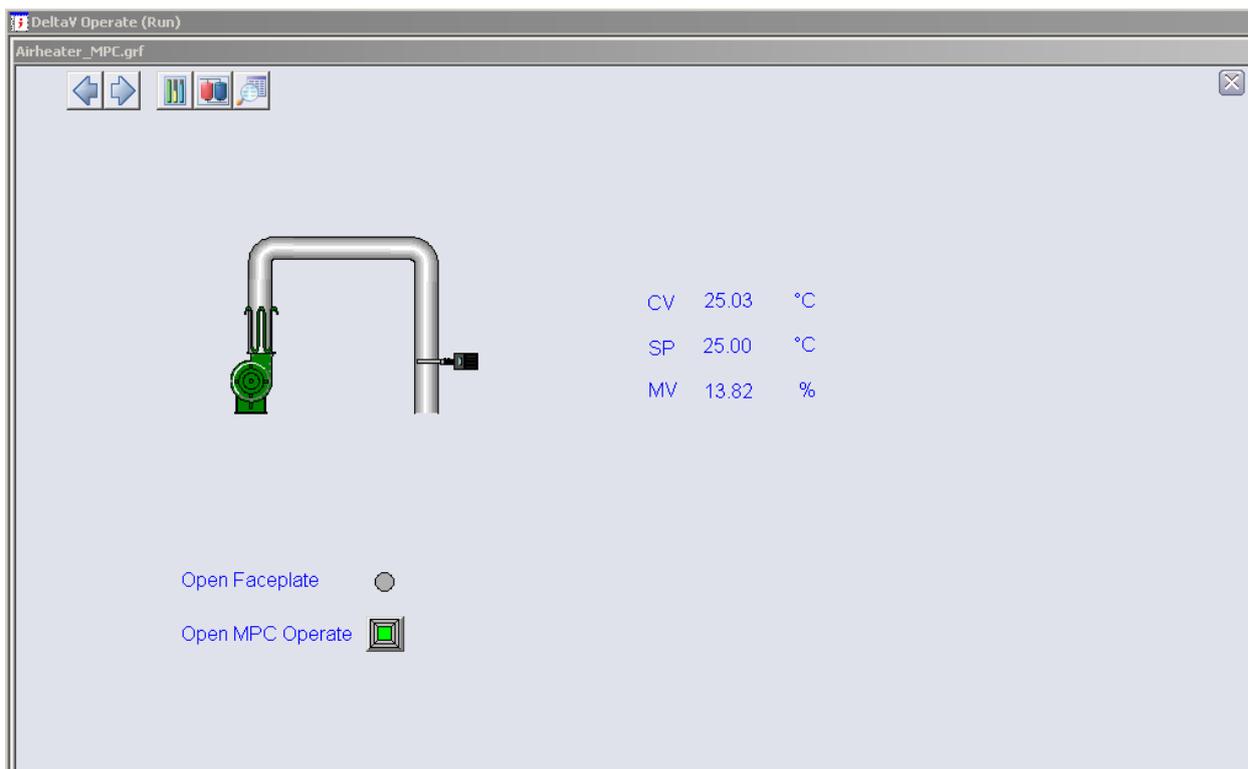


Figure 5.1 Running Air Heater system in DeltaV Operate Run.

To open the MPC Operate application just press the Open MPC Operate button you created. You can then control the Air Heater as explained in section 3.

Press the Open Faceplate button to open the faceplate. Alternatively you can mark either SP or MV and then press the faceplate button in upper left corner. Here you have the options to control the process manually or set it to auto.

You can see the trend of the variables by pressing the button that looks like a graph in the faceplate. You will then see the CV, SP and MV.

If you press the button with the magnifying glass in the faceplate, a detail window will appear. Here you can e.g. try to do further tuning changing the SP Filter Time. If your controller f.ex. has too fast control response, then by increasing the setpoint filter time the response will be relaxed.

Figure 5.2 shows the running model with its associated faceplate and detail window.

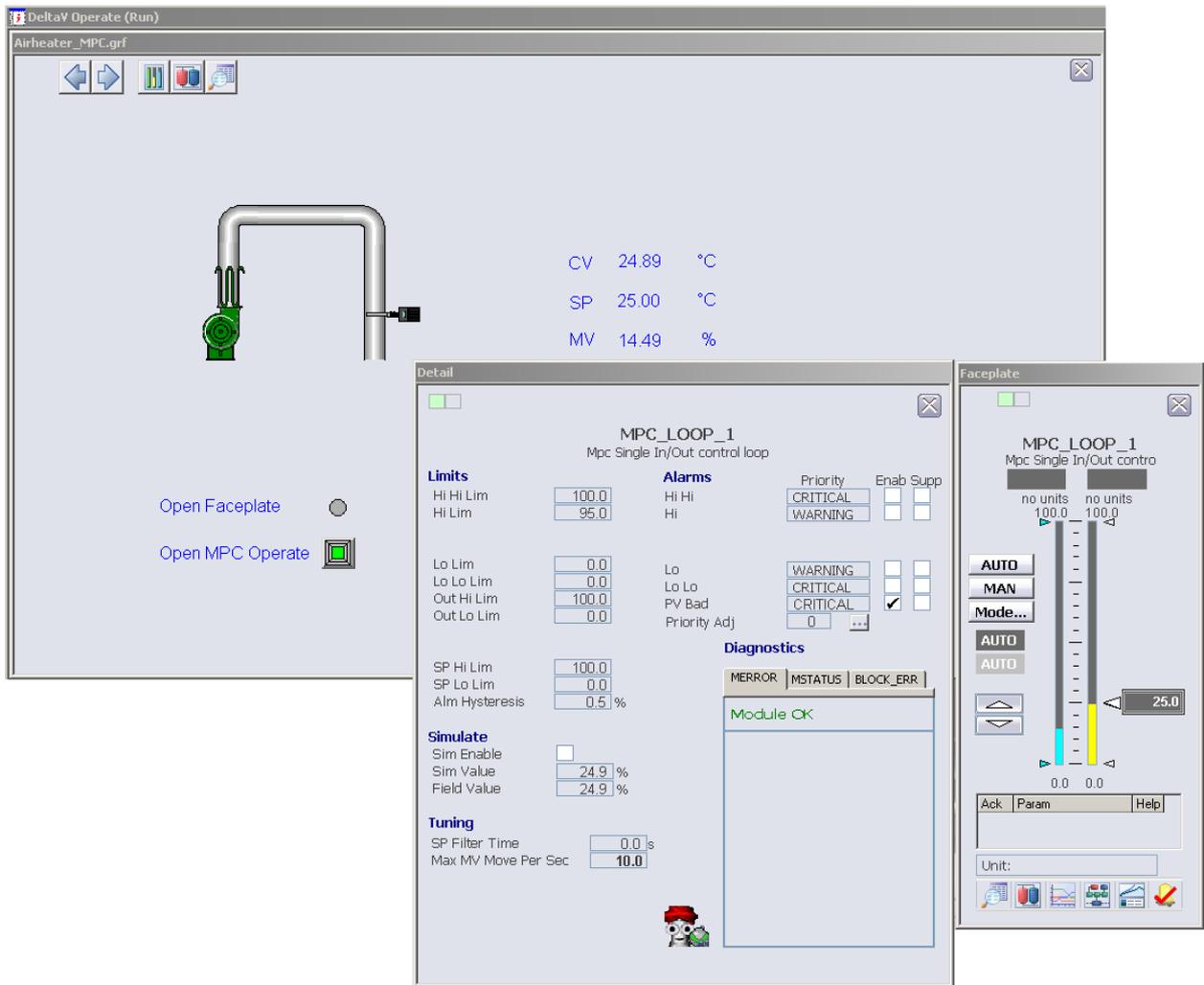


Figure 5.2 Running the Air Heater system in DeltaV Operate Run with associated faceplate and detail window.

Further tuning can be done changing the PM and PE by pressing the Generate Ctrl button in the DeltaV Predict application, and explained in section 3.3. Feel free to experiment and try to find values that might improve the performance.

In Auto mode, try to set the setpoint to 50°- or 10° Celsius, starting from e.g. an operational area around 30° Celsius, and see what happens. Hint: The controller should respect the constraints set 20°- and 40° Celsius respectively.