Project 4

System Identification of a Permanent Magnet DC Motor

Group: Sagar Vilas Jagtap, Robert Andringa

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Department of Mechanical and Aerospace Engineering

Florida Institute of Technology

Melbourne, Florida 32901

Objective

The objective of this project is to measure the input signal of the DC motor in real time using the XPC Target. And to calculate model parameters of the two gray box models of the DC motor using Prediction Error Method (PEM) in Matlab.

Setup

Selection of sampling time

As per the motor's datasheet, the motor itself counts 12 pulses/revolution. Taking into account that the motor has a gear ratio of 1:20, the encoder counts the motor shaft at the rate of 240 pulse/revolution. Since the encoder itself counts 4 counts each revolution, the number of counts per revolution is 960.

The motor at 12V gives an output of 300RPM, i.e., 5 rad/s. Which gives us a rate of 4800 Hz. That implies the maximum sampling time should be 2.083e-4 seconds. To ensure that no count is skipped, we divided that sampling time in half and took *0.0001 seconds* as our *Sampling Time*.

Input Signal

A PRBS signal was used for the model. The signal was generated using the 'idinput' function in MATLAB. With the Sampling time in mind, a desired upper range of 100001 was taken to run the experiment for about 10 seconds. An array of zeroes and ones suitable for data sampling at a rate of 10kHz over a frequency band from 0 to 5 Hz for a time period of 10 seconds was used.

The MATLAB code snippet shown below was used to generate the signal.

simin_cal.m

```
simin = idinput(100001,'prbs',[0,.001],[0 1]);
t = 0:0.0001:10;
simin = [t', simin];
```

Figure 1: PRBS Code

Sate Space Models and Matrices

Following are the state space matrices and model parameters calculated for each of the two models.

Model 1

State Space Equation:

In the form $\dot{x} = Ax + Bu; y = Cx + Du$

$$\begin{bmatrix} \frac{di}{dt} \\ \frac{d\theta}{dt} \\ \frac{d\dot{\theta}}{dt} \end{bmatrix} = \begin{bmatrix} -R/L & 0 & -\frac{K_b}{L} \\ 0 & 0 & 1 \\ \frac{K_t}{(J_M+J_L)} & 0 & \frac{-c}{(J_M+J_L)} \end{bmatrix} \begin{bmatrix} i \\ \theta \\ \dot{\theta} \end{bmatrix} + \begin{bmatrix} \frac{1}{L} \\ 0 \\ 0 \end{bmatrix} V \qquad \begin{bmatrix} i \\ \theta \\ \dot{\theta} \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} i \\ \theta \\ \dot{\theta} \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix} V$$

State Space with estimated parameters:

$$A = \begin{bmatrix} -584.4154 & 0 & -0.2646 \\ 0 & 0 & 1 \\ 947.2686 & 0 & -2.0630 \end{bmatrix} \qquad B = \begin{bmatrix} 104.5180 \\ 0 \\ 0 \end{bmatrix} \qquad C = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \qquad D = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}$$

Equating the calculated values with the state space equations result in the following parameter values.

L = 0.00956773 H

R = 5.591528732 Ohm

Kb = Kt = 0.025316214

Jm+Jl = 2.672548631e-5 kgm2

c = 5.513467825e-5

Model 2

State Space Equation:

In the form $\dot{x} = Ax + Bu; y = Cx + Du$

$$\begin{bmatrix} \frac{d\theta}{dt} \\ \frac{d\dot{\theta}}{dt} \end{bmatrix} = \begin{bmatrix} 0 & 1 \\ 0 & \frac{-cR-K_BK_T}{R(J_M+J_L)} \end{bmatrix} \begin{bmatrix} \theta \\ \dot{\theta} \end{bmatrix} + \begin{bmatrix} 0 \\ \frac{K_t}{R(J_M+J_L)} \end{bmatrix} V \qquad \begin{bmatrix} \theta \\ \dot{\theta} \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} \theta \\ \dot{\theta} \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \end{bmatrix} V$$

State Space with estimated parameters:

$$A = \begin{bmatrix} 0 & 1 \\ 0 & -1.0479 \end{bmatrix} \qquad B = \begin{bmatrix} 0 \\ 69.5039 \end{bmatrix} \qquad C = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} \qquad D = \begin{bmatrix} 0 \\ 0 \end{bmatrix}$$

Plots

Model 1

a) Time Domain PRBS fitting data compared with simulated response

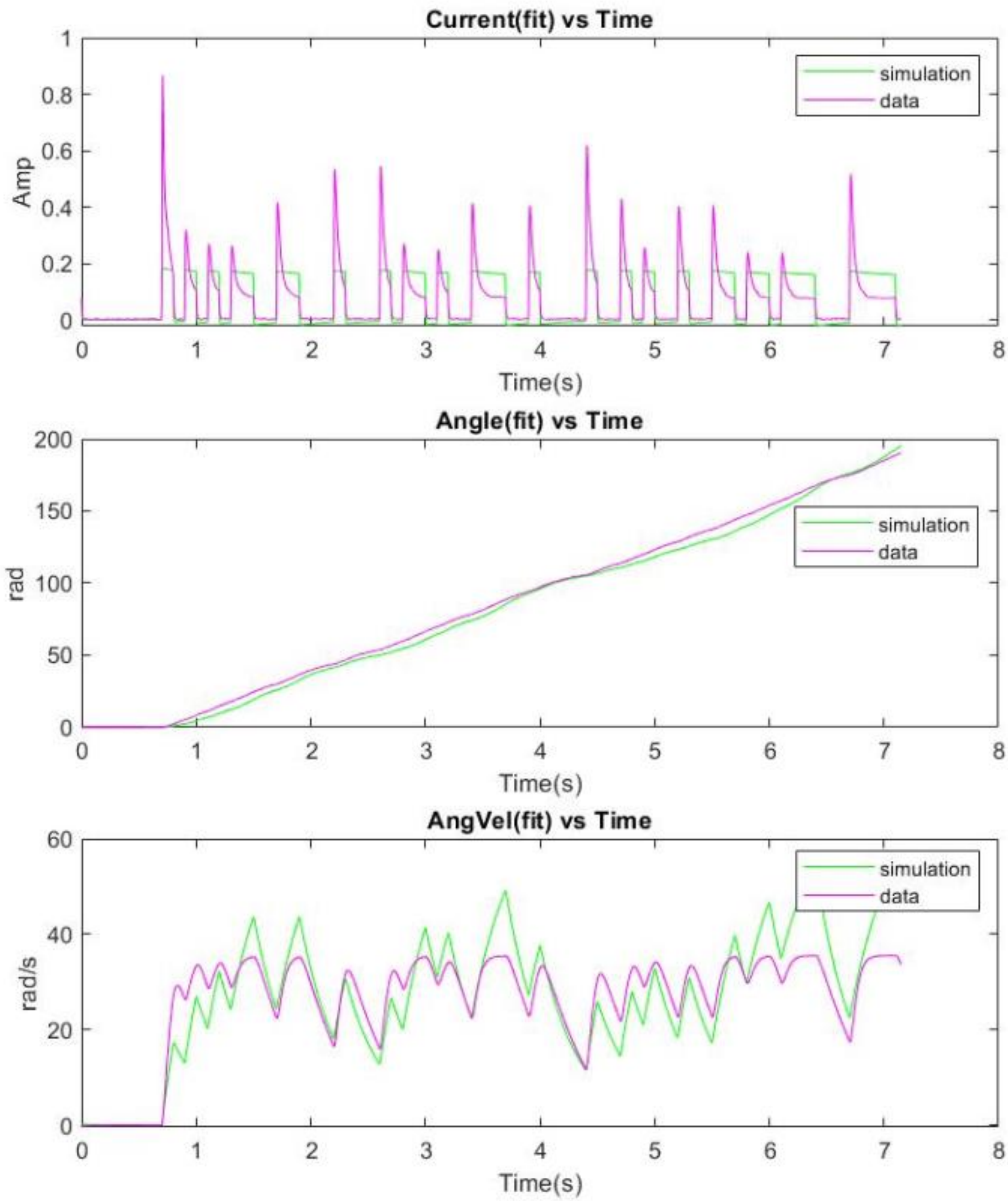


Figure 2: Simulated model compared with training set

b) Time Domain: PRBS validation set compared with simulated response

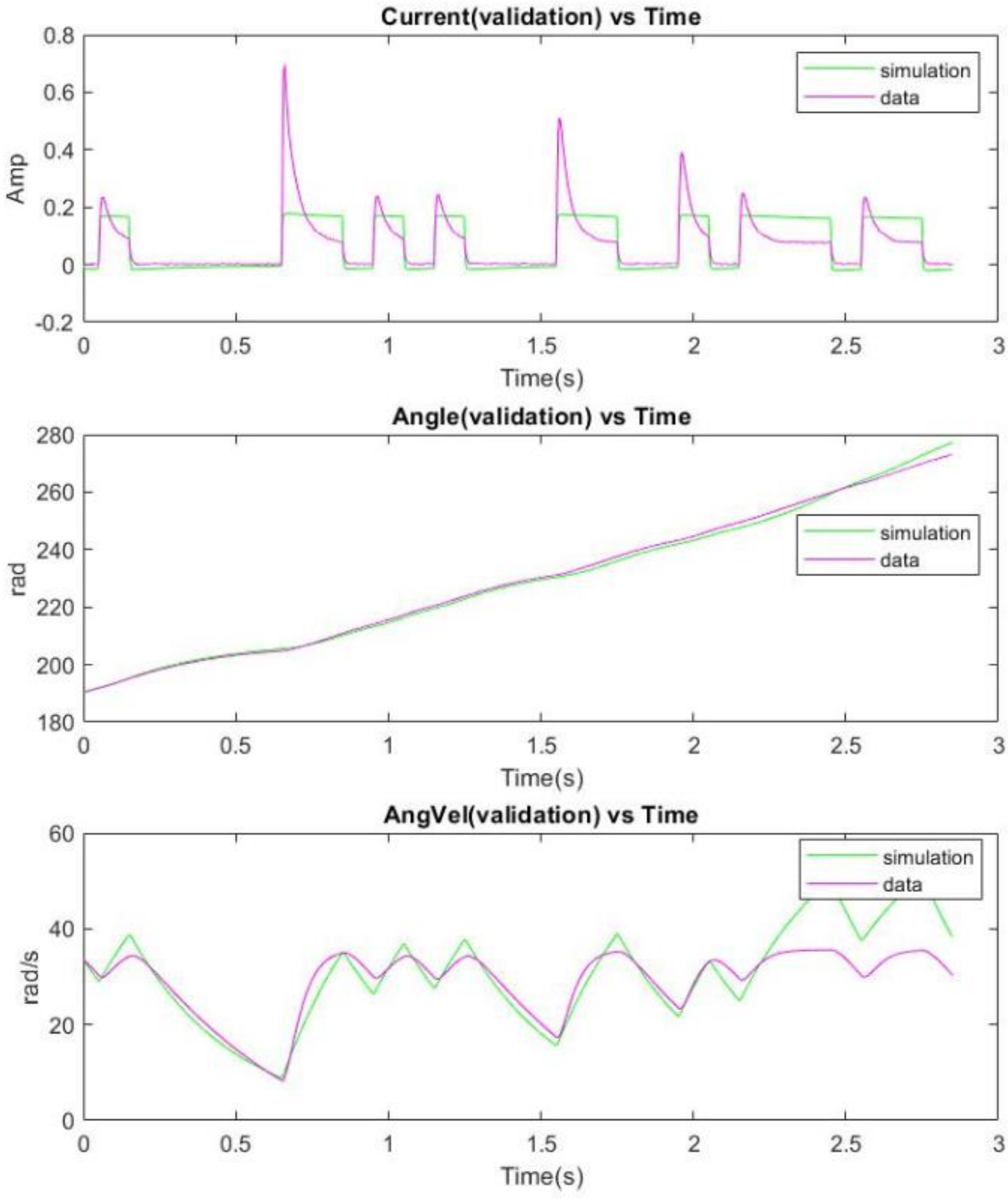


Figure 3: Simulated model compared to validation.

c) Frequency response

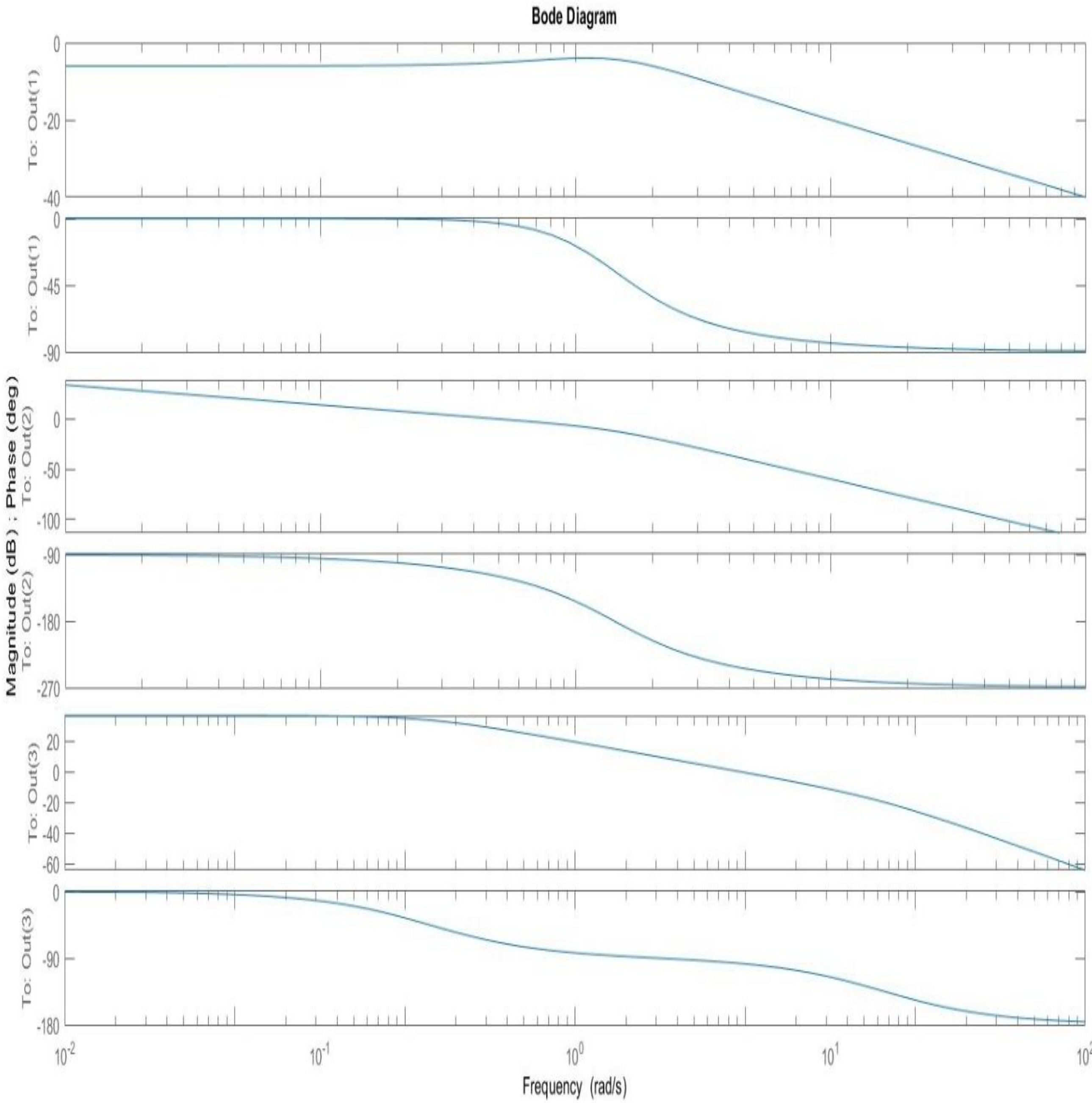
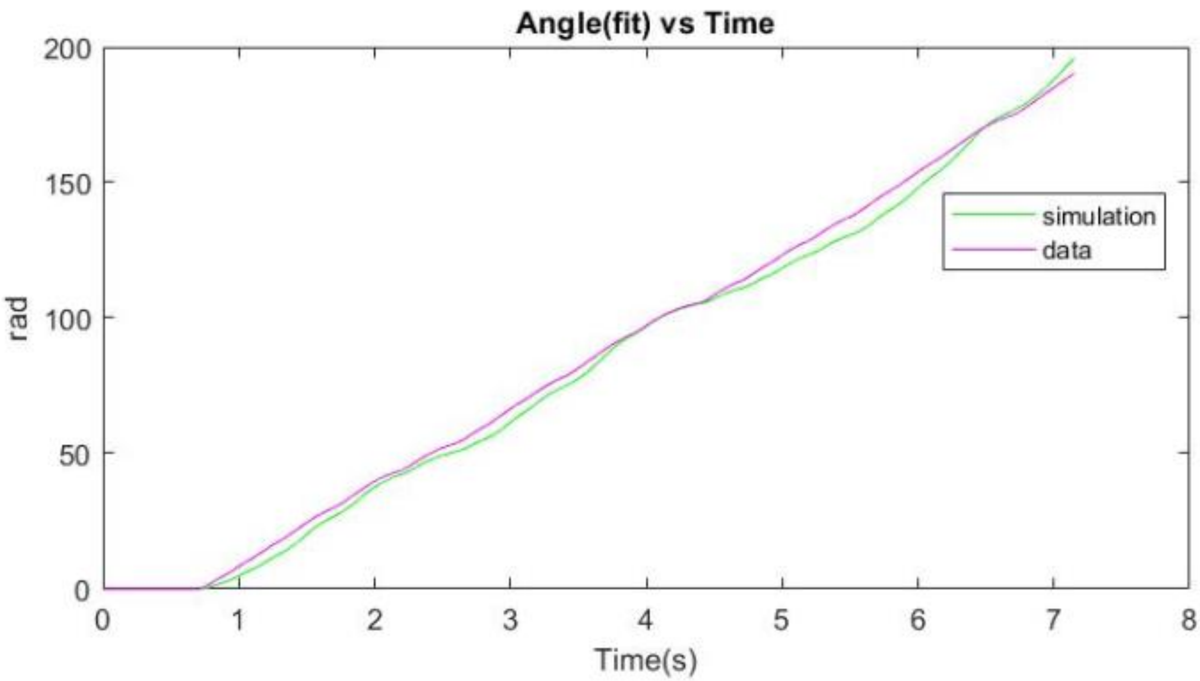


Figure 4: Frequency response (Out(1): Current, Out(2): Angle, Out(3): Angular Velocity)

Model 2

a) Time Domain PRBS fitting data compared with simulated response



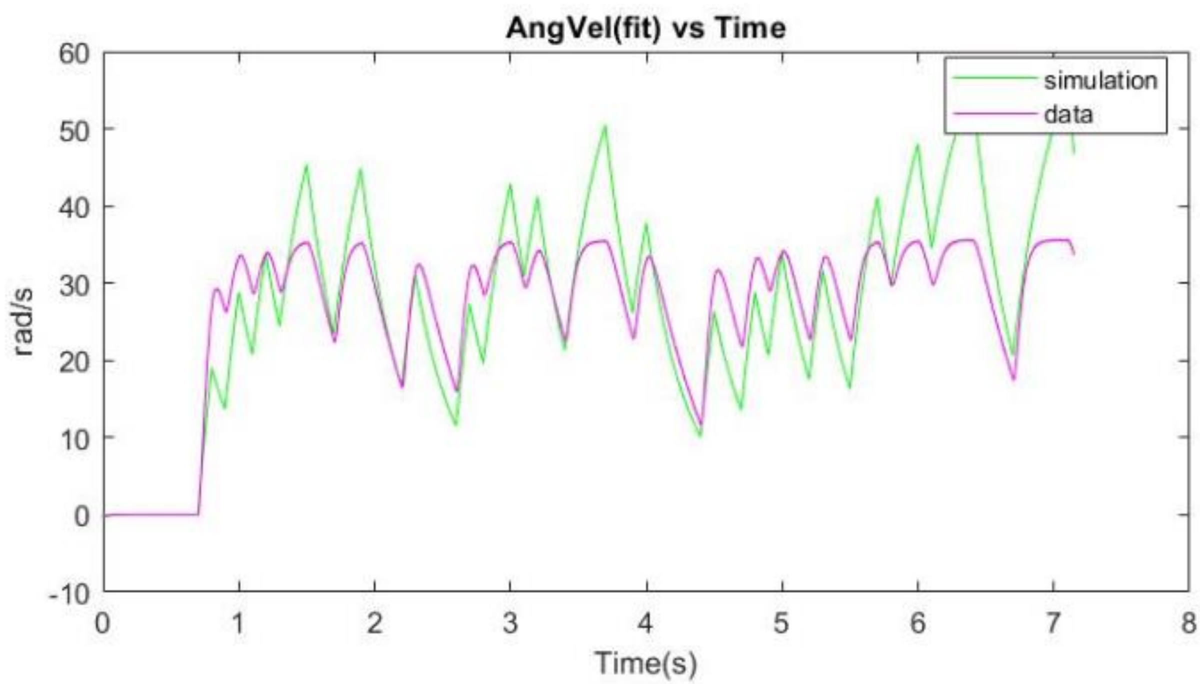


Figure 5: Simulated model compared with fitting data

b) Time Domain: PRBS validation set compared with simulated response

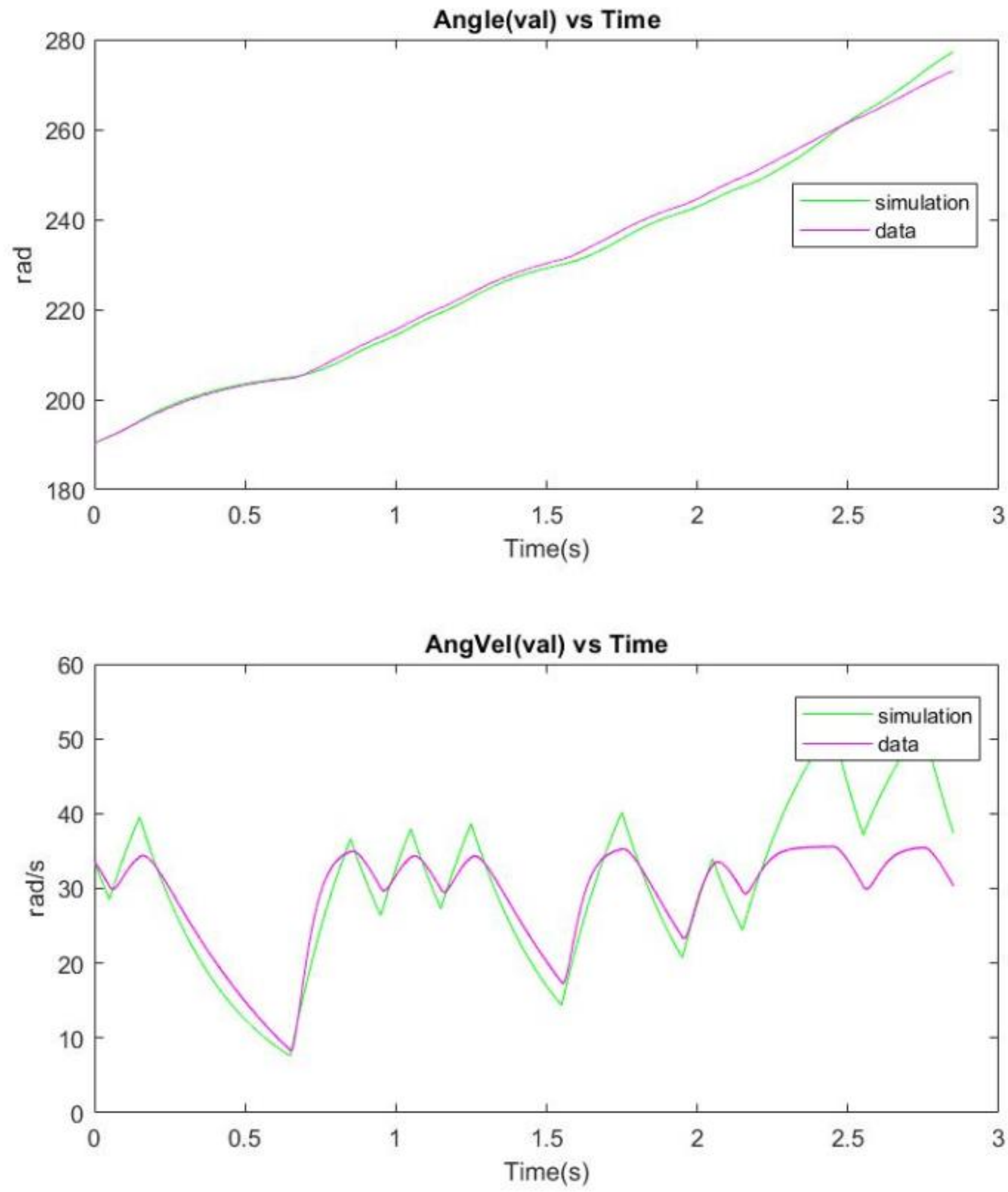
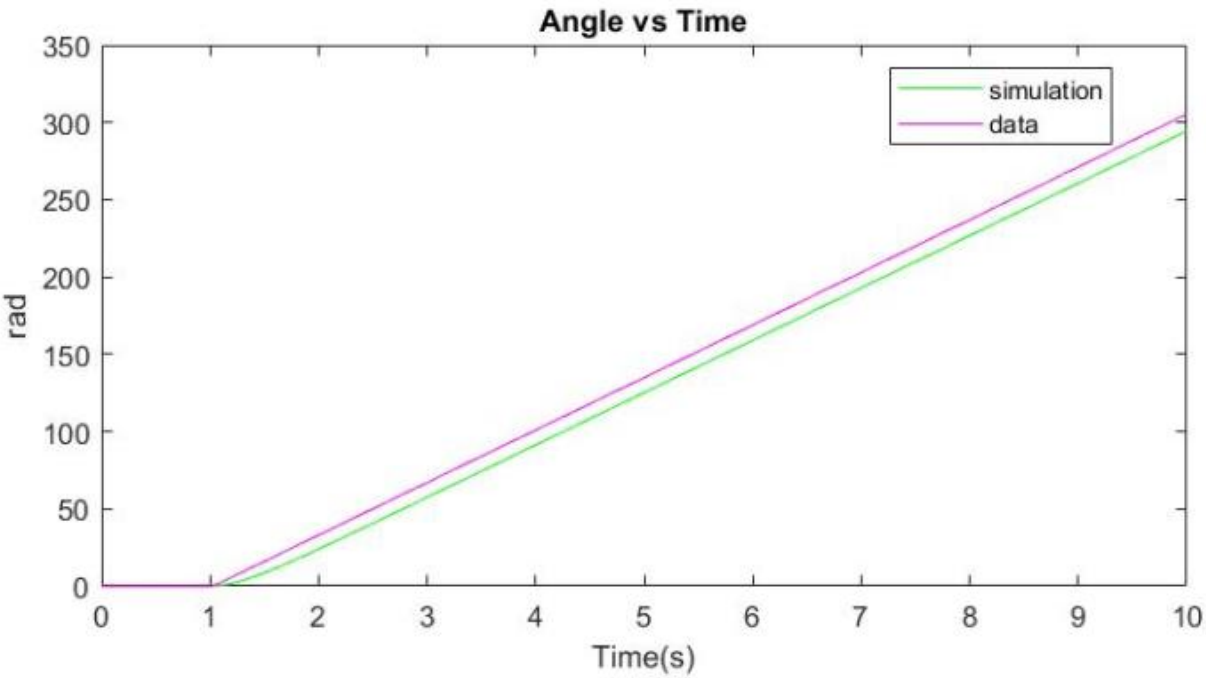


Figure 6: Simulated model compared with validation data

c) Model Validation with Step Signal



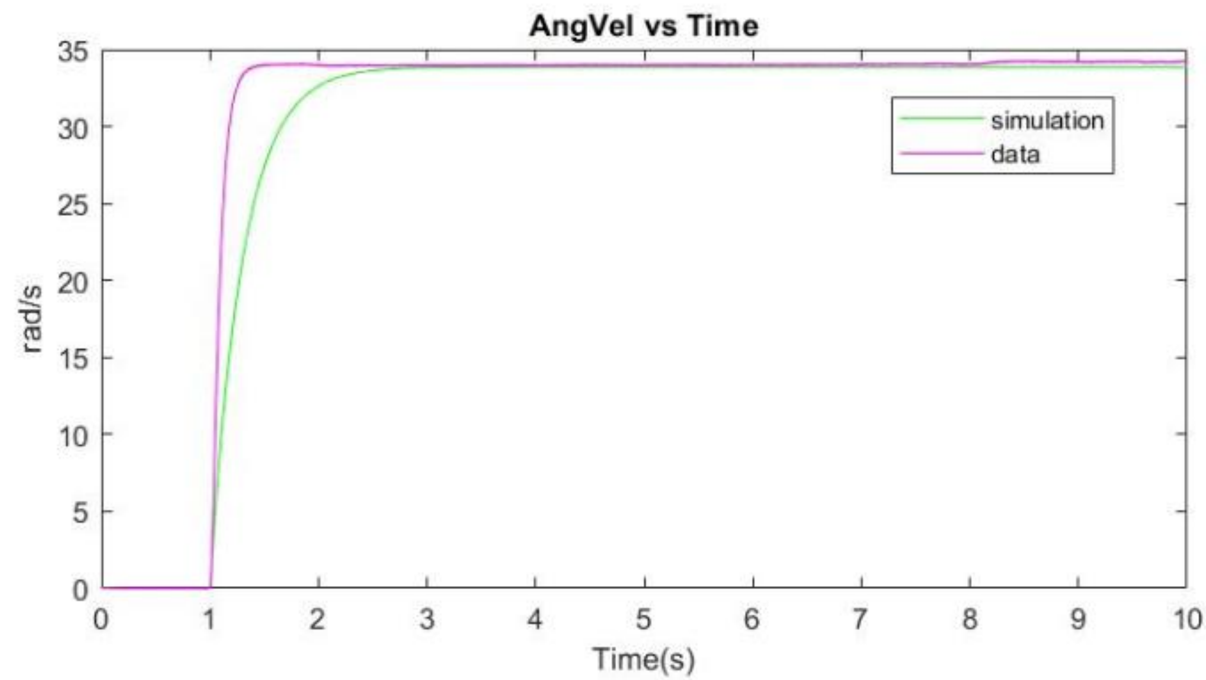
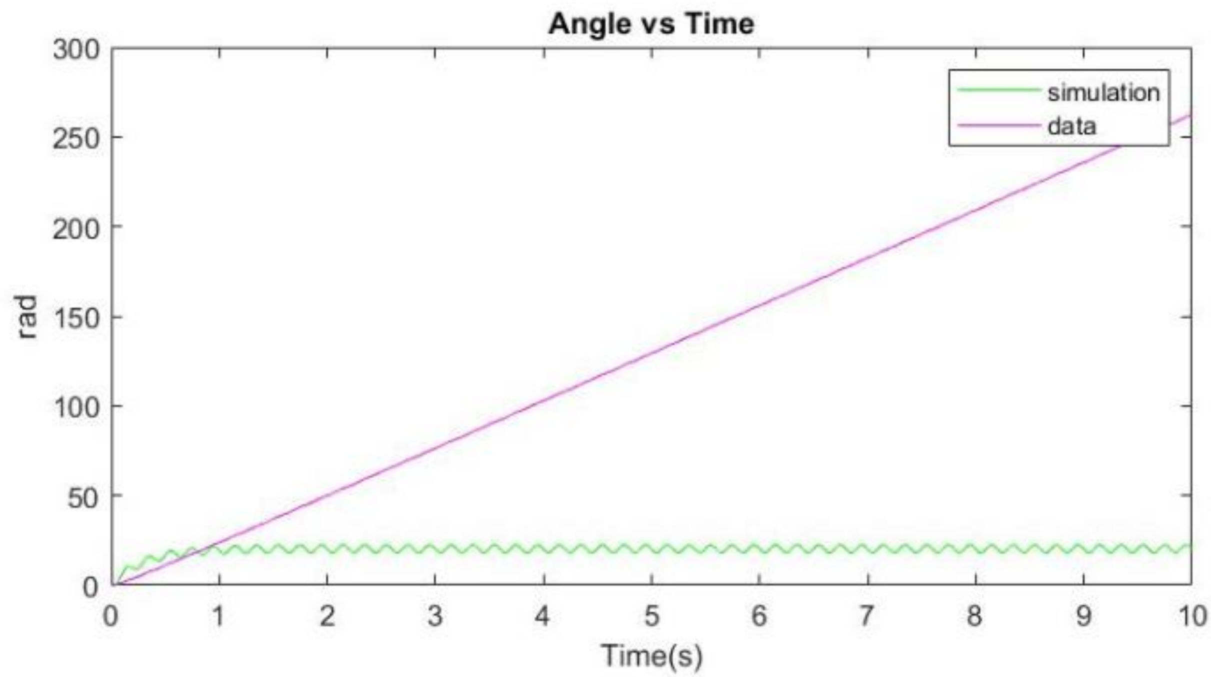


Figure 7: Simulated response for step input compared with measured data

d) Model Validation with Triangle Signal



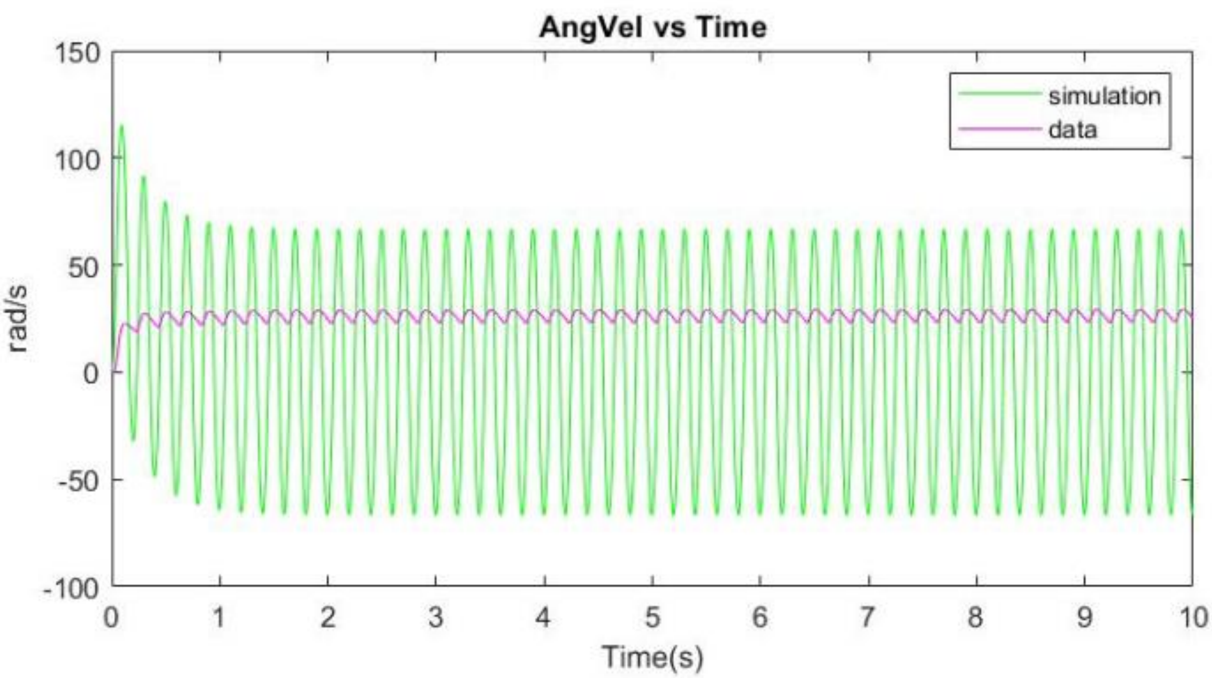


Figure 8: Simulated response for step impulse compared with measured data

e) Frequency response/Bode Plot (y1: Angle, y2: Angular Velocity)

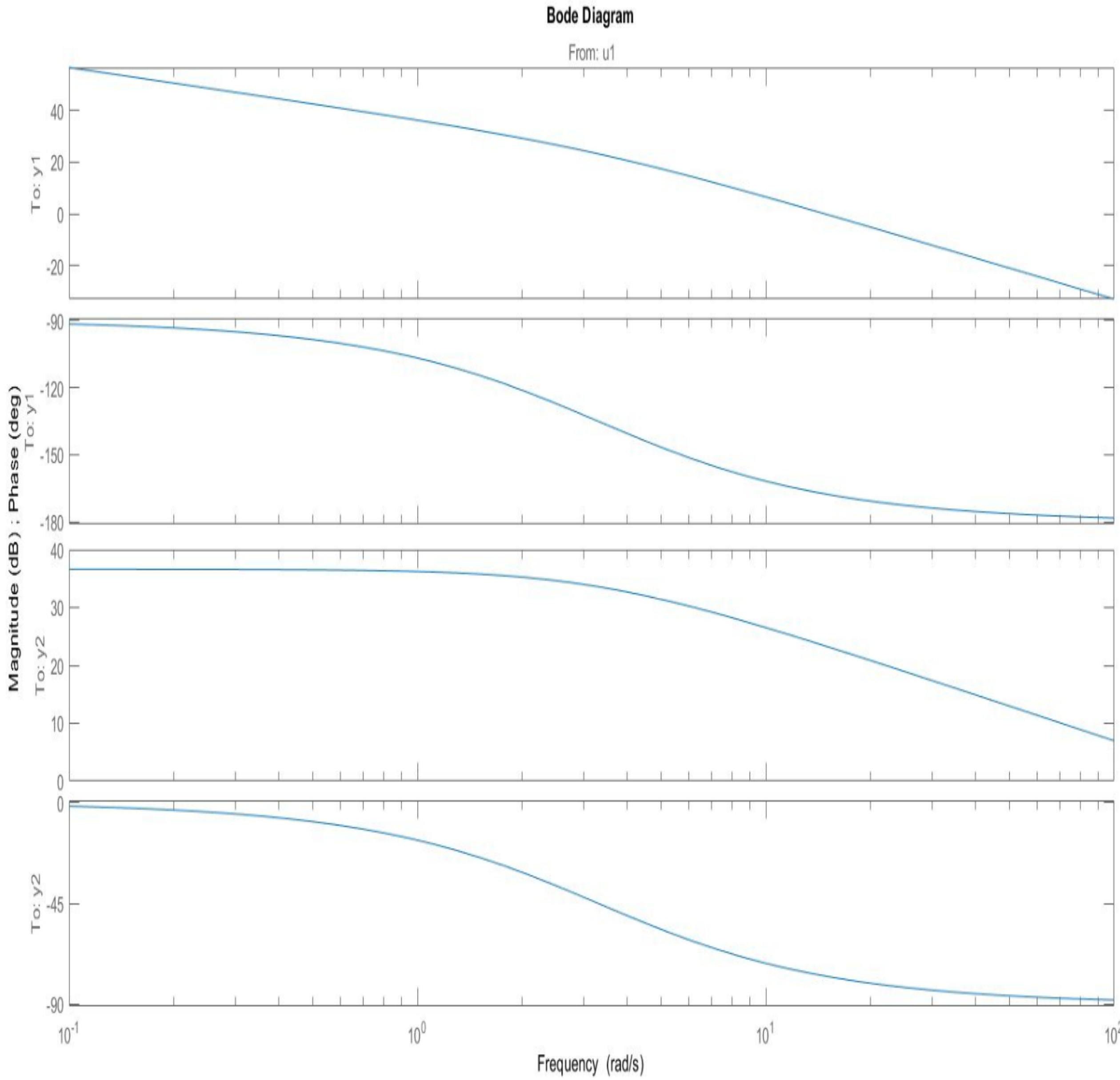


Figure 9: Frequency response (y1: Angle, y2: Angular Velocity)