Fired Heater Model Predictive Control (MPC) Simulation

Installing the simulation

To install the simulation simply unzip the files in Design Project/Software into a convenient location and add the mpcsim folder and its subfolders to the Matlab path using the Set Path option.

There are two different casadi folders, one for Windows and one for Mac. Delete the one that you do not need. Rename the other folder casadi.

If you are on a Mac, you may need to open each .dylib file in casadi by right clicking on it, to let the operating system know that you think the files are safe. You may also need to right click and open casadiMEX.mexmaci64.

Running the simulation

To start the simulation, run the file heater_mpcsim.m:

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>> heater_mpcsim
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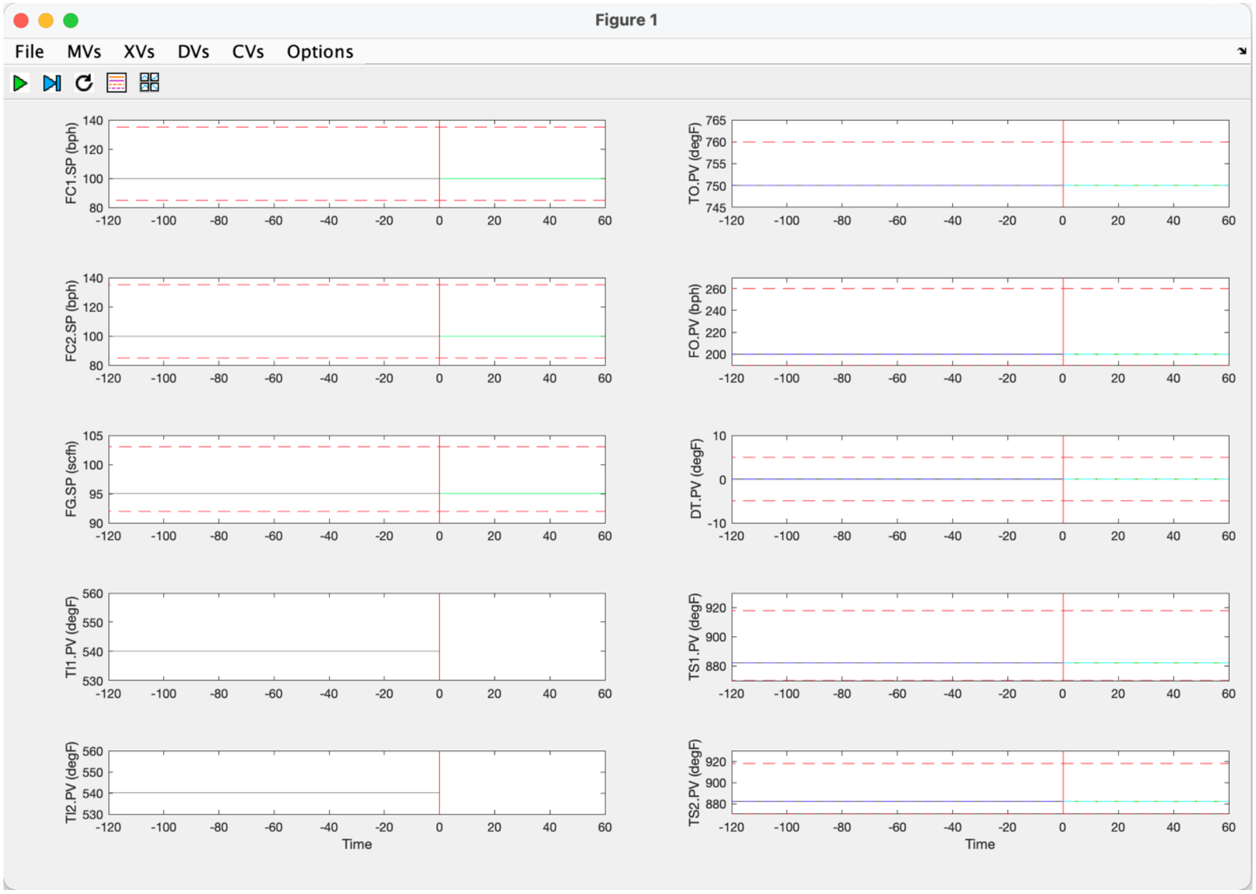
The following simulation window should appear on your screen:



The simulation window shows two columns of plots. The fired heater process inputs are plotted in the left-hand column, and the process outputs are plotted in the right-hand column.

The first three process inputs in the left-hand column are the Manipulated Variable (MVs):

- FC1.SP – pass 1 flow controller setpoint (bph)
- FC2.SP – pass 2 flow controller setpoint (bph)
- FG.SP – fuel gas flow controller setpoint (scfh)

The last two process inputs in the left-hand column are the Disturbance Variables (DVs):

- TI1.PV – pass 1 inlet temperature (degF)
- TI2.PV – pass 2 inlet temperature (degF)

The process outputs plotted on the right-hand side are the Controlled Variables (CVs):

- TO.PV – combined outlet temperature (degF)
- FO.PV – combined outlet flow (bph)
- DT.PV – pass outlet temperature difference (degF)
- TS1.PV – pass 1 tubeskin temperature (degF)
- TS2.PV – pass 2 tubeskin temperature (degF)

Within each plot is a vertical red line that separates past measurements on the left from future predictions on the right. Two hours of past measurements are plotted on the left, and future predictions for the next hour are plotted on the right. Dashed red lines at the top and bottom of each plot represent maximum and minimum limits.

The simulation is controlled using the buttons and menus that appear at the top left of the simulation window. The buttons are used to start/stop the simulation, turn the control on and off, add legends to the plots, and resize the plots:

 Run button - toggles the simulation on/off

 Step button - runs the simulation for one time step

 Control button - toggles the controller on/off

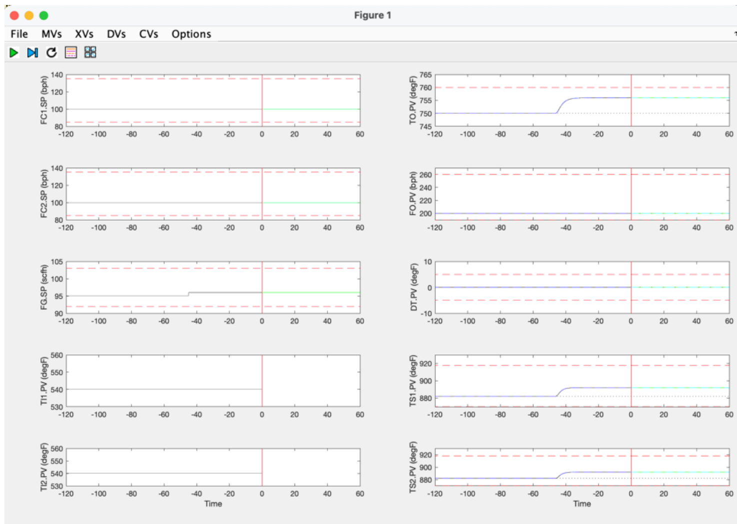
 Legend button - toggles the plot legends on/off

 Rescale button - rescales the plots

The menus for the MVs, DVs, and CVs allow you to change variable values, setpoints, and controller tuning. The Options menu allows you to set the measurement noise level, change the estimator tuning, and choose which disturbance model will be used to estimate unmeasured disturbances.

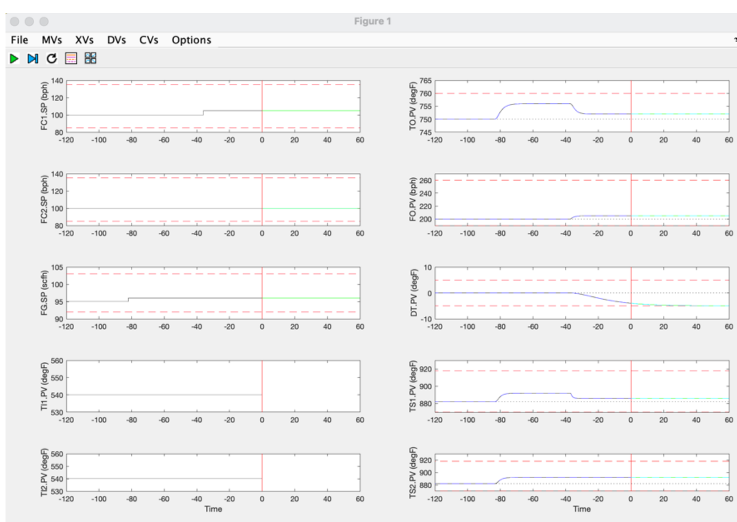
Open-loop (control off) experiments

As a first experiment with the simulator, use the MVs menu to increase the FG Value from 95 to 96 scfh. Press the Run button and you should see the FG.SP increase from 95 to 96 scfh, and the corresponding dynamic response of TO.PV, TS1.PV, and TS2.PV. Press the Run button again to stop the simulation. You should see something like this:

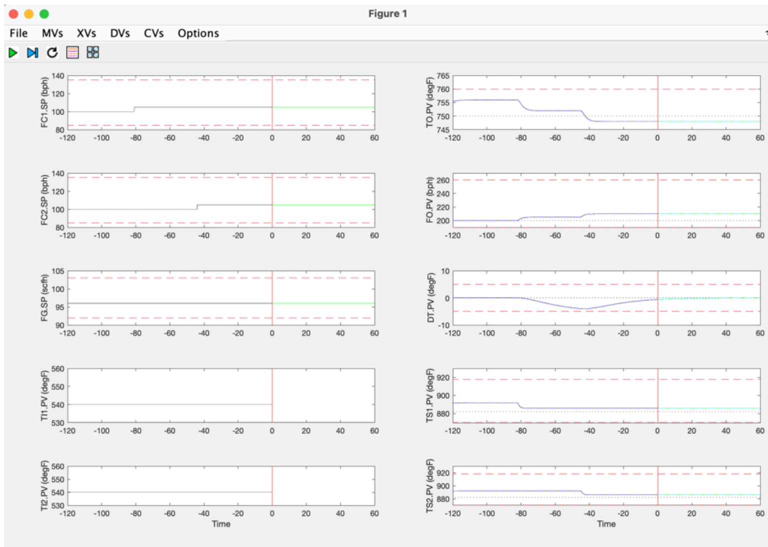


The increase in fuel gas flow has warmed the heater up, so the combined outlet temperature has increased, along with the pass 1 and 3 tubeskin temperatures.

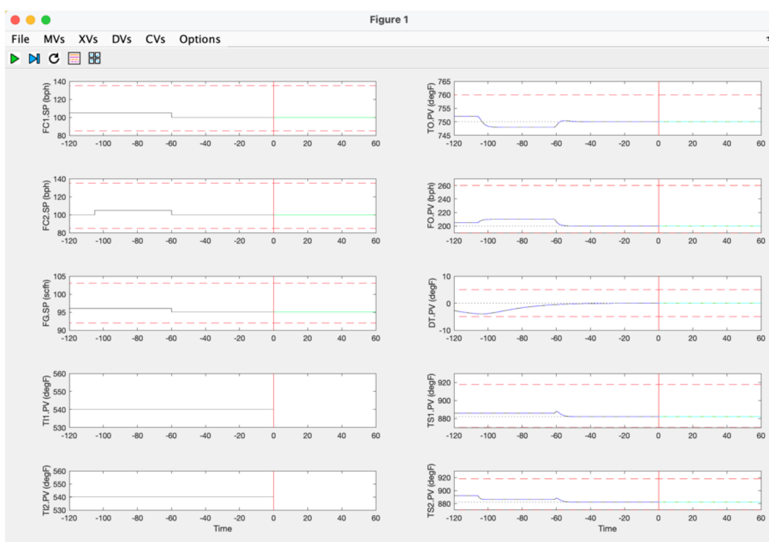
Next use the MVs menu to increase FC1 from 100 to 105 bph. Increasing the flow through pass 1 will cool off the tubeskin temperature of that pass (TS1.PV) and will increase the total flow through the heater (FO.PV). This will also decrease the combined outlet temperature (TO.PV). The first pass becomes cooler than the second pass so the temperature difference between them (DT.PV) goes negative:



Now increase the pass 2 flow from 100 to 105 bph and you should see the combined outlet temperature TO.PV decrease, the combined flow FO.PV increase, the pass temperature difference DT.PV come back to zero, and the pass 2 tubeskin temperature TS2.PV decrease:

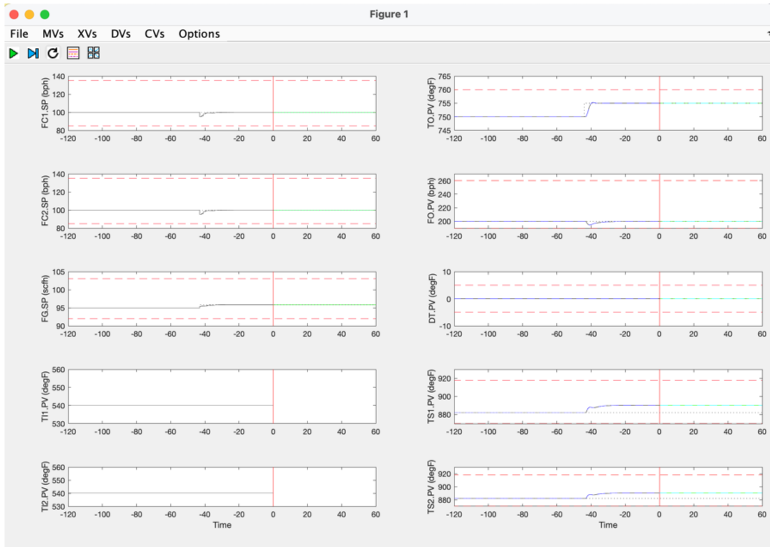


Now return the three MV variables back to their initial values. Set FC1 and FC2 to 100 bph, and FG to 95 scfh. This will cause the CVs to return to their original values:

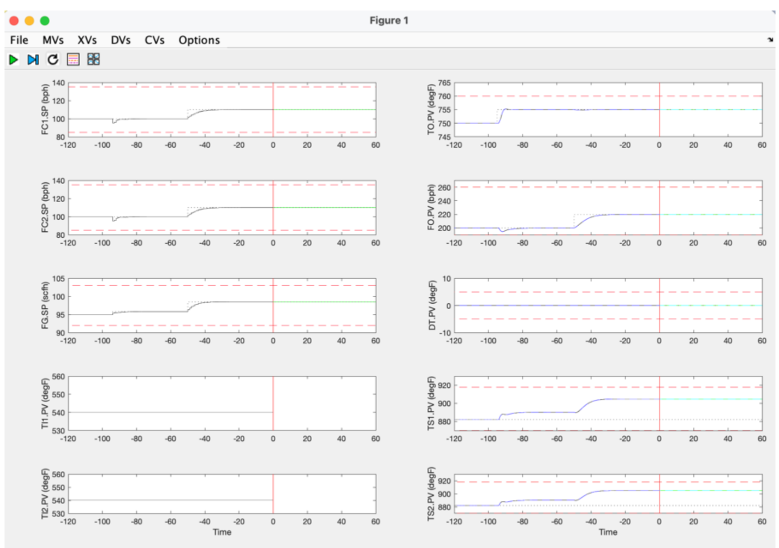


Closed-loop (control on) experiments

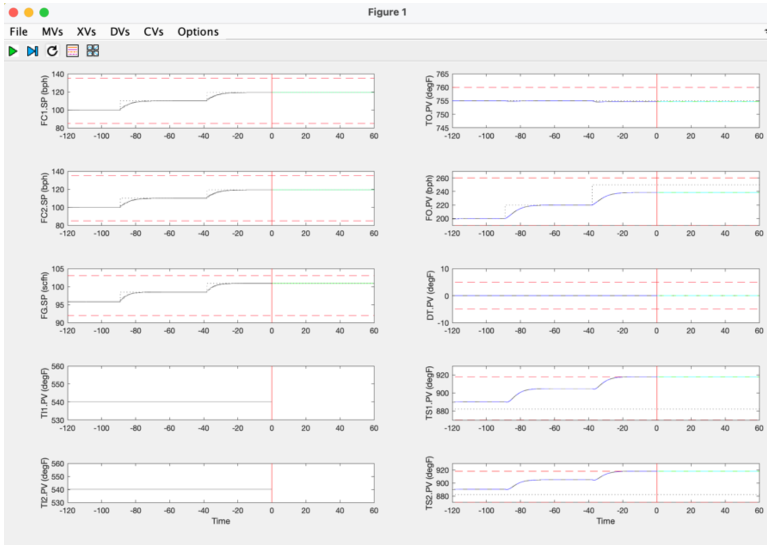
Use the CV menu to change the TO Setpoint from 750 to 755 degF. Click the Control button and then click the Run button. You should see the control make adjustments to the three MVs to take the TO up to its new setpoint of 755 degF. This is accomplished mainly by adjusting the fuel gas flow, although the pass flows are also temporarily decreased in order to help speed up the TO change:



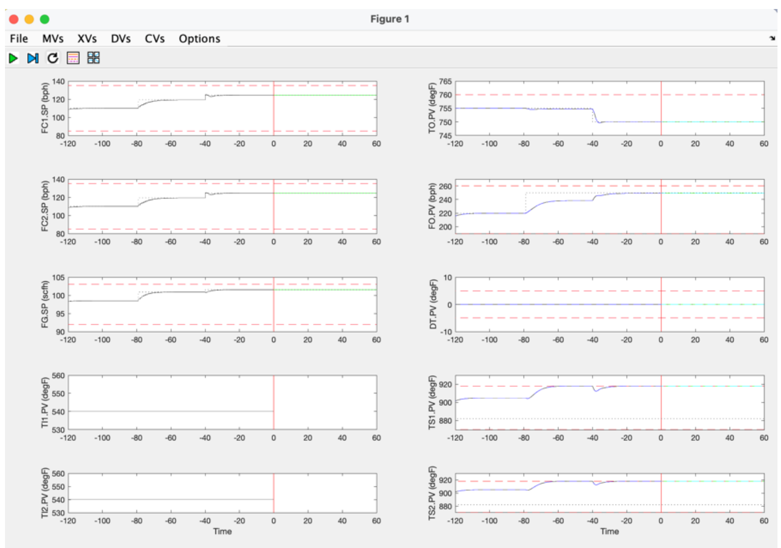
Now change the FO setpoint from 200 to 220 bph. The control accomplishes this FO setpoint change by increasing the pass flows FC1 and FC2, while simultaneously increasing the fuel gas FG so that that TO stays at its setpoint. FC1 and FC2 are increased in exactly the same way so as to keep the pass temperature difference DT at its setpoint of zero:



Now change the FO setpoint from 220 to 250 bph. Notice that the control is not able to bring FO all the way up to its new setpoint since this would cause the tubeskin temperatures TS1 and TS2 to exceed their maximum limits. The control has been configured to respect the tubeskin temperature limits as its top priority. The next priority is to hold TO at its setpoint, followed by holding FO at its setpoint, with holding DT at its setpoint as the lowest priority.



Now decrease the TO setpoint from 755 to 750 degF. Notice that this allow the control to bring FO up to its setpoint while still respecting the tubeskin temperature limits.



Now change the FO setpoint back to 200 bph. This returns the simulation back to its initial condition:

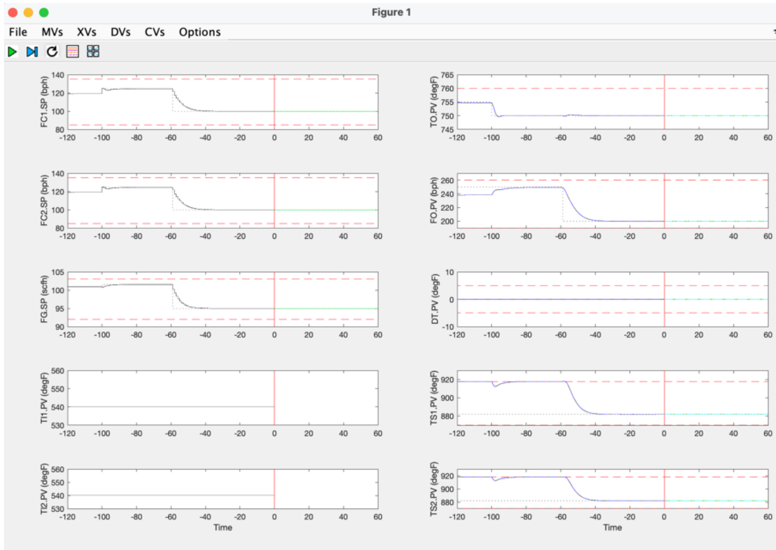


Figure 1
File
MVs
XVs
DVs
CVs
Options
FC1.SP (bph)
FC2.SP (bph)
FG.SP (scfh)
TI1.PV (degF)
TI2.PV (degF)
TO.PV (degF)
FO.PV (bph)
DT.PV (degF)
TS1.PV (degF)
TS2.PV (degF)
Time
Time