System Identification and Controller Design for SBMHS System from Perturbation Data

Course Project: CL686

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Submission Date: 2018/04/24

Brief Introduction of the Project

- Single Board Multi-Heater System (SBMHS) consists of a rectangular metal plate on which four heating elements are mounted in the middle of the four edges of the plate.
- Five temperature sensors are attached at different location on the metal plate and a small cooling fan is fixed underneath the plate to introduce the disturbances.
- The Arduino Board is further interfaced to a PC through combination of LabView and MATLAB to faciliate as ADC and DAC.

Project work Description

The project was overall subdivided into following work division:

- MIMO System Identification: Development of ARMAX / OE Models using PRBS data and their comparison was done.
- The order of the system was chosen based on their stability observed via cross and auto correlation.
- Linear Quadratic Optimal Control (LQOC) Design and Implementation
- Model Predictive Control (MPC) Design

System Identification Work Description

- 2500 perturbation data were collected from temperature sensor T0 and T2 fixed under the plate heater section H1 and H3.
- In heater H1, perturbation amplitude of 2 was given along with the steady-state input value of 10. Similarly, perturbation amplitude of 3 was given to the heater H3.
- ARMAX and OE model was designed using MATLAB system identification toolbox for the MISO-I and MISO-II system individually, and later combined both models to formulate the single MIMO model of the system.

System Identification Models Results – MISO-I

- Detailed information of the models designed via MATLAB system identification toolbox are listed below:

ARMAX Model - I

- Order = 4 x 4
- Delay = [2 5]
- Fitness = 91.21 %
- MSE = 0.06337

OE Model - I

- Order = 2 x 2
- Delay = [2 5]
- Fitness = 87.46 %
- MSE = 0.129

System Identification Models Results – MISO-II

- Detailed information of the models designed via MATLAB system identification toolbox are listed below:

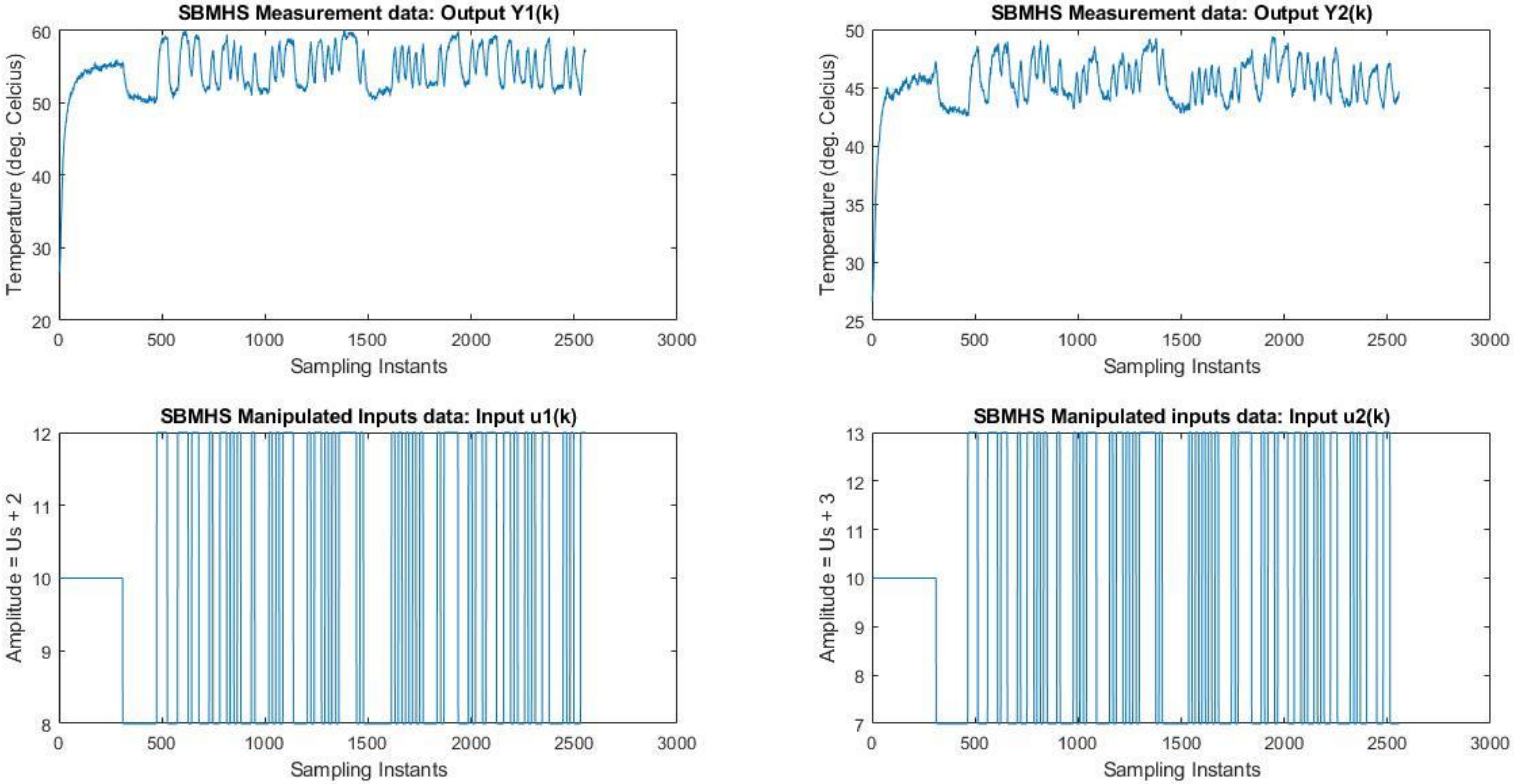
ARMAX Model - II

- Order = 4 x 4
- Delay = [7 3]
- Fitness = 88.29 %
- MSE = 0.03994

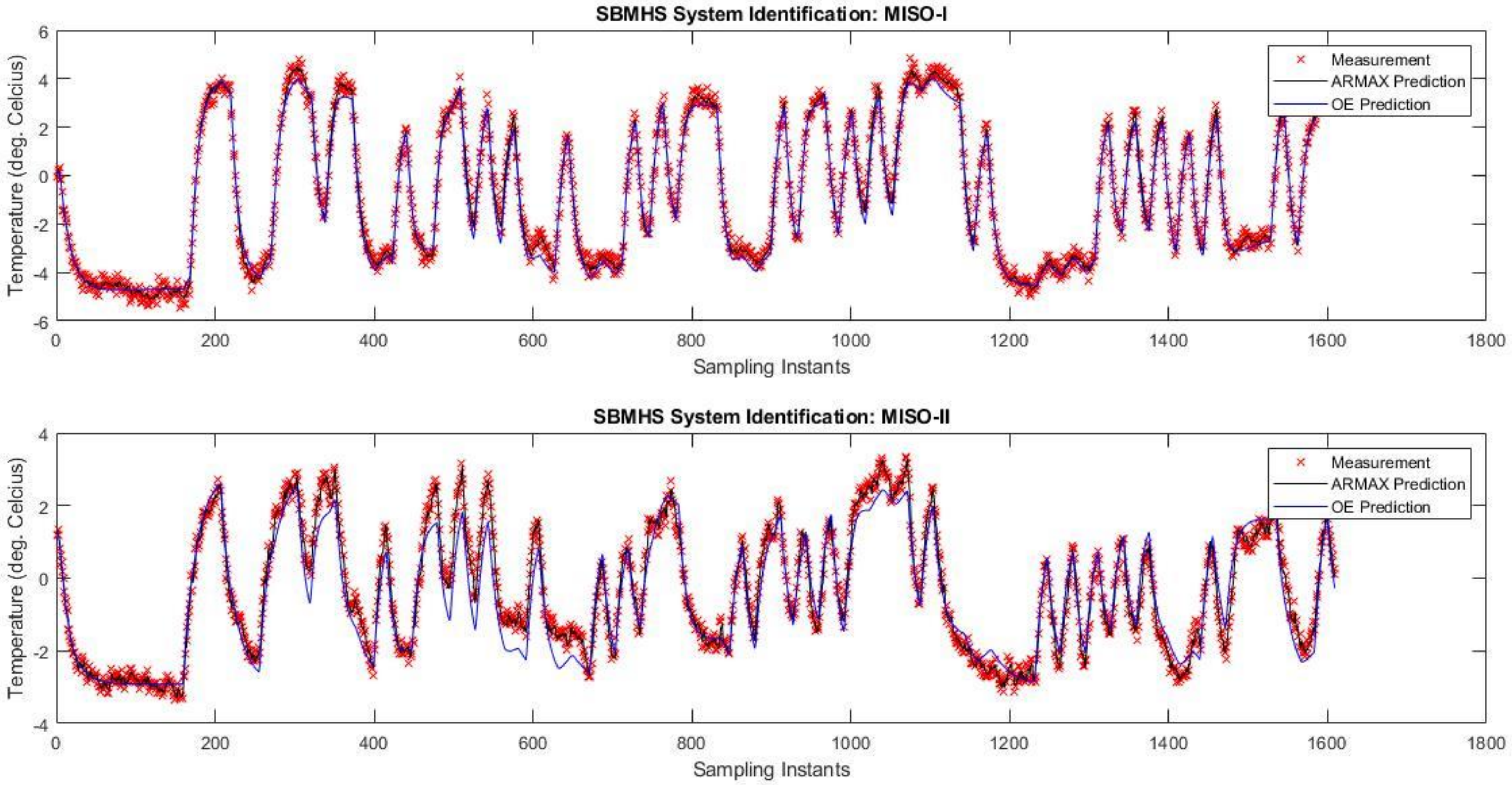
OE Model - II

- Order = 2 x 2
- Delay = [7 3]
- Fitness = 70.68 %
- MSE = 0.2504

SBMHS: Measurement and Manipulated Inputs Data

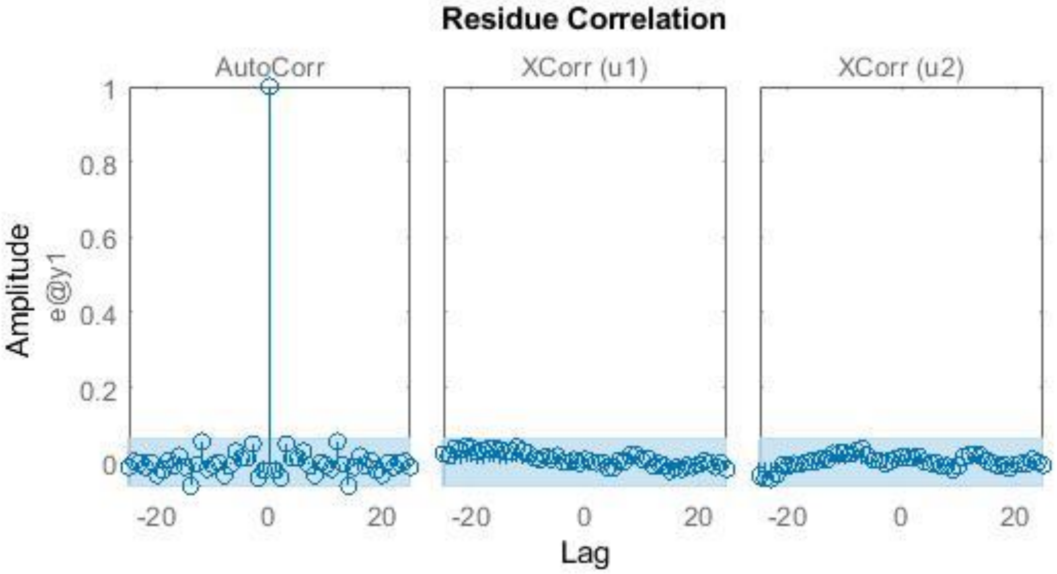


SBMHS: System Identification of MISO-I and MISO-II systems

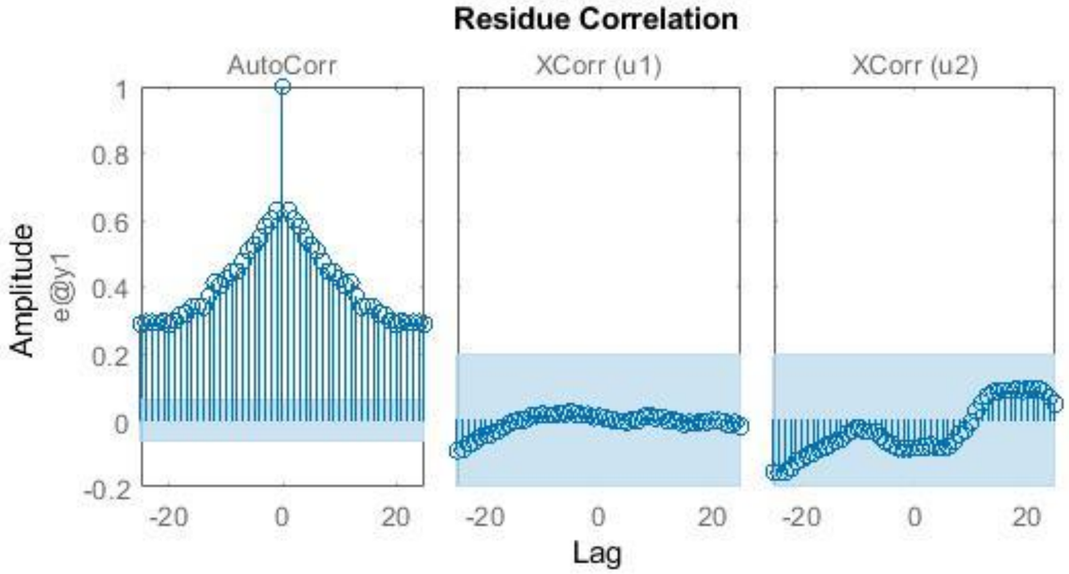


SBMHS: Residue Auto / Cross Correlation – MISO I & II

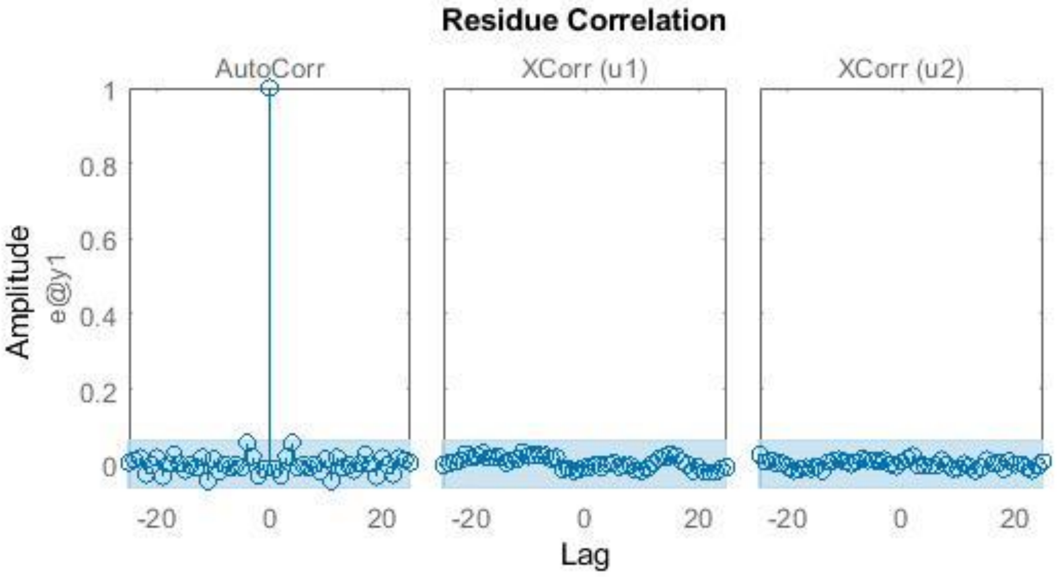
MISO-I (ARMAX)



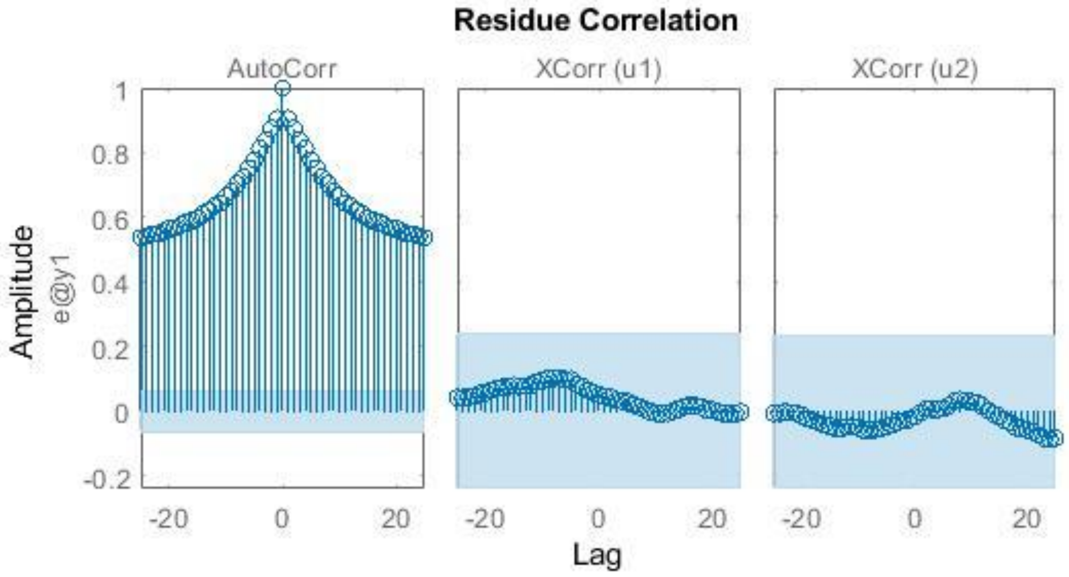
MISO-I (OE)



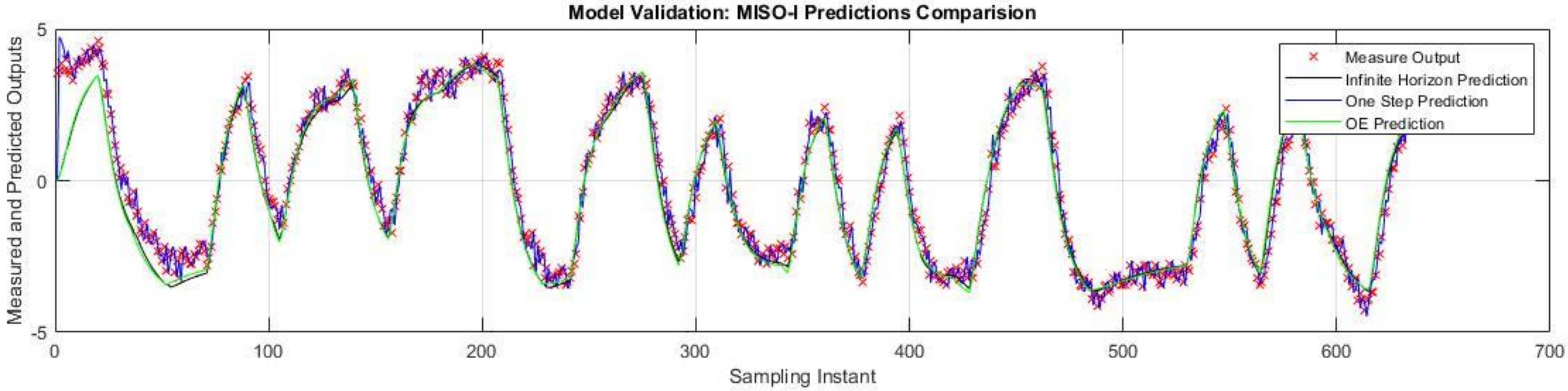
MISO-II (ARMAX)

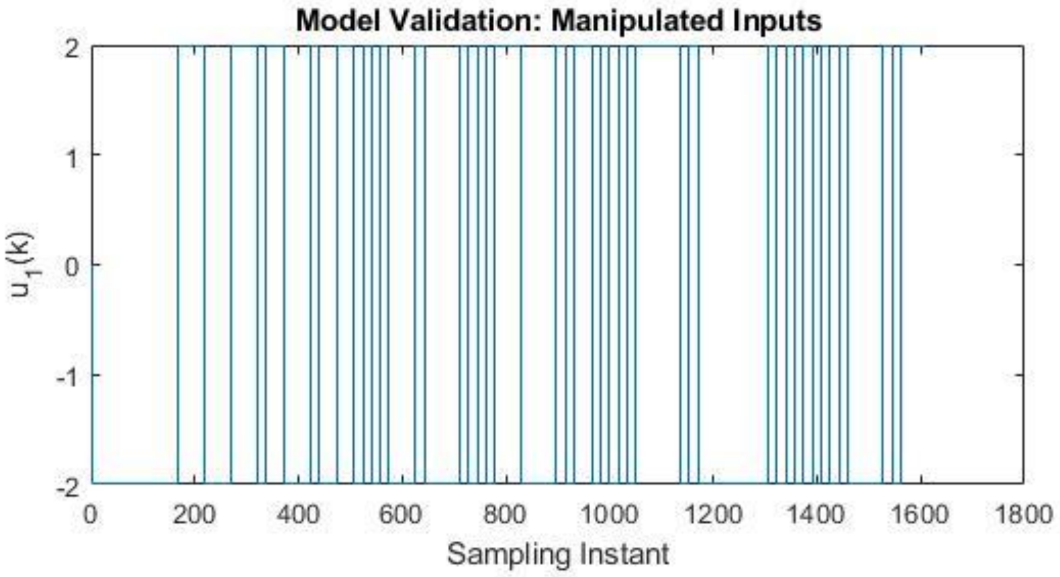


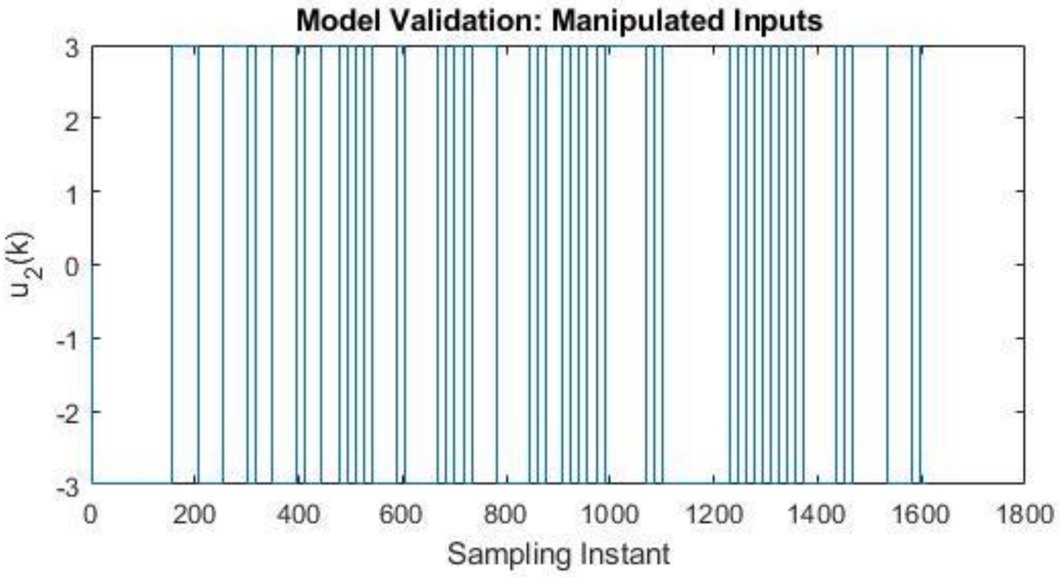
MISO-II (OE)



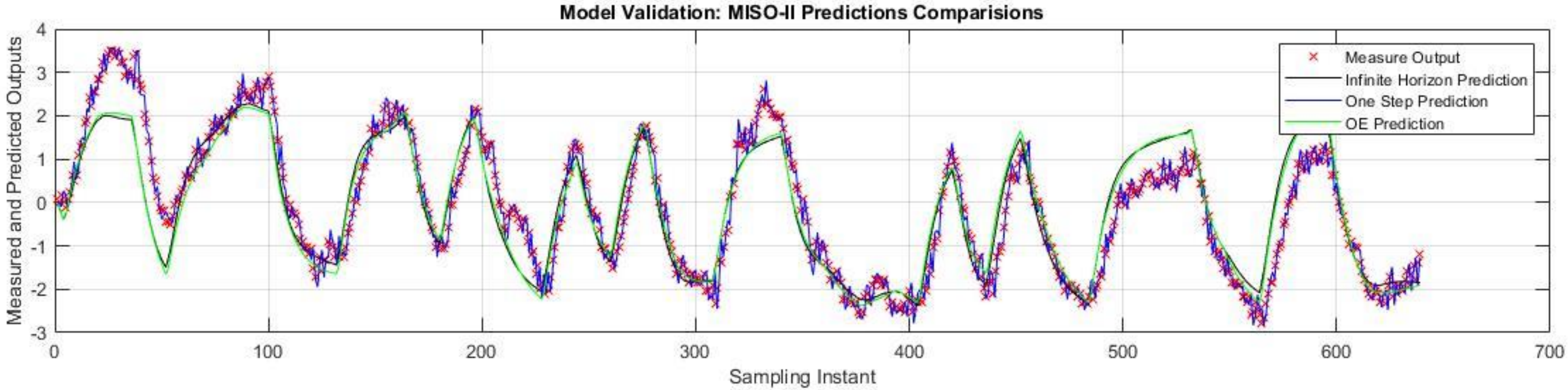
SBMHS: Model Validation – MISO - I

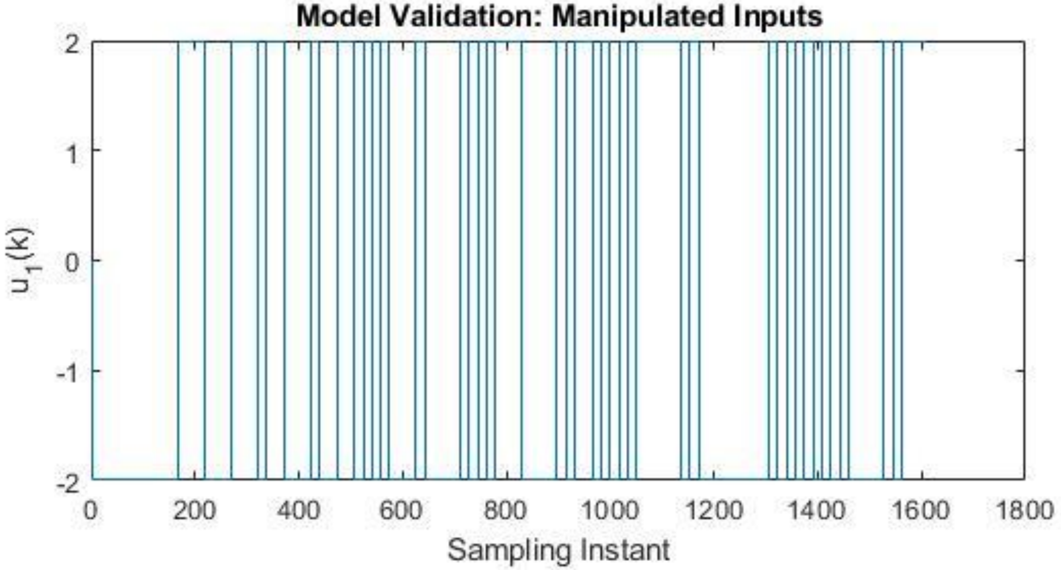


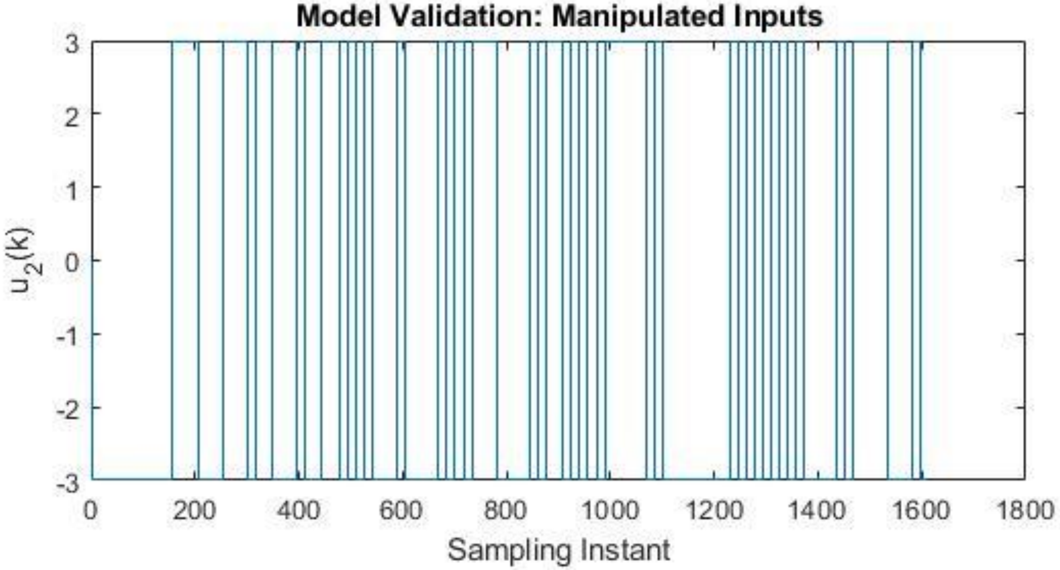




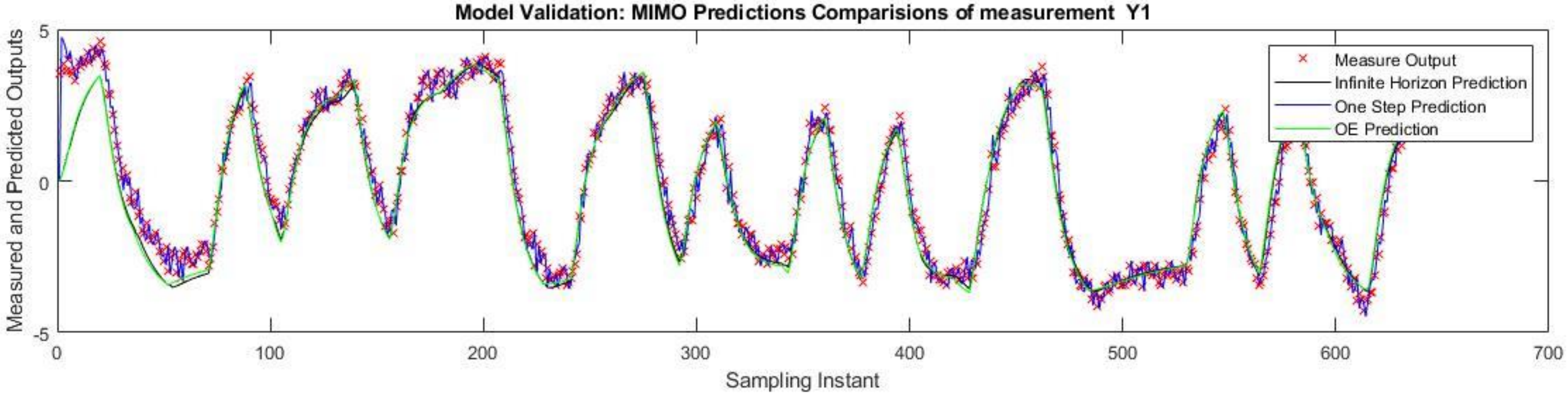
SBMHS: Model Validation – MISO - II

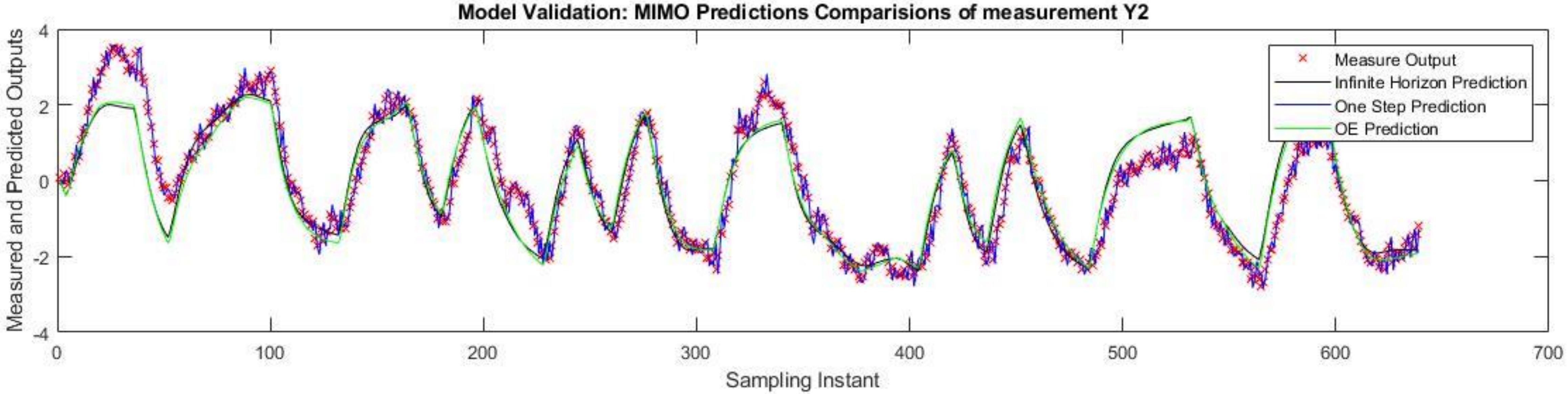




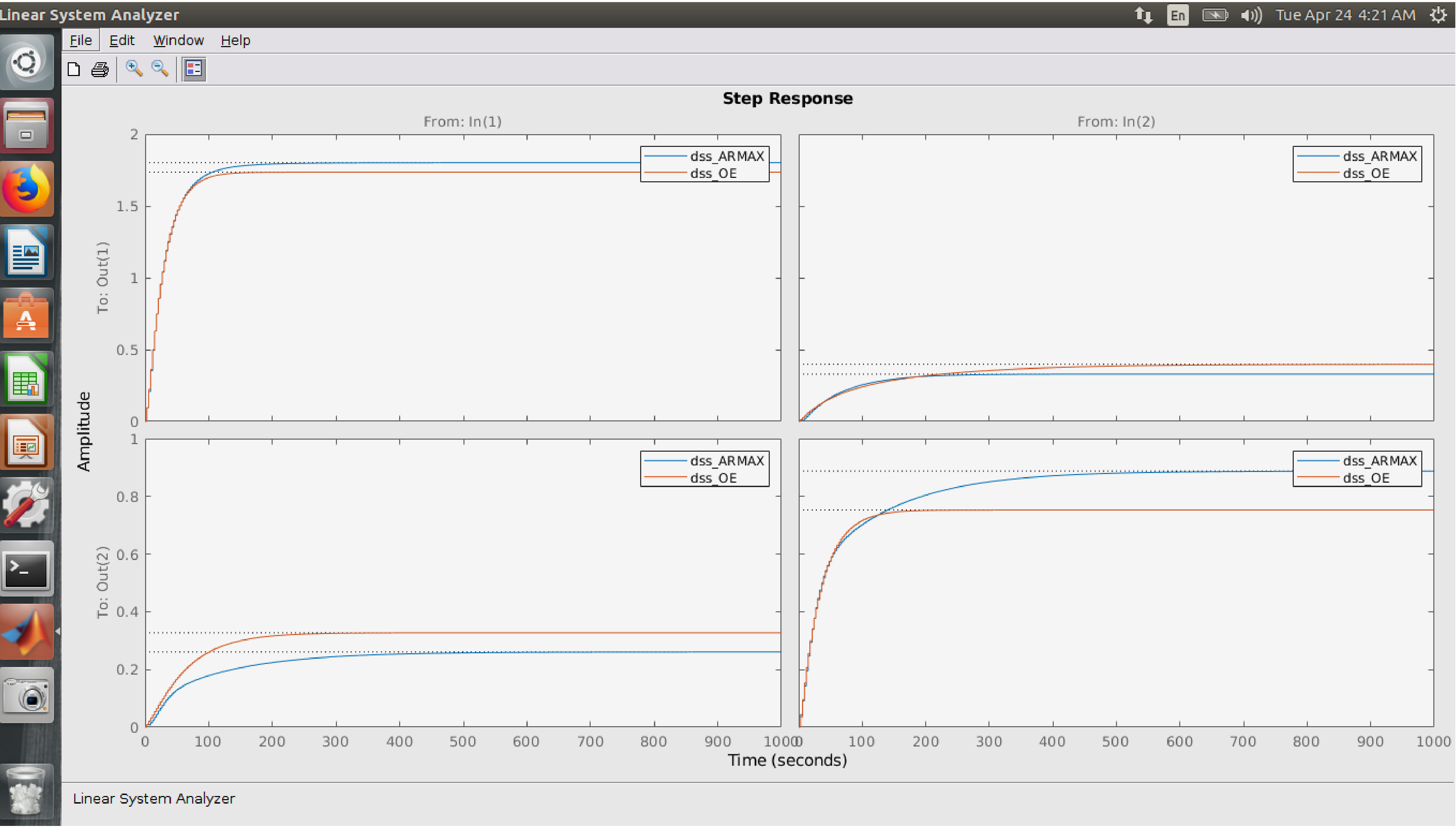


SBMHS: Model Validation – MIMO

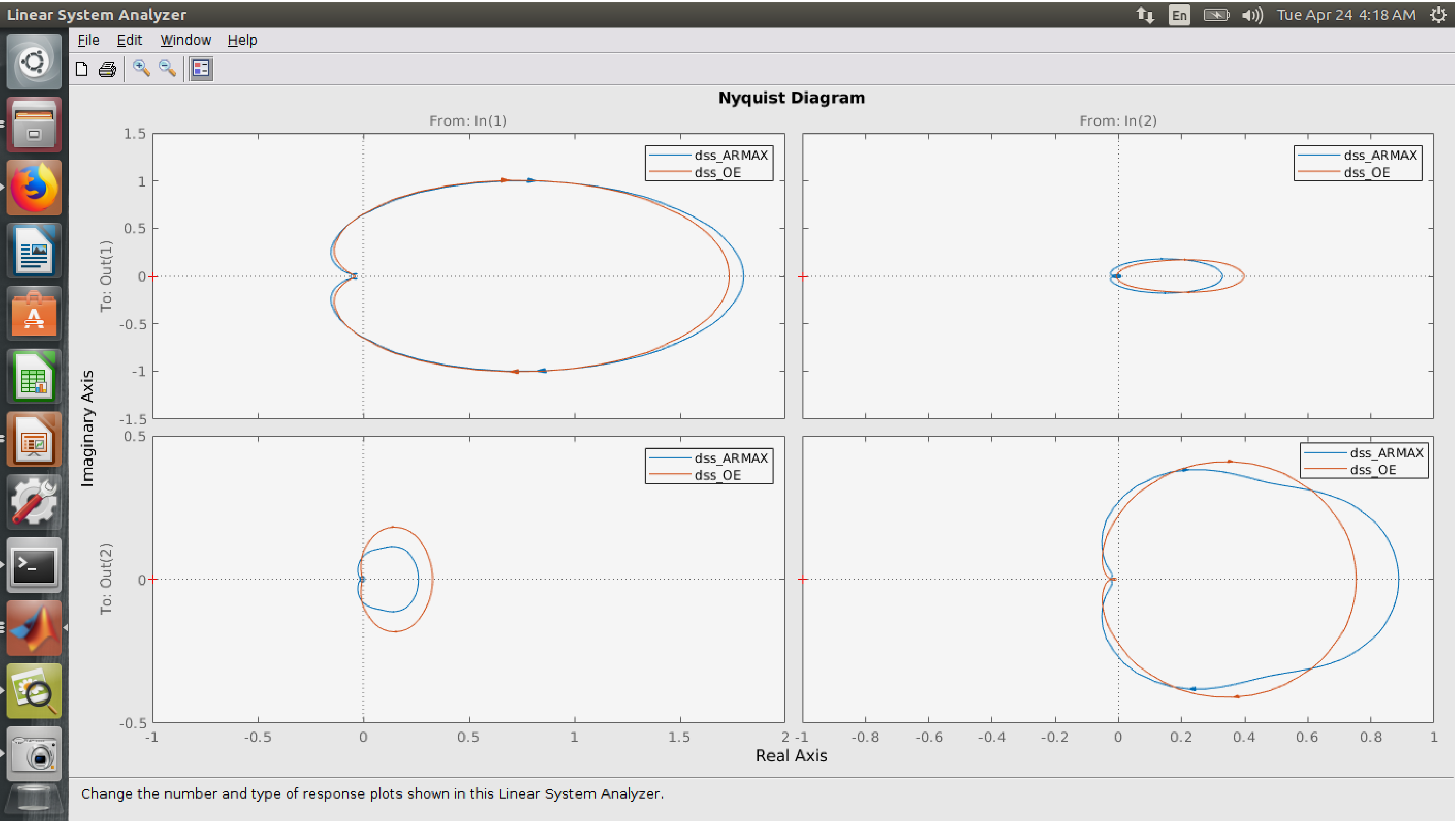




Step Response of ARMAX and OE Models



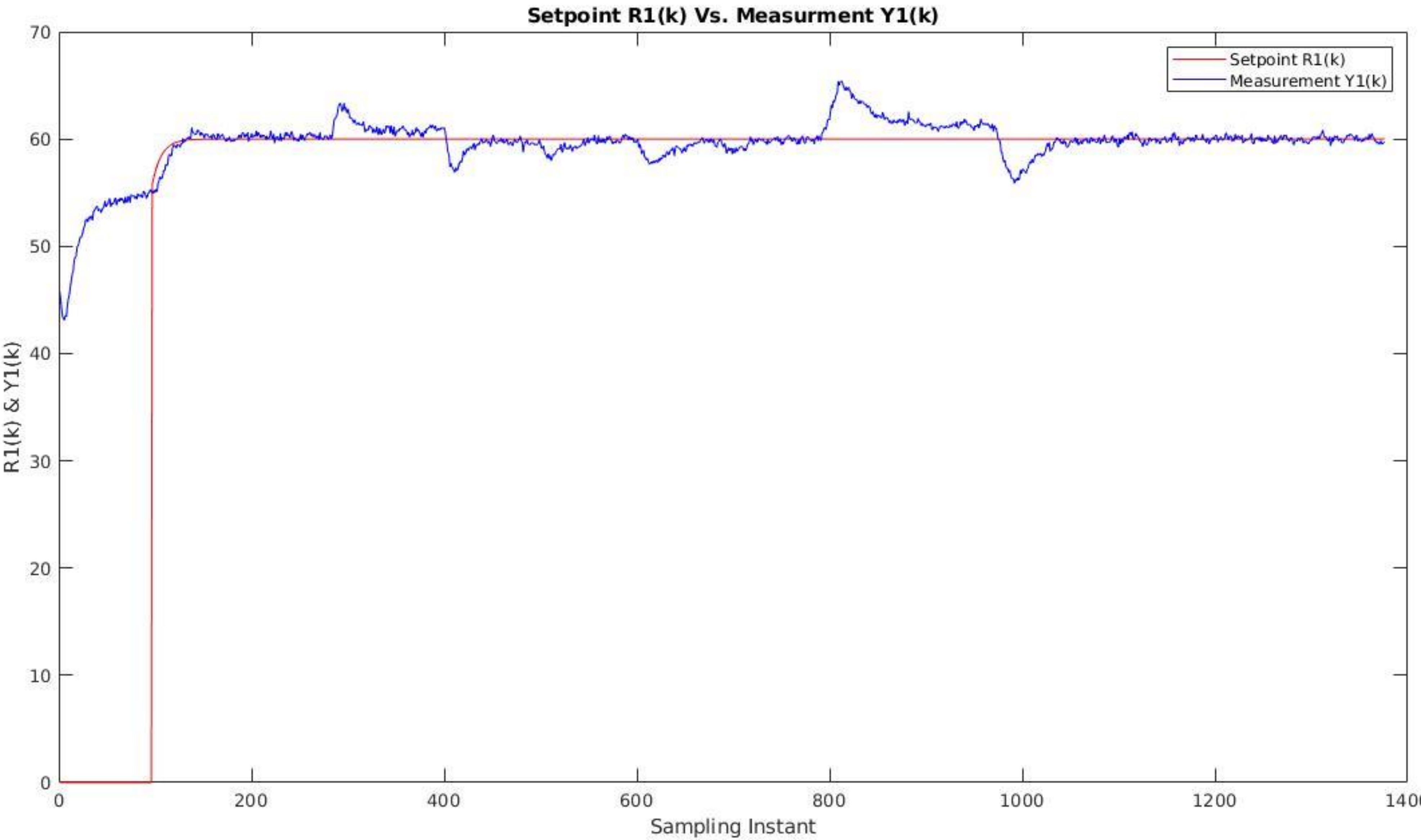
Nyquist Diagram of ARMAX and OE Models



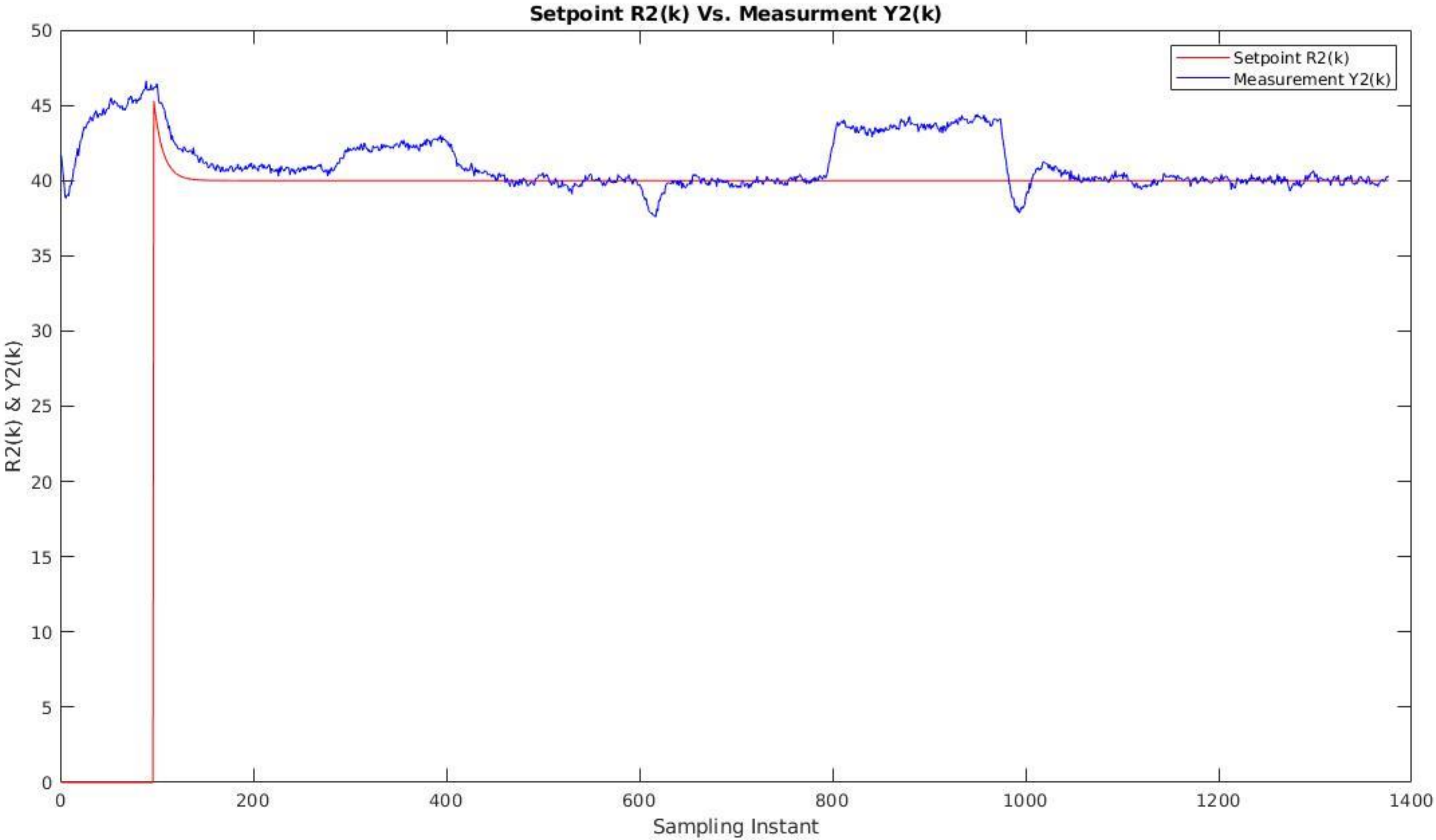
Linear Quadratic Optimal Controller Design and Implementation in the real Plant

Results and Plottings

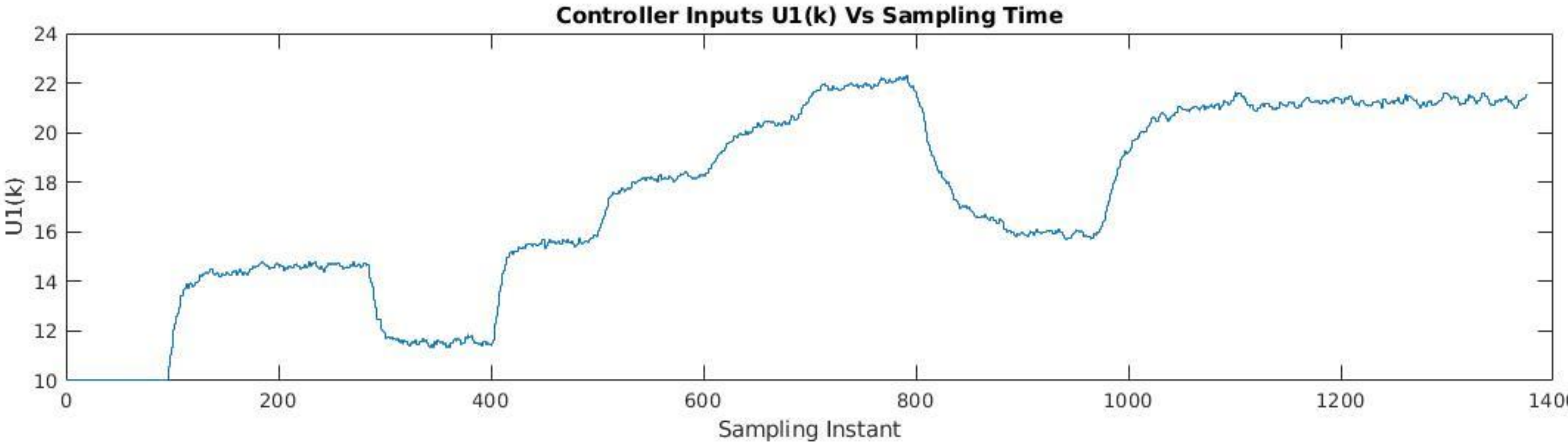
SetPoint_1 Vs. Measurement (Y_1(k)) Plot

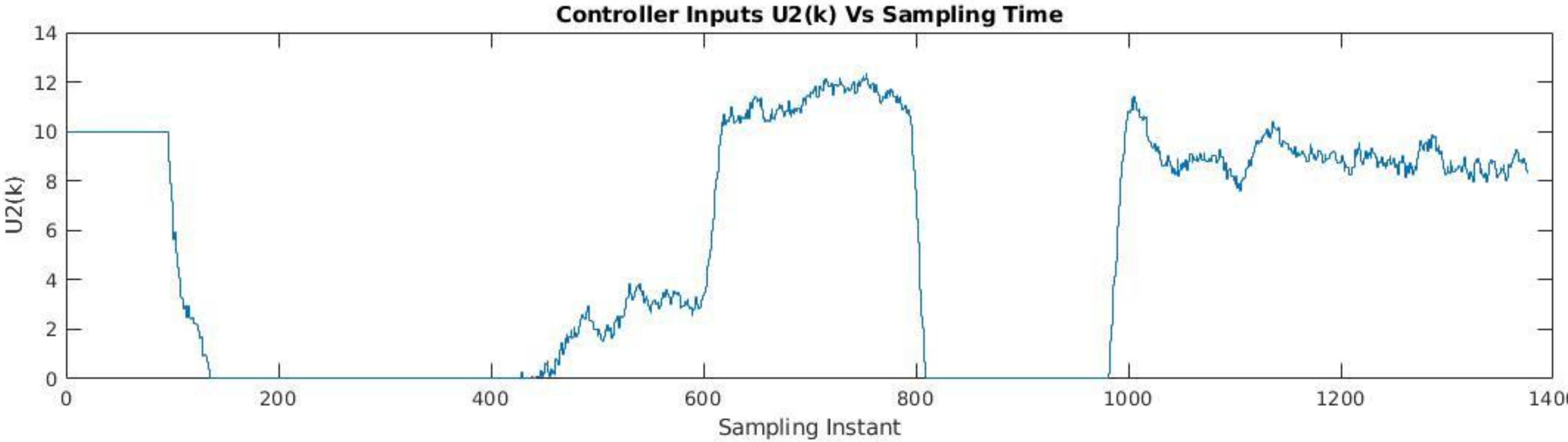


SetPoint_2 Vs. Measurement (Y_2(k)) Plot

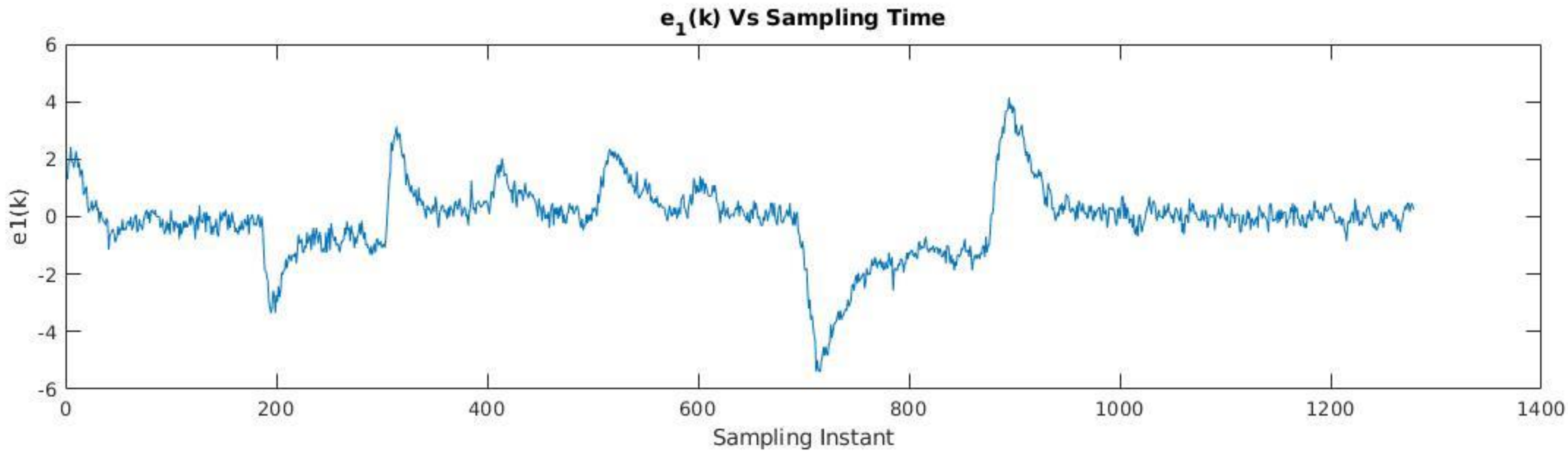


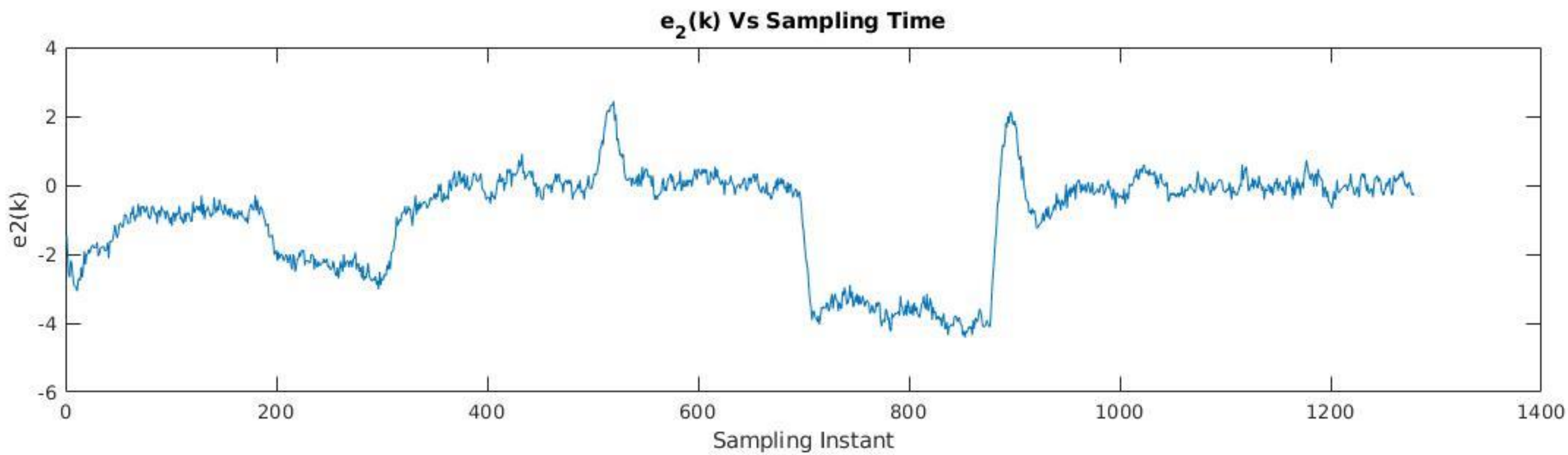
Controller Inputs Uk_1 and Uk_2





Plant-Model Mismatch (ek_1 and ek_2)





Disturbances employed during LQOC Implementation

Initial Conditions

- Fan Speed: 60
- H1=H2=H3=H4 = 10

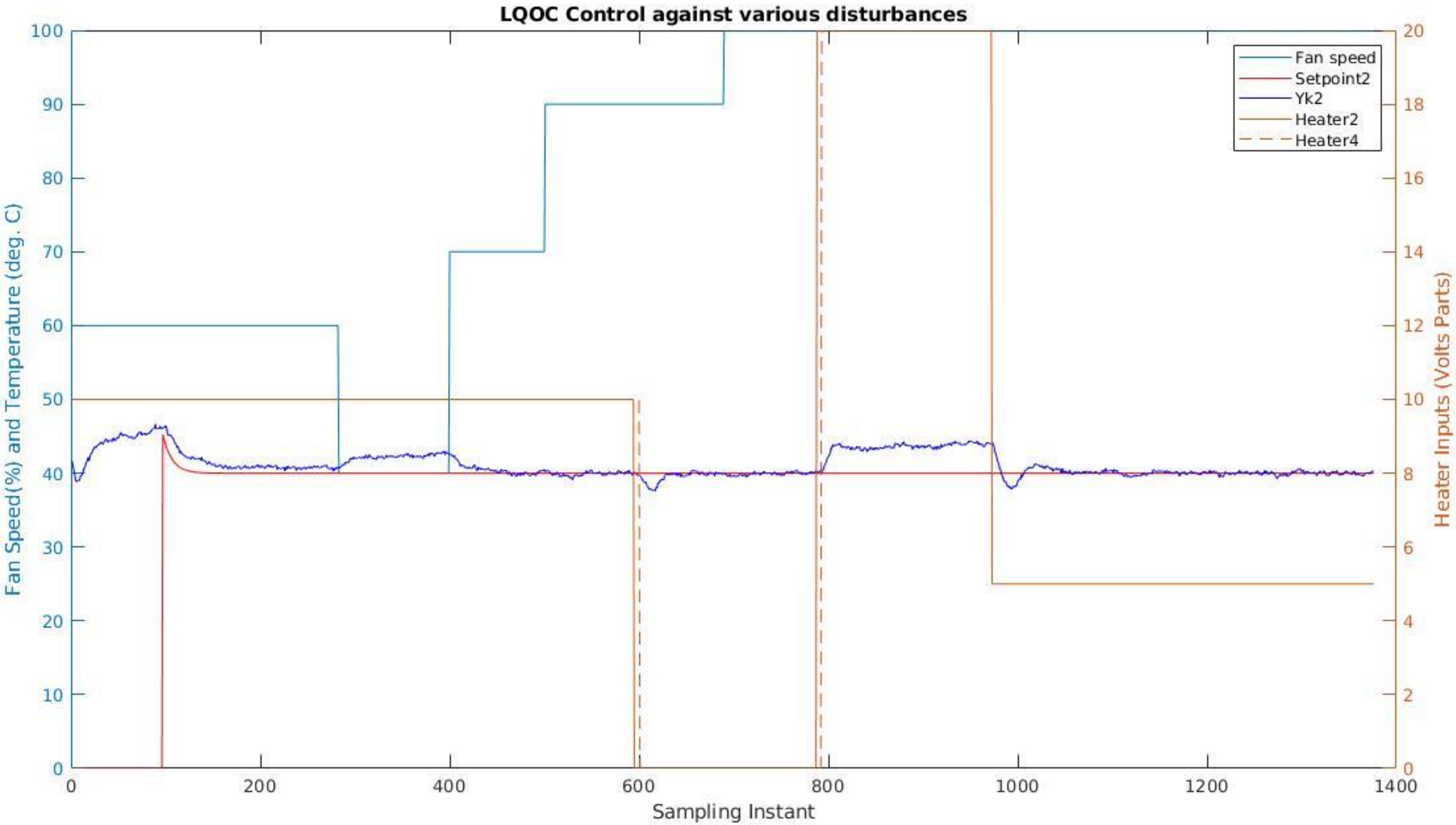
Set point employed

- Set_point_1 = 60
- Set_point_2 = 40

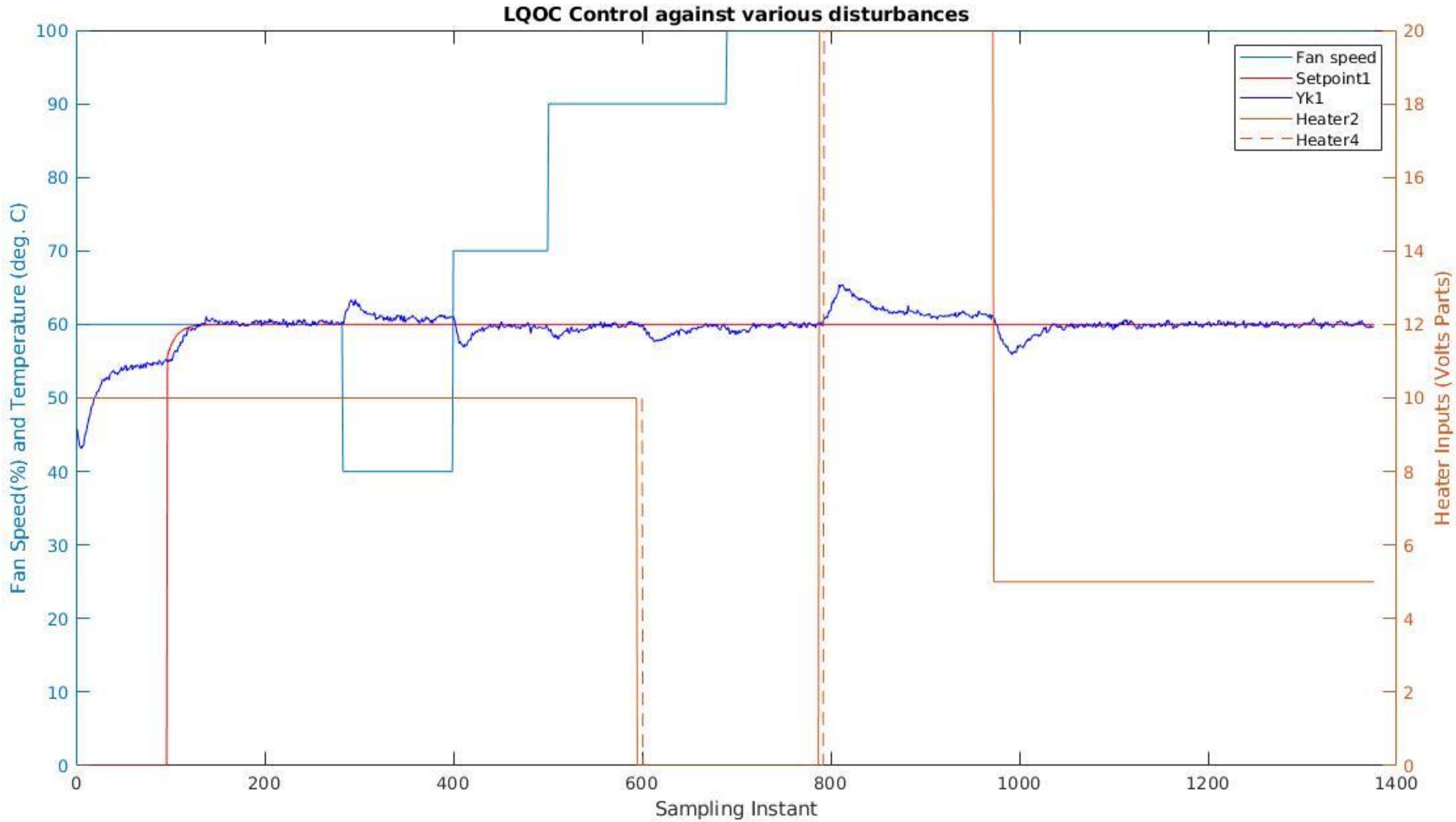
At different sampling instants

- K = 282 Fan-speed = 40
- K = 400 Fan-speed = 70
- K = 500 Fan-speed = 90
- K = 600 H2 = 0, H4 = 0
- K = 680 Fan-speed = 100
  & H2 = 0, H4 = 0
- K = 790 Fan-speed = 100
  H2 = 20, H4 = 20
- K = 970 Fan-speed = 100
  H2 = 5, H4 = 5

Setpoint_1 and Yk_1 against various disturbances



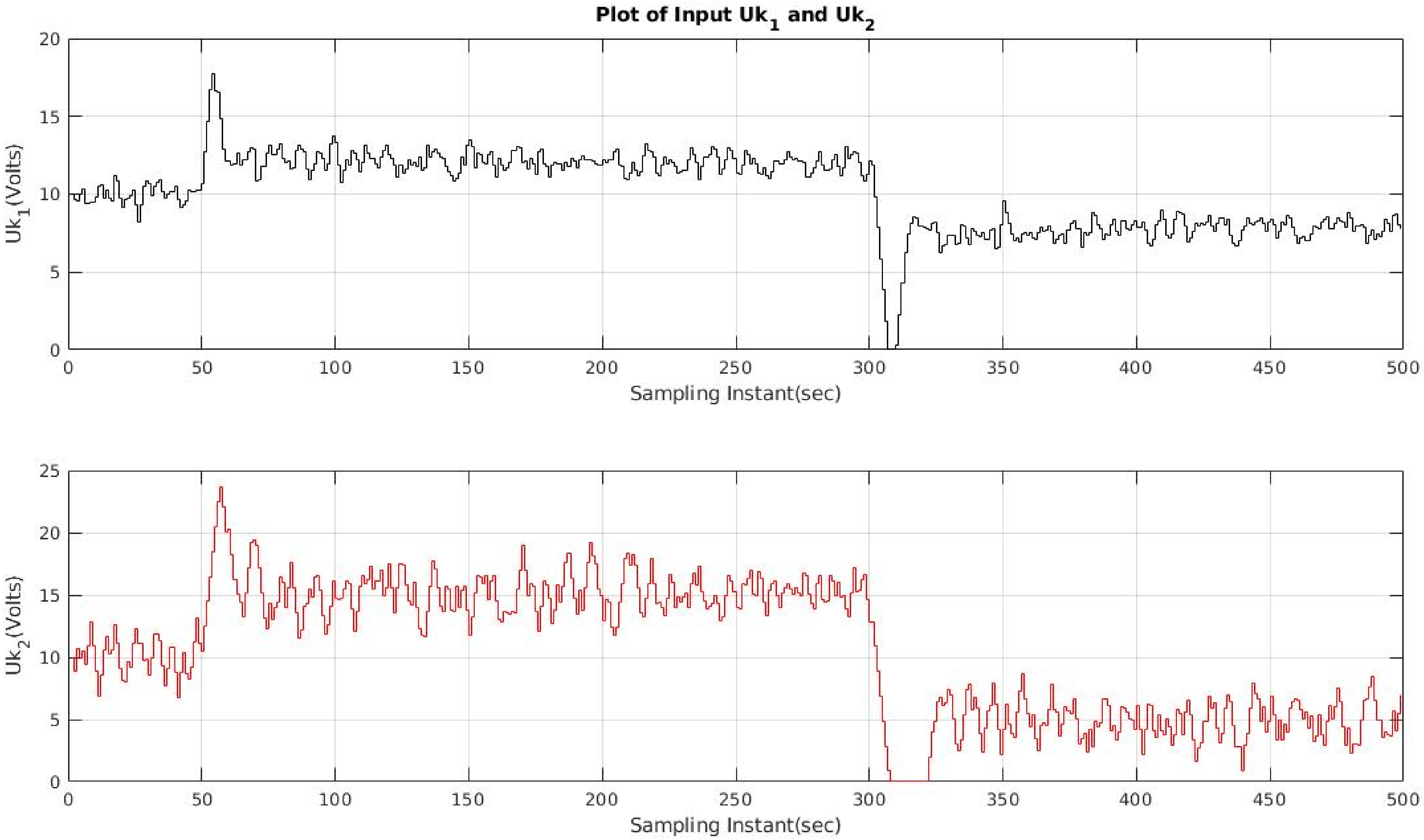
Setpoint_2 and Yk_2 against various disturbances



Model Predictive Control (MPC) Design

Results and Plottings

Plotting of MPC Controller Inputs Uk_1 (Volts) and Uk_2(Volts)



Plottings of Plant Outputs Yk_1 and Yk_2 after MPC Implementation