Name:_________________________________

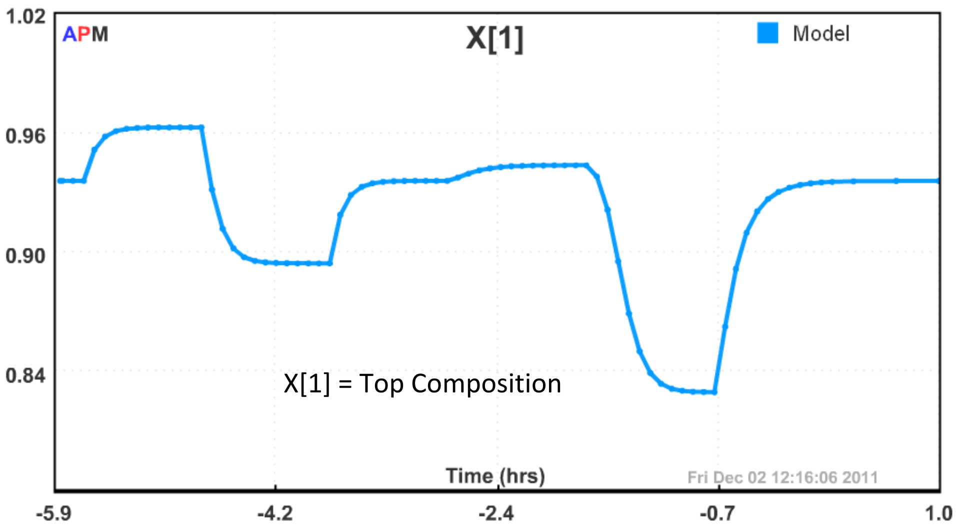
SP16 - Process Control 436

The purpose of this assignment is to design a control system for a distillation column. A distillation column is typically a highly coupled system that leads to interacting controllers. Techniques from this class that are useful for designing the control system are:

- Empirical model fitting of a Multiple Input Multiple Output (MIMO) System
- Relative Gain Array (RGA) analysis to determine best pairing of Manipulated and Controlled Variables
- Trial Controller with PID Non-interacting controllers
- Trial PID Controllers with Feedforward information from other controllers
- Derivation of First Principles model
- Nonlinear Control (NLC)

Part a) Calculate transfer functions for the distillation column model response and put model into the form

$$\begin{bmatrix} X[1] \\ X[32] \end{bmatrix} = \begin{bmatrix} \frac{K_{p,11}}{\tau_{p,11}s+1} & \frac{K_{p,12}}{\tau_{p,12}s+1} \\ \frac{K_{p,21}}{\tau_{p,21}s+1} & \frac{K_{p,22}}{\tau_{p,22}s+1} \end{bmatrix} \begin{bmatrix} RR \\ FBOT \end{bmatrix} =$$

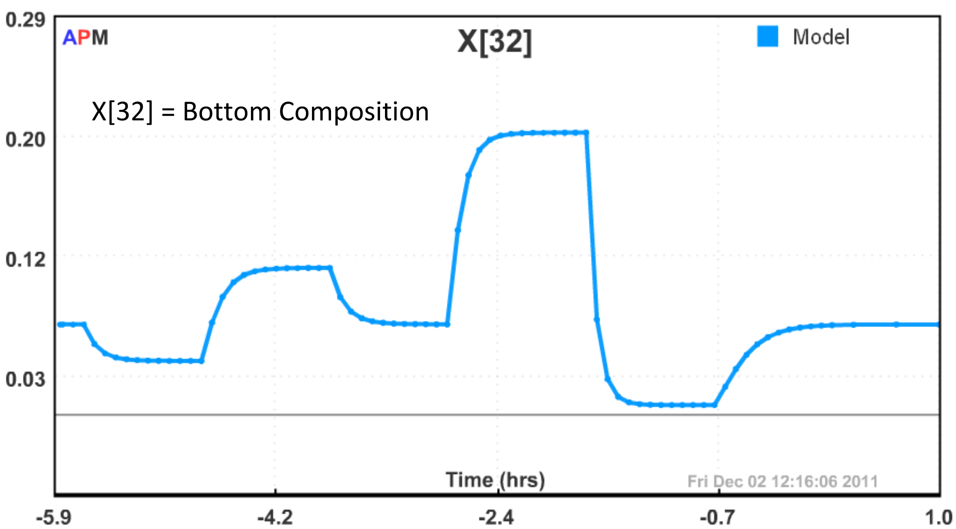


$K_{p,11}$=

$K_{p,12}$=

$\tau_{p,11}$=

$\tau_{p,12}$=

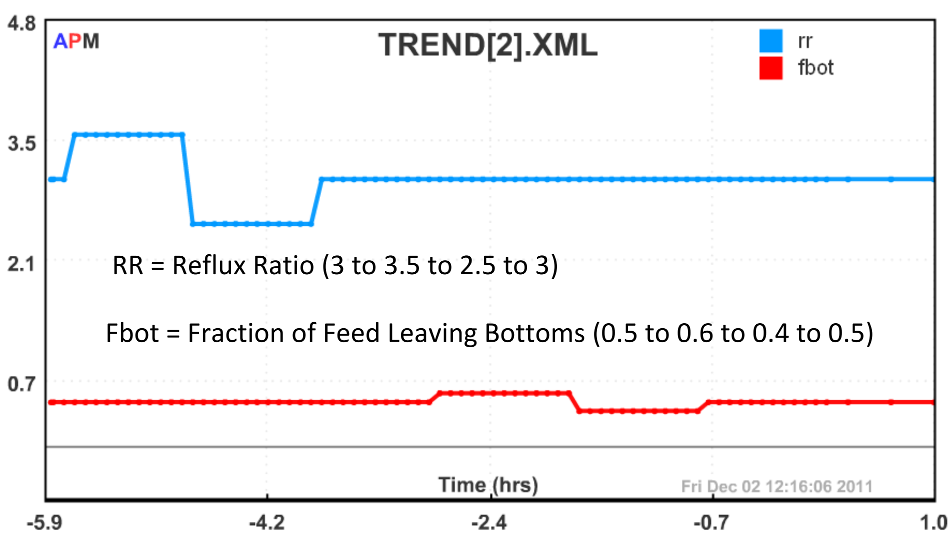


$K_{p,21}$=

$K_{p,22}$=

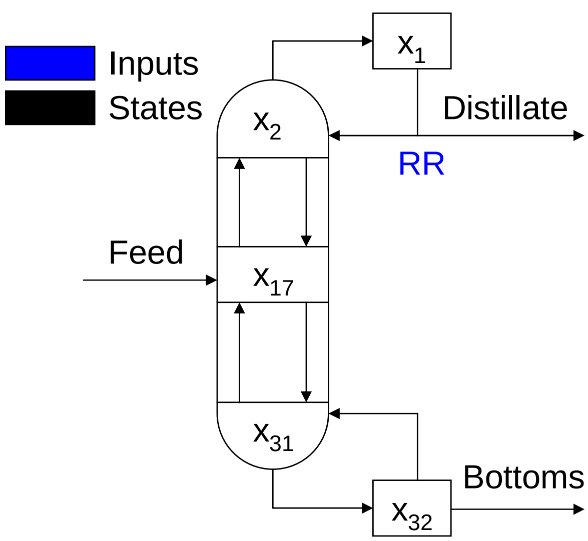
$\tau_{p,21}$=

$\tau_{p,22}$=



Part b) Derive a single tray model for the distillation column:

- Two Components
- Constant Relative Volatility
- Constant Tray Molar Holdup
- Liquid Feed at the Bubble Point
- 30 Trays, Reboiler, and Condenser
- Manipulated Variables
  - RR – Reflux Ratio
  - FBOT – Fraction of Feed Leaving at Bottoms Product
- Controlled Variables
  - x[1] – Light component composition in overhead product
  - x[32] – Light component composition in bottoms product



Part c) Using Relative Gain Array (RGA) analysis, suggest best pairing options for the MVs (RR and FBOT) and CVs (X[1] and X[32]). The steady state gains at a nominal operating condition are provided below.

APMonitor		CV(1)	CV(2)	SV(1)	SV(2)	SV(3)	SV(4)	SV(5)	SV(6)	SV(7)	SV(8)
	Sensitivities	ss.x[1]	ss.x[32]	ss.x[2]	ss.x[5]	ss.x[10]	ss.x[15]	ss.x[20]	ss.x[25]	ss.x[30]	ss.x[31]
FV(1)	ss.feed	-4.204E-09	4.204E-09	-5.313E-09	-5.383E-09	-2.321E-09	8.049E-09	5.356E-09	6.675E-09	5.061E-09	4.792E-09
FV(2)	ss.x_feed	0.880362	1.11964	1.30545	2.42762	2.64995	1.80586	2.16519	3.25674	2.00723	1.55214
FV(3)	ss.alpha	0.446683	-0.446683	0.606380	0.889874	0.565205	0.095437	-0.178455	-0.702162	-0.689056	-0.574441
FV(4)	ss.atray	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FV(5)	ss.acond	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FV(6)	ss.areb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MV(1)	ss.rr	0.068707	-0.068707	0.101883	0.170145	0.121322	0.019434	-0.050178	-0.152264	-0.118547	-0.093852
MV(2)	ss.fbot	0.314140	1.42754	0.465825	0.866247	0.945584	0.644385	1.43757	3.39092	2.48516	1.95664

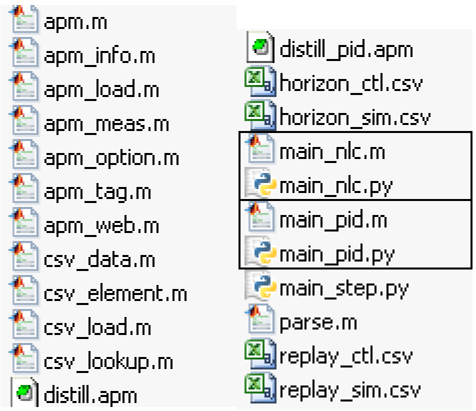
The RGA analysis can be completed by using the gains above or the gains from Part a)

$$\lambda_{11} = \lambda_{22} = \frac{1}{1 - \dfrac{K_{12}K_{21}}{K_{11}K_{22}}}$$

$$\lambda_{12} = \lambda_{21} = 1 - \lambda_{11}$$

$$\Lambda = \begin{bmatrix} \lambda_{11} & \lambda_{12} \\ \lambda_{21} & \lambda_{22} \end{bmatrix} =$$

Part d) Simulate a PID controller for the distillation column using files provided with this assignment (run **main_pid.py**). Adjust the PI controller tuning parameters to achieve acceptable set point and disturbance tracking. PI controller tuning can be adjusted by opening **distill_pid.apm** with a text editor and modifying the values of Kc_1, Kc_2, taui_1, and taui_2.

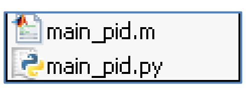


Edit distill_pid.apm with a text editor to change the PID tuning parameters.

```
! pid tuning parameters for top composition control
kc_1   = 1/0.069   ! ~1/Kp1
taui_1 = 30        ! ~taup1
taud_1 = 0         !  0
sp_x[1]  = 0.935

! pid tuning parameters for bottom composition control
kc_2   = 1/1.42    ! ~1/Kp2
taui_2 = 60        ! ~taup2
taud_2 = 0         !  0
sp_x[32]  = 0.065
```

Run PID Control with either MATLAB or Python

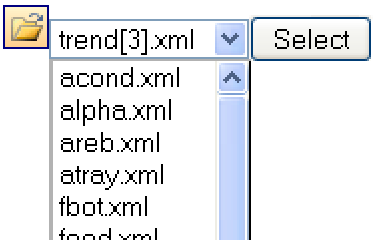


(**Extra**): Adjust the PID equations in distill_pid.apm to make them interacting controllers (i.e. a feedforward element) that accounts for changes in the other controller.

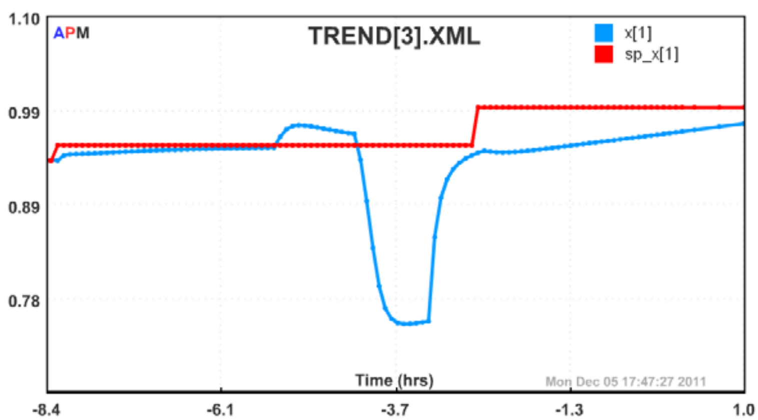
Part e) Compare the performance of the PID controller with Nonlinear Control.

Run Nonlinear Control with either MATLAB (**main_nlc.m**) or Python (**main_nlc.py**):

When the web-viewer starts, select custom trends **Trend[3]** or **Trend[4]** to view controller performance.



PID Control Performance for Distillate Composition Control



NLC Control Performance for Distillate Composition Control