Tecnológico de Monterrey
Escuela de Ingeniería y Ciencias

Monterrey Campus

Autonomy of Unmanned Aerial Vehicles

MR3003C.601

Report:

Practice 02 System Identification of DC Motor Velocity

Name:

Carlos Hernán Auquilla Larriva | A00834778

Teachers:

Carlos Gustavo Sotelo Molina, Ph.D

David Alejandro Sotelo Molina, Ph.D

Due date:

August 13th, 2024

Table of contents

Table of figures

1. Complete Block Diagram

The behavior of the three models (Ziegler-Nichols, Miller, Analytic) and the actual measured system was simulated in the following block diagram, as you can see in Figure 1.

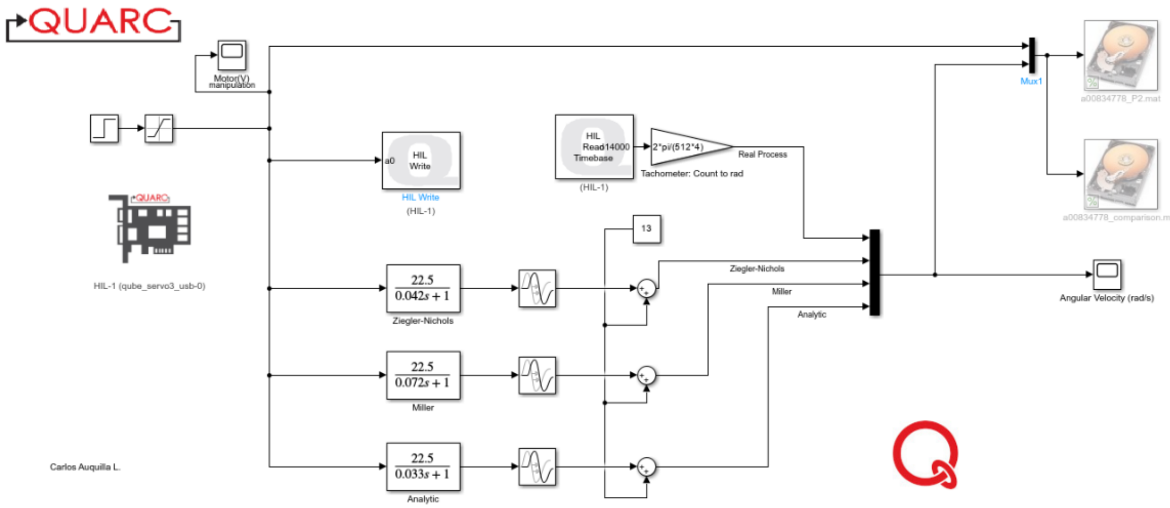

Figure 1 Complete Block Diagram

2. Code Generated to Plot the Input-Output Data

After obtaining the necessary data from real measurements, the code in figure 2 was generated to plot the measurements and then apply different techniques to model the actual system.

```
%Instituto Tecnológico y de Estudios Superiores de Monterrey
%Name: Carlos Hernán Auquilla Larriva
%Course: Autonomy of Unmanned Aerial Vehicles
%Last update: August 13th 2024
clc; clear;close all;

%%Practice 2
%Load data
load('a00834778_comparison.mat');

%Period of time for analysis
init_time = 3;
final_time = 5;
init_index = init_time * 500 + 1;
final_index = final_time * 500 + 1;
partial_index = init_index:final_index; %Takes values from init_time to final_time

%Load only necessary data
t = data(1,partial_index);
voltage = data(2,partial_index);
ang_vel_real = data(3,partial_index);
ang_vel_zn = data(4,partial_index);
ang_vel_miller = data(5,partial_index);
ang_vel_an = data(6,partial_index);

```

Figure 2 Code to Extract Data Obtained from Real Measurements

```
%Plot section
subplot(2,1,1);
plot(t,ang_vel_real,"r");
ylabel('w_m(t) [rad/s]');
xlim([init_time final_time])
ylim([70 140])
grid on;

subplot(2,1,2);
plot(t,voltage,"--b")
ylabel('V_m [V]');
xlabel('Time [sec]')
xlim([init_time final_time])
ylim([2 6])
grid on;

%Real response
figure;
plot(t,ang_vel_real,"r");
ylabel('w_m(t) [rad/s]');
xlabel('Time [sec]');
grid on;

```

Figure 3 Code for Plot Data

3. Parameter Identification Process and 1st Order Transfer Function with Time Delay Obtained

An input step from 3 to 5 volts was applied in the system, in the following steps the initial value of velocity obtained in the period before the 3 seconds will become important to improve our models.

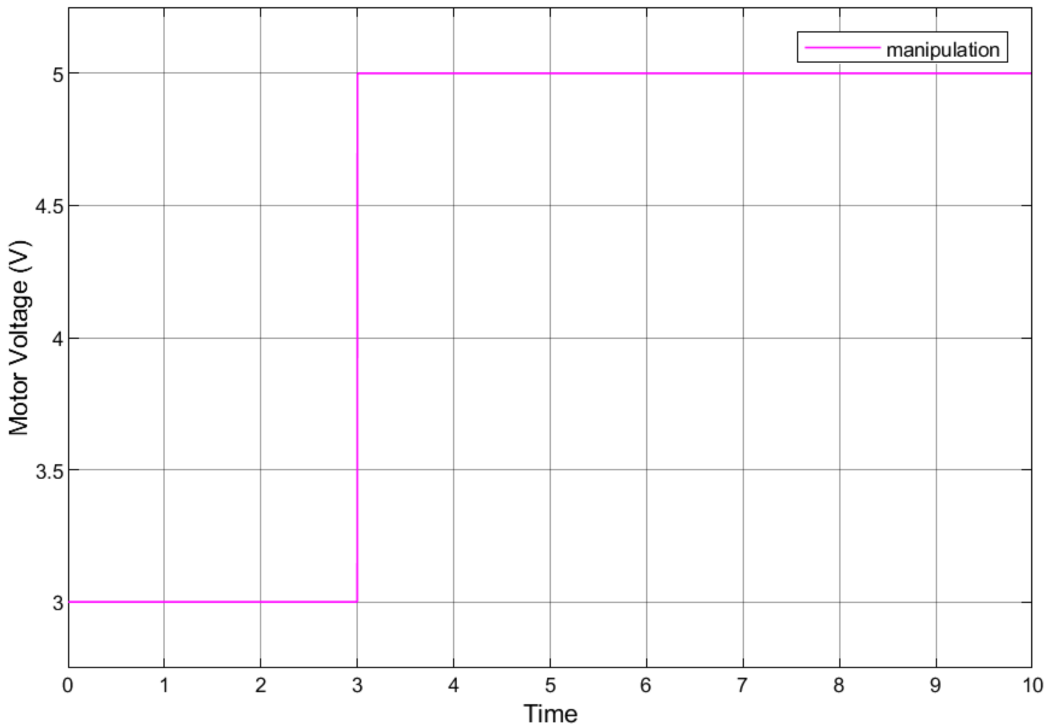

Figure 4 Input Step

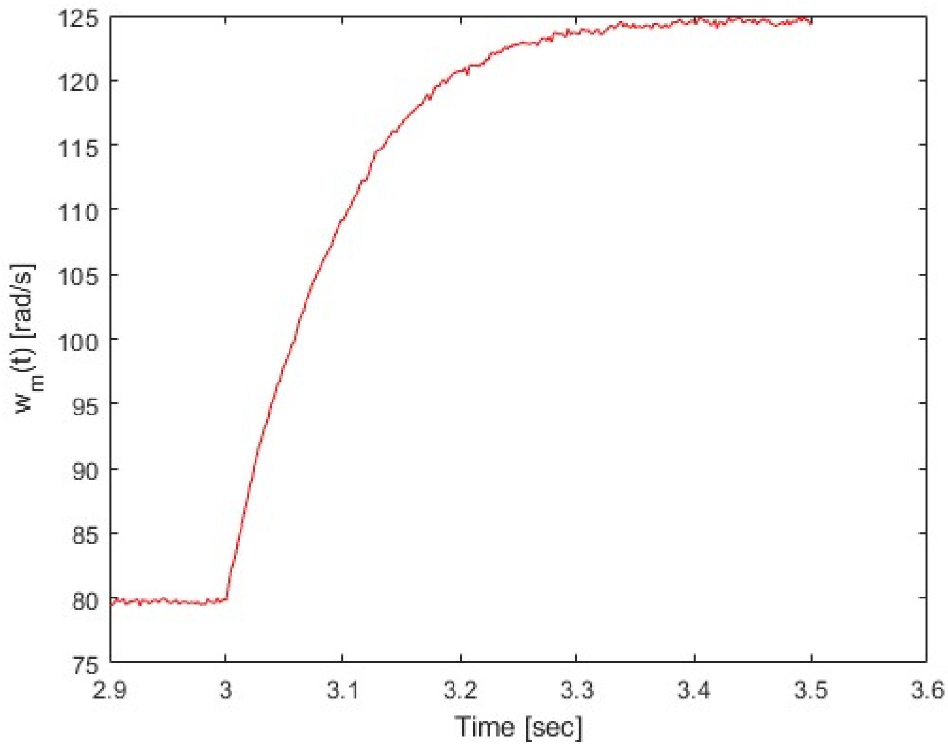

Figure 5 Response of the System

Ziegler-Nichols Parameter Identification Process

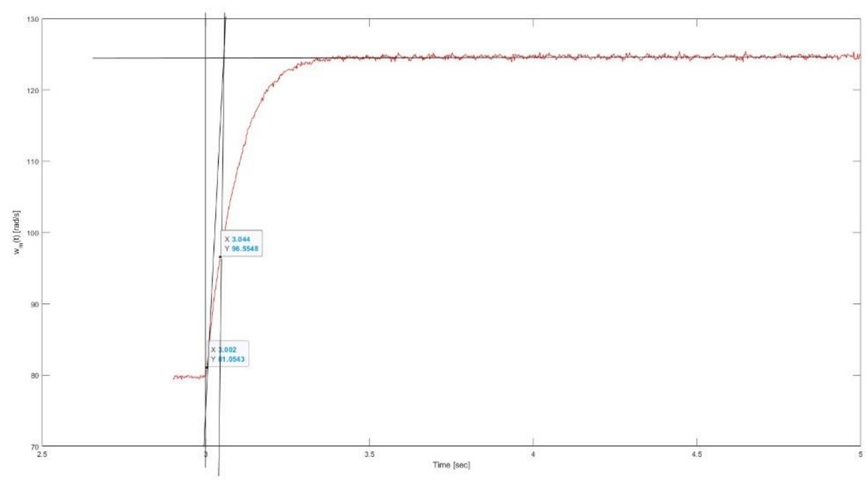

Figure 6 Ziegler-Nichols Parameter Estimation

ç

$$K = \frac{\Delta Y}{\Delta U}$$

$$K = \frac{125 - 80}{5 - 3}$$

$$K = \frac{45}{2}$$

$$K = 22.5$$

$$\theta = 3.002 - 3$$

$$\theta = 0.002$$

$$\tau = 0.044 - 0.002$$

$$\tau = 0.042$$

$$G_p(s) = \frac{22.5e^{-0.002s}}{0.042s + 1}$$

Miller Parameter Identification Process

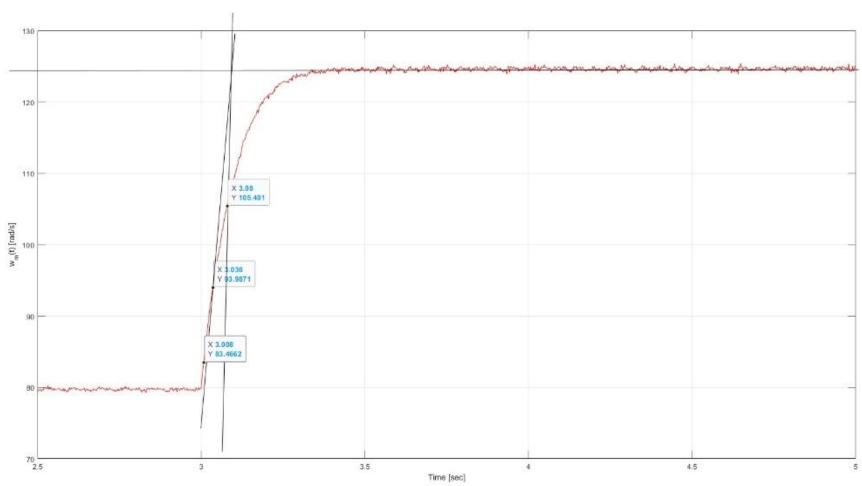

Figure 7 Miller Parameter Estimation

$$K = \frac{\Delta Y}{\Delta U}$$

$$K = \frac{125 - 80}{5 - 3}$$

$$K = \frac{45}{2}$$

$$K = 22.5$$

$$\%63.2K = 0.632 * 22.5$$

$$\%63.2K = 14.22$$

$$\%63.2K = 14.22$$

$$\%63.2K + \omega_0 = 14.22 + 80$$

$$\%63.2K + \omega_0 = 94.22$$

$$\theta = 3.008 - 3$$

$$\theta = 0.008$$

$$\tau + \theta = 3.08 - 3$$

$$\tau = 0.08 - 0.008$$

$$\tau = 0.072$$

$$G_p(s) = \frac{22.5e^{-0.008s}}{0.072s + 1}$$

Analytic Parameter Identification Process

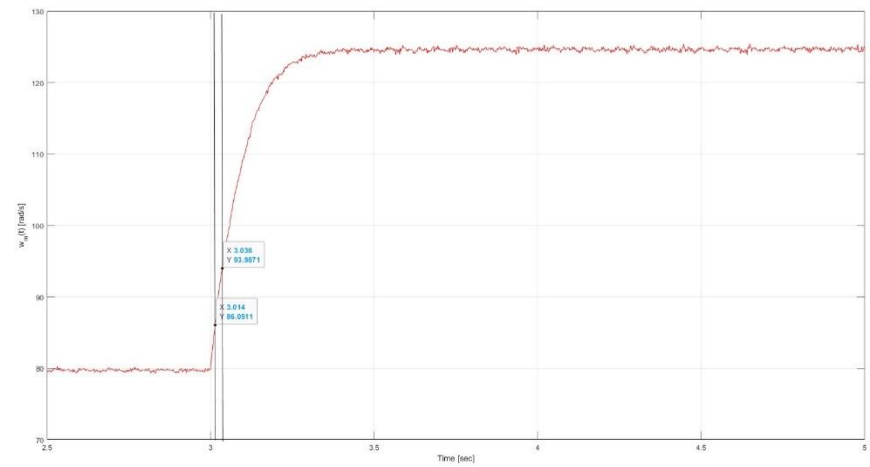

Figure 8 Analytic Parameter Estimation

$$K = \frac{\Delta Y}{\Delta U}$$

$$K = \frac{125 - 80}{5 - 3}$$

$$K = \frac{45}{2}$$

$$K = 22.5$$

$$\%63.2K = 0.632 * 22.5$$

$$\%63.2K = 14.22$$

$$\%63.2K = 14.22$$

$$\%63.2K + \omega_0 = 14.22 + 80$$

$$\%63.2K + \omega_0 = 94.22$$

$$\%28.4K = 0.284 * 22.5$$

$$\%28.4K = 6.39$$

$$\%28.4K + \omega_0 = 6.39 + 80$$

$$\%28.4K + \omega_0 = 86.39$$

$$G_p(s) = \frac{22.5e^{-0.003s}}{0.033s + 1}$$

Parameter values of the 1st Order Transfer Function

	Ziegler-Nichols	**Miller**	**Analytic**
Gain	22.5	22.5	22.5
Time Constant	0.042	0.072	0.033
Dead Time	0.002	0.008	0.003

4. Model Comparison with the Actual Measured System Exactly

At first none of the models matched to the actual measured system. Because transfer functions don´t take in consideration initial values from previous stages before 3 seconds, our models were different, however a vertical shift could be observed.

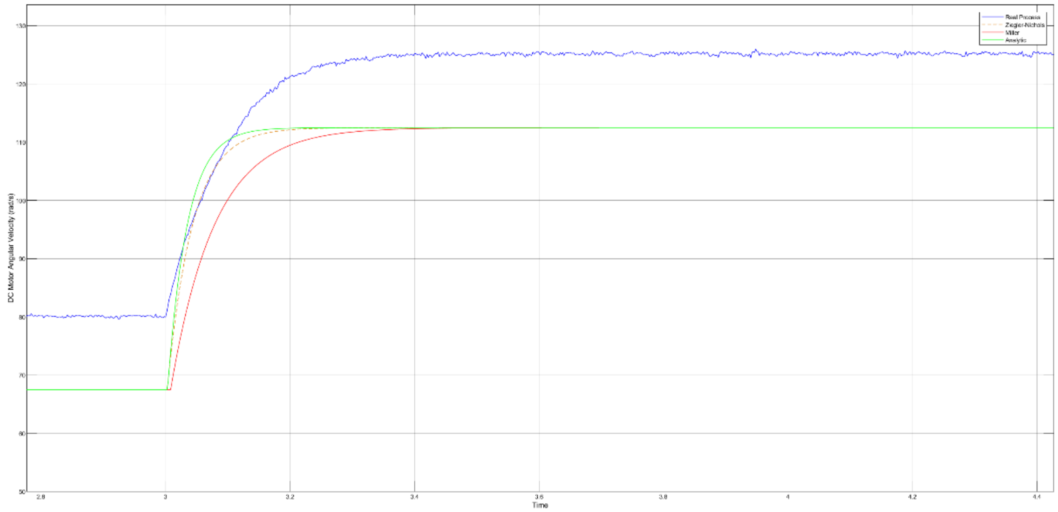

Figure 9 Models First Comparison

To correct this error, a compensation term of 13 was added directly to the outputs of the models.

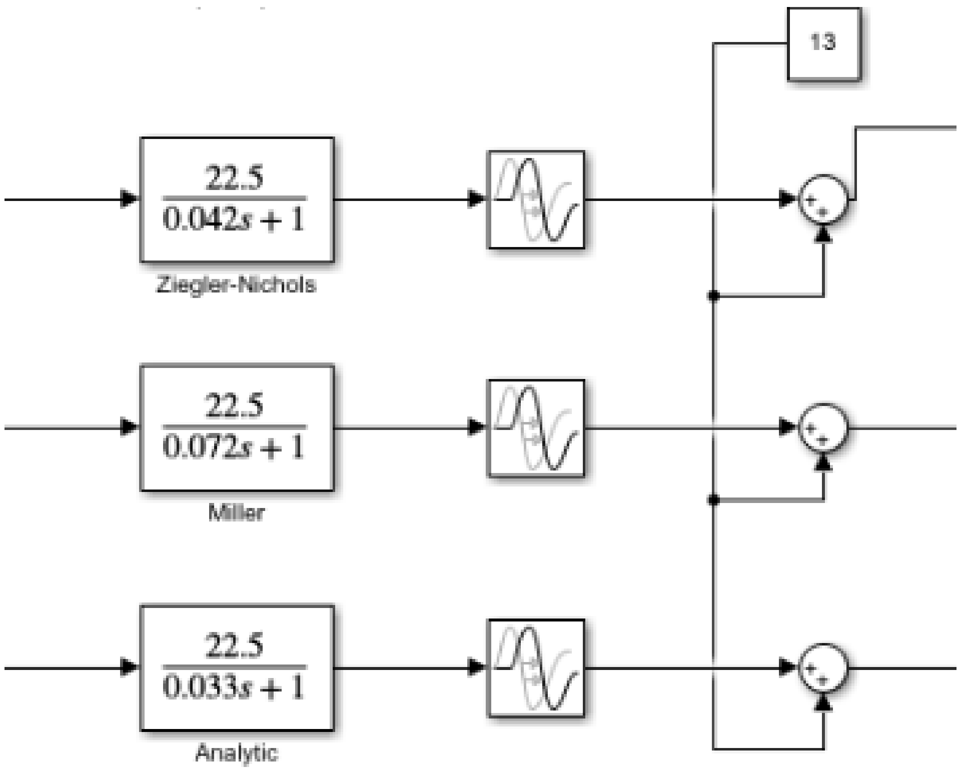

Figure 10 Block Diagram of the Final Models

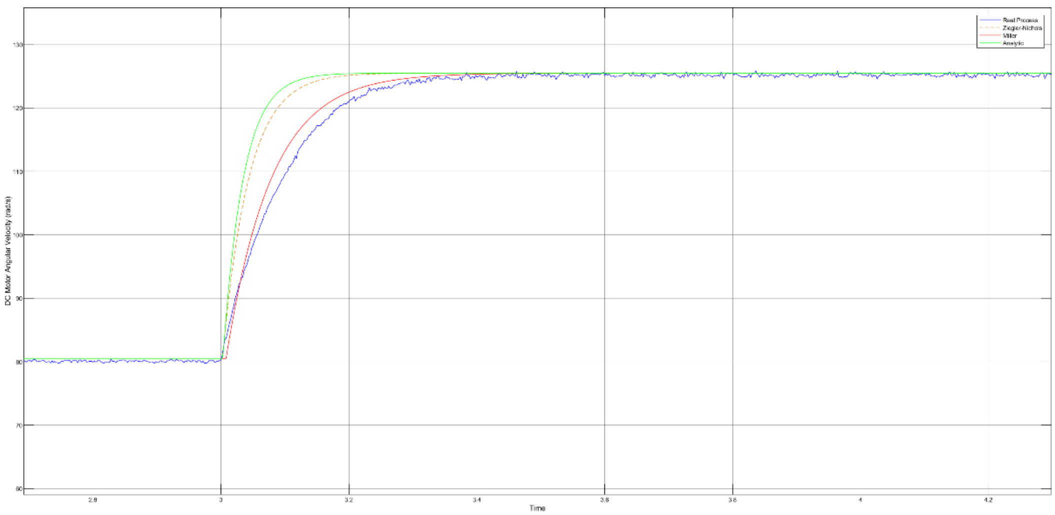

Figure 11 Final Models Comparison

In the same script as the plot section, comparison was done between all the data obtained from the three estimated models.

```
%Comparison
%Ziegler-Nichols
r_zn = ang_vel_real - ang_vel_zn;
SS2_zn = norm(r_zn,2)^2 %The sum of squared errors

%Miller
r_miller = ang_vel_real - ang_vel_miller;
SS2_miller = norm(r_miller,2)^2

%Analytic
r_an = ang_vel_real - ang_vel_an;
SS2_an = norm(r_an,2)^2
```

Figure 12 Error Computation Code

```
SS2_zn =

   9.9037e+03


SS2_miller =

  953.8675


SS2_an =

   1.4467e+04
```

Figure 13 Results for Error in Models

As it could be seen Miller´s method demonstrated the best approximation based on the sum of the squared errors.

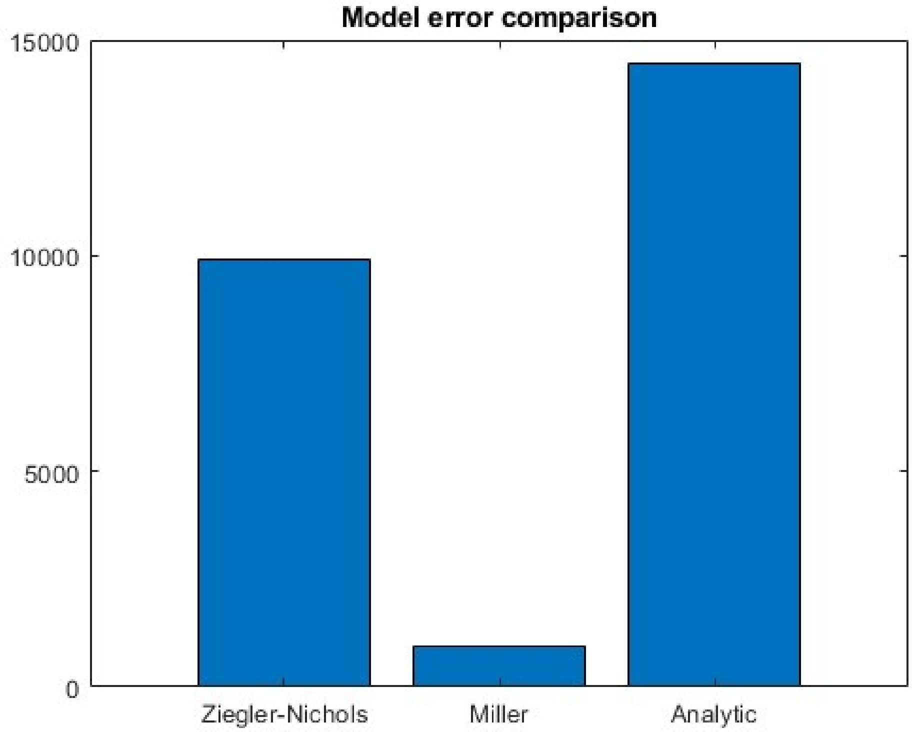

Figure 14 Bar Graph of Errors of the Models

5. Conclusions

The system identification of the DC motor's velocity was successfully achieved using Ziegler-Nichols, Miller, and Analytic methods. Although initial comparisons revealed discrepancies between the models and the actual system, primarily due to the neglect of initial conditions, a correction factor was applied to align the models more closely with the measured data. Interestingly, while the Analytic method was initially expected to provide the most accurate approximation, the Miller method demonstrated superior performance in terms of minimizing error. The final models provided a good approximation of the system's behavior, particularly at steady-state velocities. This outcome underscores the importance of empirical validation in model selection and highlights the need to carefully consider initial conditions and model assumptions when developing accurate representations of physical systems, especially in control applications for unmanned aerial vehicles.