# Model Identification from Data

Using System Identification Toolbox MATLAB

We have a temperature control system with 2 inputs and 2 outputs

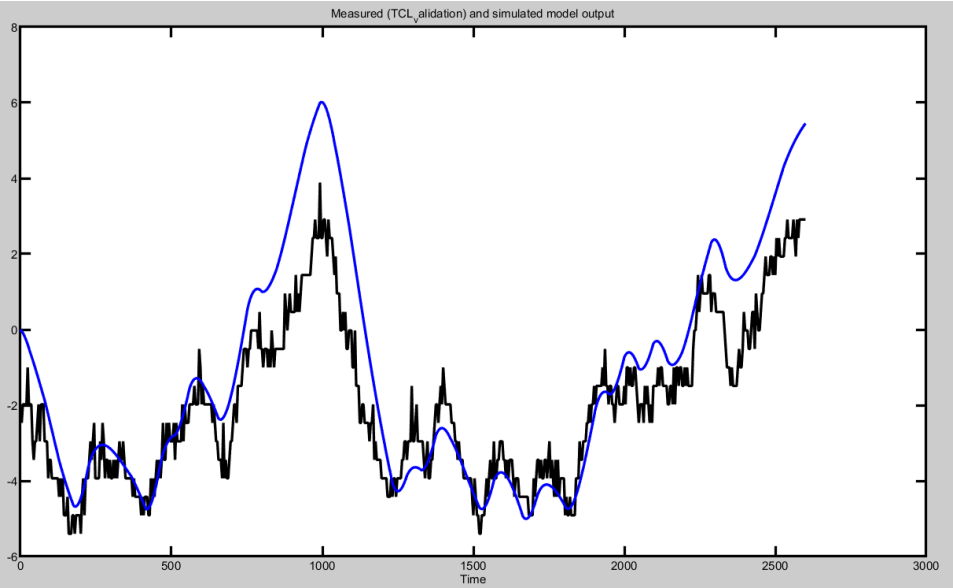
Let's try out first State space model for the system

## State Space Model

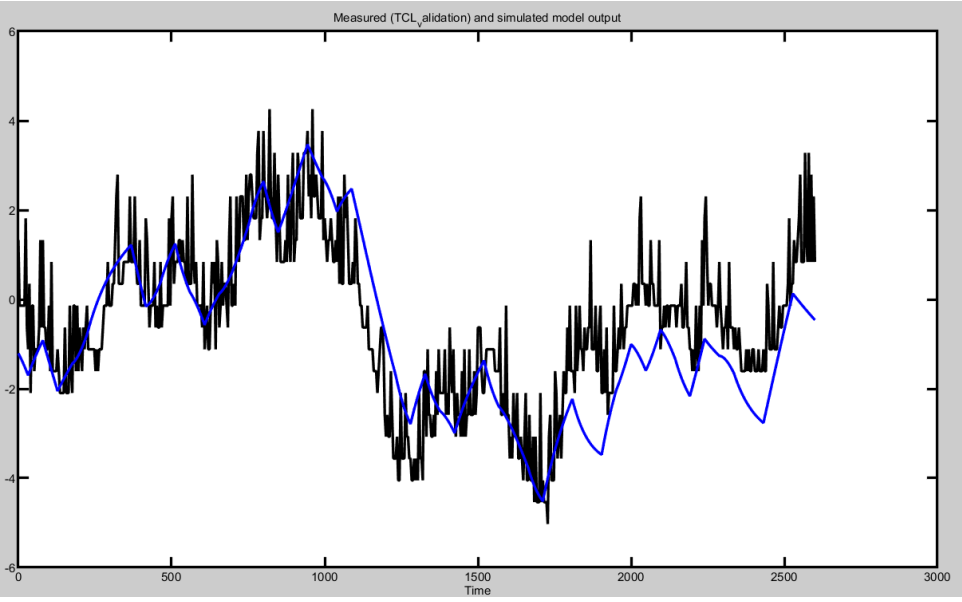
The blue curve represents the predictions using the state space model and black curve is the true output

Validation of State Space model:

Output Y-1:

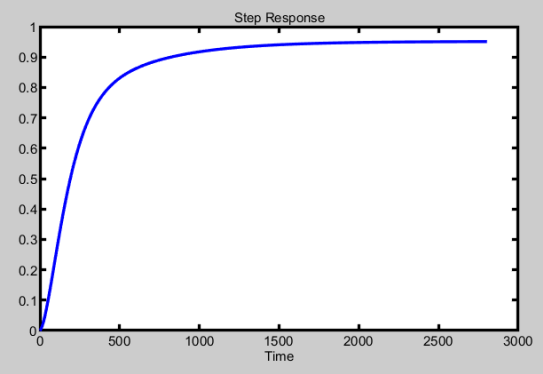



Output Y-2 :

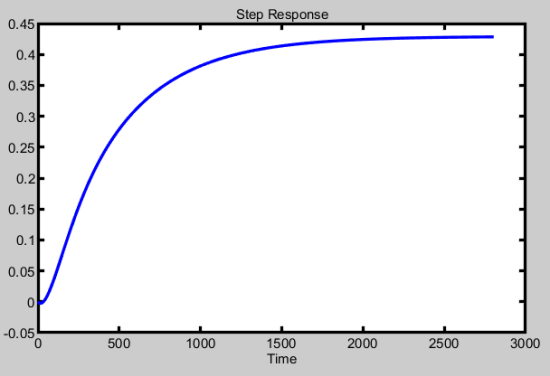


Transient Response: Step Response

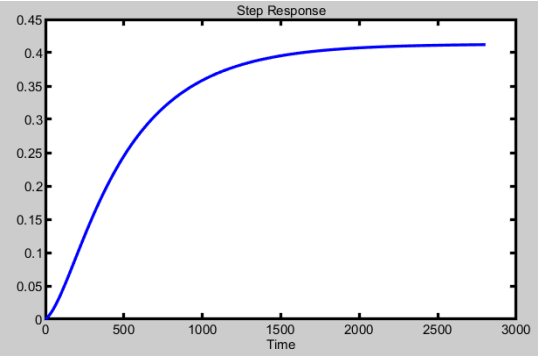
U_1→ Y_1:



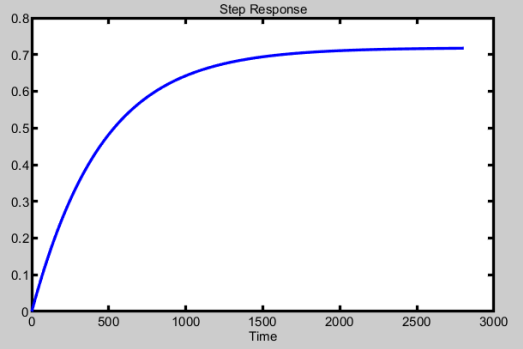

U_1→ Y_2:




U_2→ Y_1:



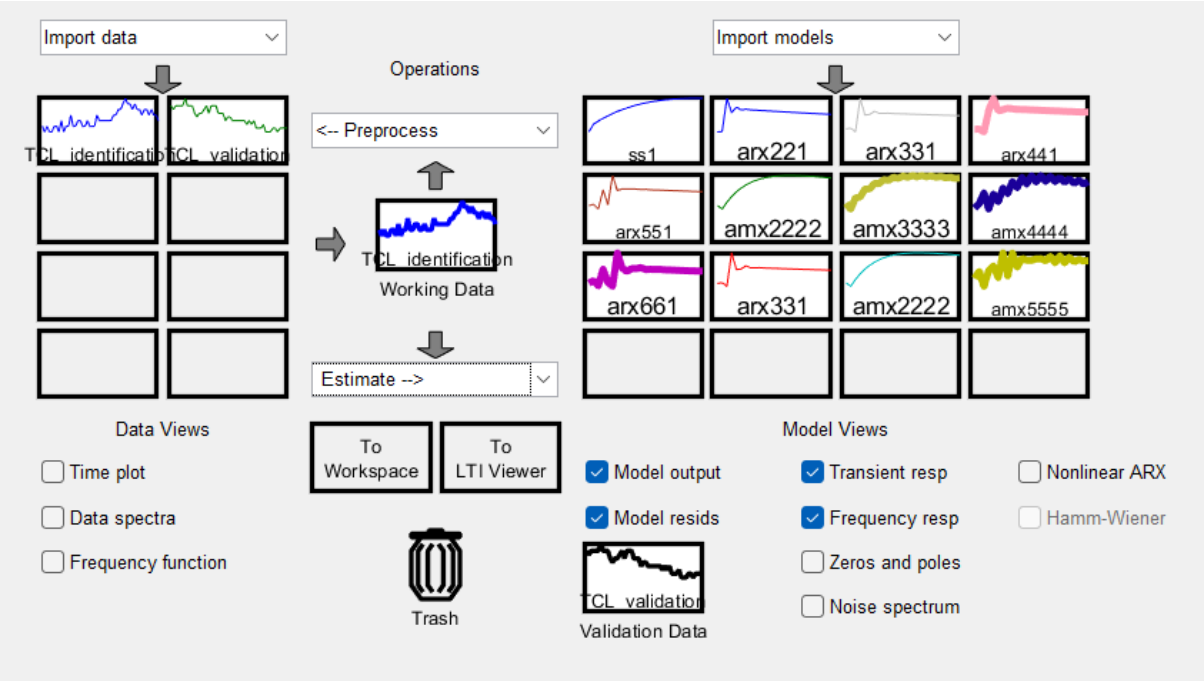

U_2→ Y_1:




We can do better than this …

Let’s move to polynomial models like ARX and ARMX

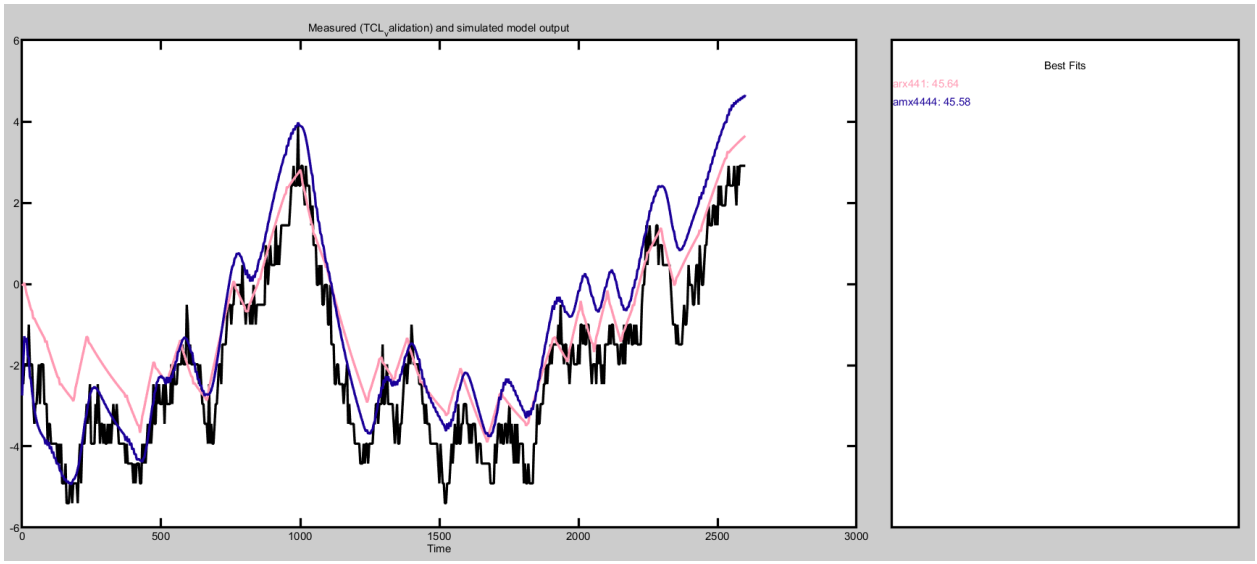
## ARX -Model AND ARMAX MODEL:

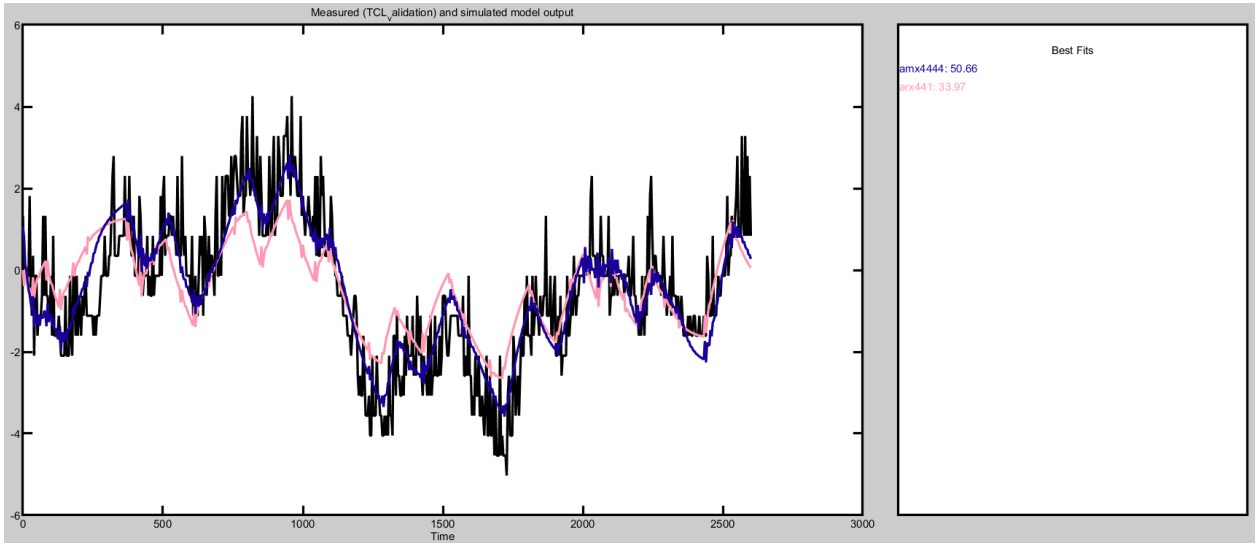


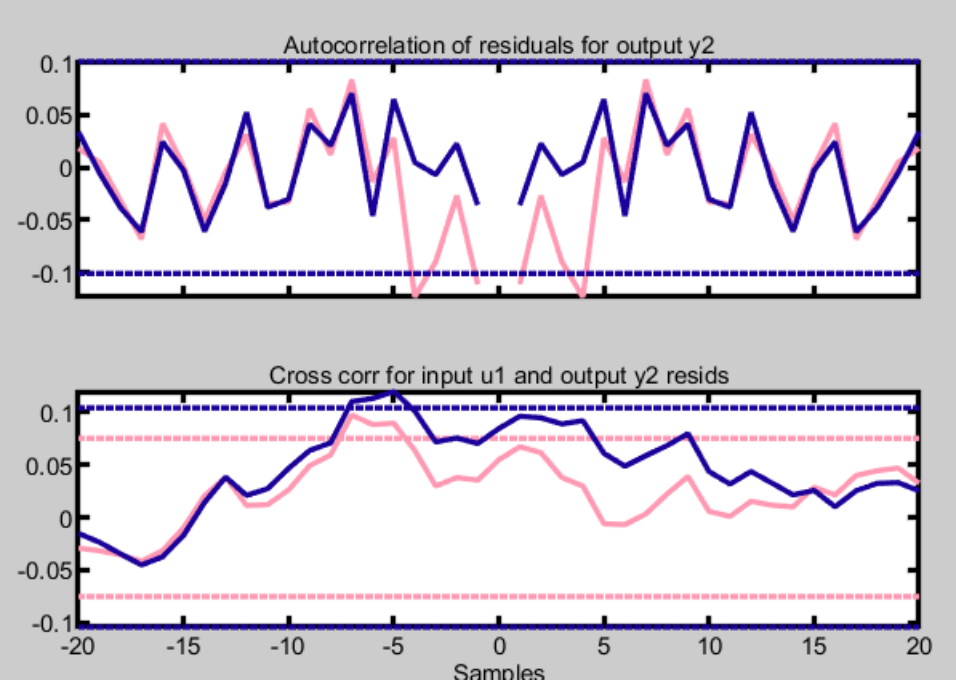

Different orders of ARX and ARMAX are estimated and the performance of the resulting models are analysed with the

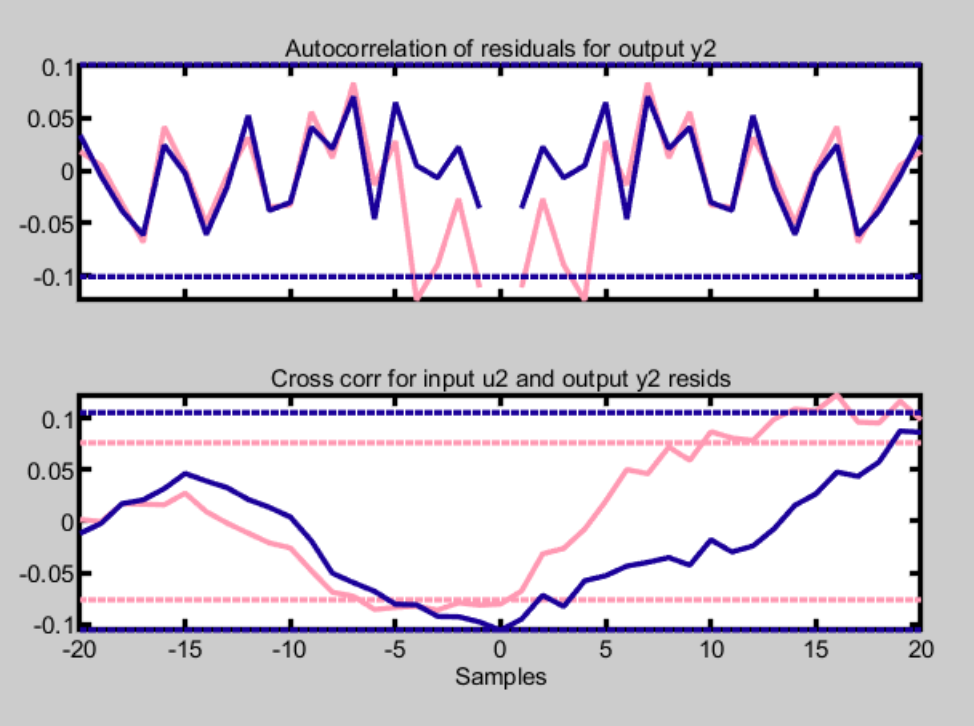
1. Output predictions
2. Model Residuals (very imp. as the models are built with the assumption of white noise)
3. Transient Response (for stability)
4. Frequency Response (for stability)

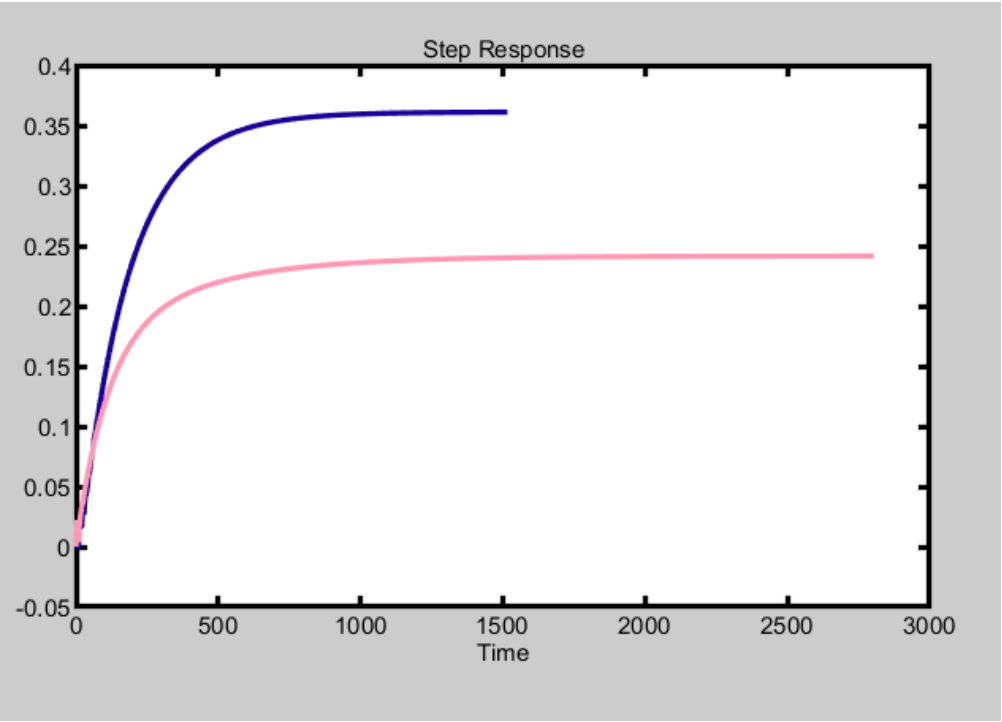
After testing out these models on the above-mentioned criteria ARMAX $4^{th}$ order model turn out to be the best. In performance wise ARX $4^{th}$ order and ARMAX $4^{th}$ order were very similar but it was found that ARX is auto-correlated.

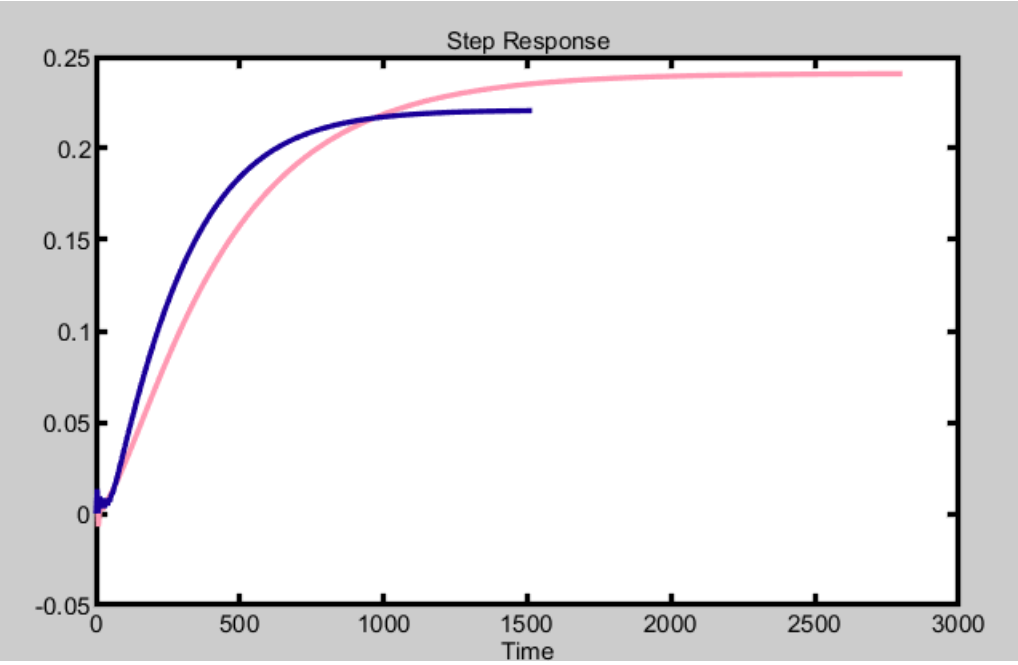

Measured (TCL_validation) and simulated model output
Time
Best Fits
arx441: 45.64
amx4444: 45.58


Measured (TCL_validation) and simulated model output
Time
Best Fits
amx4444: 50.66
arx441: 33.97


Autocorrelation of residuals for output y2
0.1
0.05
0
-0.05
-0.1
Cross corr for input u1 and output y2 resids
0.1
0.05
0
-0.05
-0.1
-20
-15
-10
-5
0
5
10
15
20
Samples


Autocorrelation of residuals for output y2
0.1
0.05
0
-0.05
-0.1
Cross corr for input u2 and output y2 resids
0.1
0.05
0
-0.05
-0.1
-20
-15
-10
-5
0
5
10
15
20
Samples

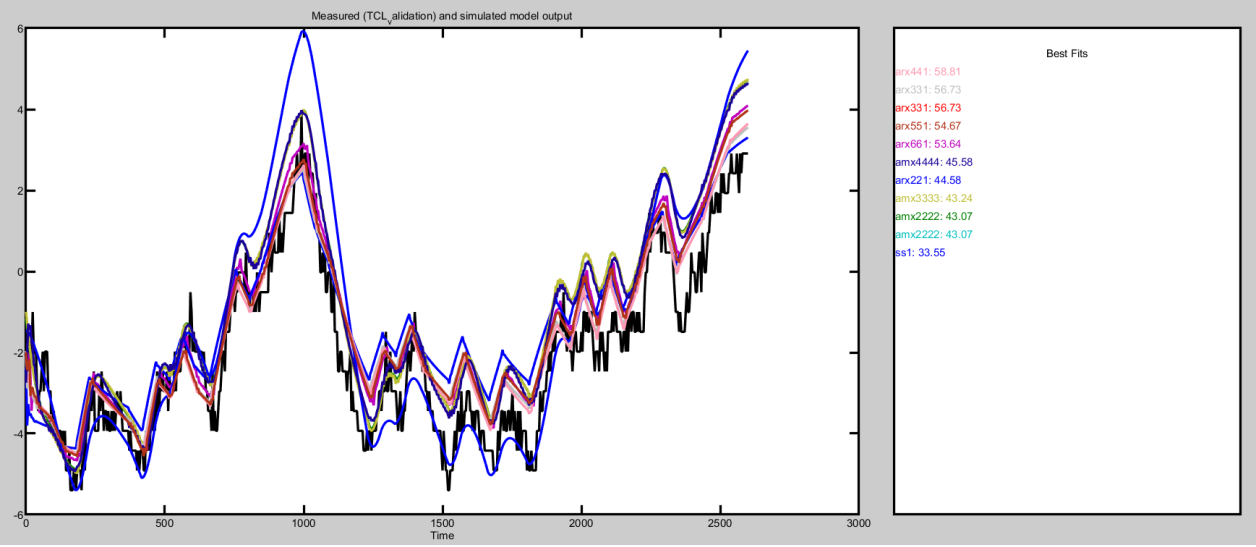

Step Response
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
-0.05
0
500
1000
1500
2000
2500
3000
Time

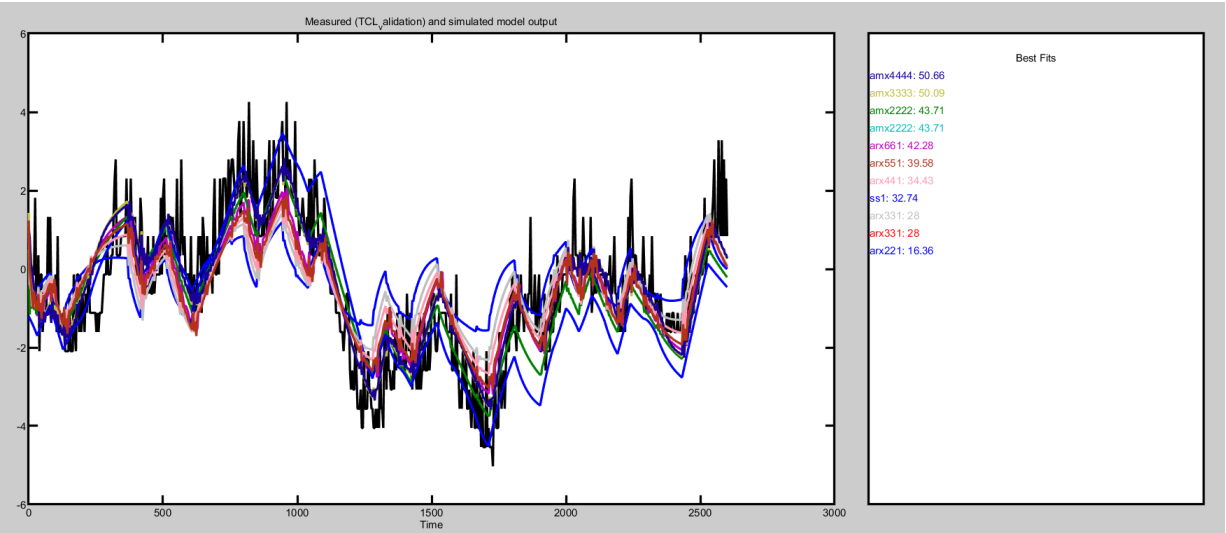

Step Response
0.25
0.2
0.15
0.1
0.05
0
-0.05
0
500
1000
1500
2000
2500
3000
Time

# FINAL MODEL:

```
amx4444 =
Discrete-time ARMAX model:
  Model for output "y1": A(z)y_1(t) = - A_i(z)y_i(t) + B(z)u(t) + C(z)e_1(t)
    A(z) = 1 - 1.496 z^-1 - 0.3103 z^-2 + 1.305 z^-3 - 0.4953 z^-4

    A_2(z) = -0.01415 z^-1 - 0.0007124 z^-2 + 0.04868 z^-3 - 0.03411 z^-4

    B1(z) = 0.0017 z^-1 + 0.003082 z^-2 - 0.009475 z^-3 + 0.007064 z^-4

    B2(z) = 0.00448 z^-1 - 0.01311 z^-2 + 0.01294 z^-3 - 0.003967 z^-4

    C(z) = 1 - 1.151 z^-1 - 0.5397 z^-2 + 1.065 z^-3 - 0.3256 z^-4

  Model for output "y2": A(z)y_2(t) = - A_i(z)y_i(t) + B(z)u(t) + C(z)e_2(t)
    A(z) = 1 - 0.4166 z^-1 - 0.88 z^-2 - 0.2321 z^-3 + 0.5459 z^-4

    A_1(z) = -0.0855 z^-1 + 0.04324 z^-2 - 0.05946 z^-3 + 0.09431 z^-4

    B1(z) = 0.01347 z^-1 - 0.01901 z^-2 + 0.002323 z^-3 + 0.002028 z^-4

    B2(z) = 0.01925 z^-1 - 0.02972 z^-2 + 0.01346 z^-3 + 0.002311 z^-4

    C(z) = 1 - 0.2112 z^-1 - 0.8309 z^-2 - 0.328 z^-3 + 0.495 z^-4

Name: amx4444
Sample time: 4 seconds
```

A glimpse of all models predictions on a single plot




Measured (TCL_validation) and simulated model output
6
4
2
0
-2
-4
-6
0
500
1000
1500
2000
2500
3000
Time
Best Fits
amx4444: 50.66
amx3333: 50.09
amx2222: 43.71
amx2222: 43.71
arx661: 42.28
arx551: 39.58
arx441: 34.43
ss1: 32.74
arx331: 28
arx331: 28
arx221: 16.36