MIDDLE EAST TECHNICAL UNIVERSITY

Middle East Technical University

Electrical and Electronics Engineering Program

Northern Cyprus Campus

Spring -2021

EEE302

Simulation Project Assignment:

Designing Control System for Drone Wing Motor

Submitted By: Abduallah Damash ID: 2281772

Submitted To: Prof. Canras Batunlu

Deadline: 20/07/2021 11.55 PM

Contents

Figures and Tables Contents:

Introduction:

The aim of the project is to run an analytical simulation to decide what is the better approach for controlling the motor of drone wing. That is by designing three types of controllers for different speeds to decide which one will make the system more stable in term of the maximum overshot and settling time for all the speed. Also, the system will continue three main components which are the controller, the motor, and the negative unite feedback.

In this report, firstly, it will go over the design approach for each type of controller. Secondly, it will show the simulation result for each controller. In the end, it will discuss the results of the simulation and the design approach.

Design and Analysis:

Designing Motor Circuit:

In order to model the motor wing of the drone in a realistic way, the motor is chosen to be DC brushless motor, that can have an equivalent circuit of inductor, resistor, and back Emf voltage that has values 0.025H, 2.5Ω, 240V, respectively, assuming our input voltage is 70V to meet the initial revolution per minute which is 4000 rpm.

Thus, in order to design a control system that contain a DC motor, controller for adjusting the speed of the motor, and a unity negative feedback, we can model the DC motor by using its transfer function or a better approach would be using DC-DC boost converter that will switch when the controller need to adjust the speed.

Now, consider the DC-DC boost converter circuit to have ideal case of forwarded voltage of the diode to be zero (Short circuit), and the gate voltage of IGTB to be also zero (Open circuit). Thus, the equivalent circuit of the system including the DC motor is shown in Fig.1.

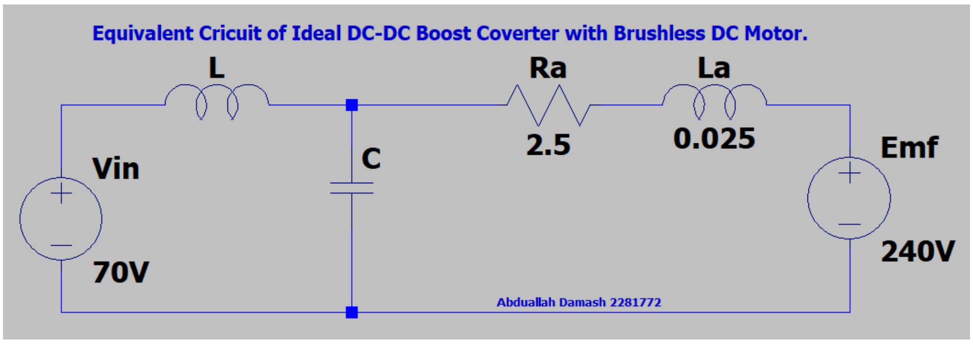

Figure 1. Equivalent Circuit of Ideal DC-DC Boost Converter with Brushless DC Motor.

In order to size the inductor and capacitance so that they meet overshot less than 15%, and settling time of around 3 second, then the DC inductor can be ignored in order to reduce the type of the system to be second order system. Thus, knowing the equations of maximum overshot and settling time, we can find the sizes as following:

$$maxmuim\ overshot = 0.15 = e^{\frac{-\pi\zeta}{\sqrt{1-\zeta^2}}} \dashrightarrow \zeta = 0.51 < 0.69$$
$$settling\ time = 3 = \frac{3.2}{\omega_n \zeta} \dashrightarrow \omega_n = 2\, krad/s$$
$$T.F = \frac{V_C}{V_{in}} = \frac{\frac{1}{LC}}{s^2 + \frac{1}{RC}s + \frac{1}{LC}} \equiv \frac{\omega^2}{s^2 + 2\zeta\omega s + \omega^2}$$
$$Thus, L \cong 250\ \mu H, C \cong 50\ \mu F$$

Finding Controller Parameters:

Now, let consider the transfer function of the PID, PD, and PI controllers in order to find the $K_P, K_I, and\ K_D$ parameters in the closed loop system. In fact, these parameters can be found using state variable method or using Ziegler-Nichols Tuning Method which is used in this report as described in Table.1.

Table 1. Ziegler-Nichols Method Results.

Type	$T.F$	K_P	K_I	K_D
PD	$K_P + K_D s$	1556	-	28.5
PI	$K_P + \frac{K_I}{s}$	1356	678	-
PID	$K_P + +K_D s + \frac{K_I}{s}$	2250	1250	25

Notice that each type of controller has different gain parameters because they need to meet the requirement of maximum overshot to be less than 15% and settling time around 3 seconds.

MATLAB Circuit:

Now, construct the system on the Simulink simulation tool of MATLAB Program as in Fig.2:

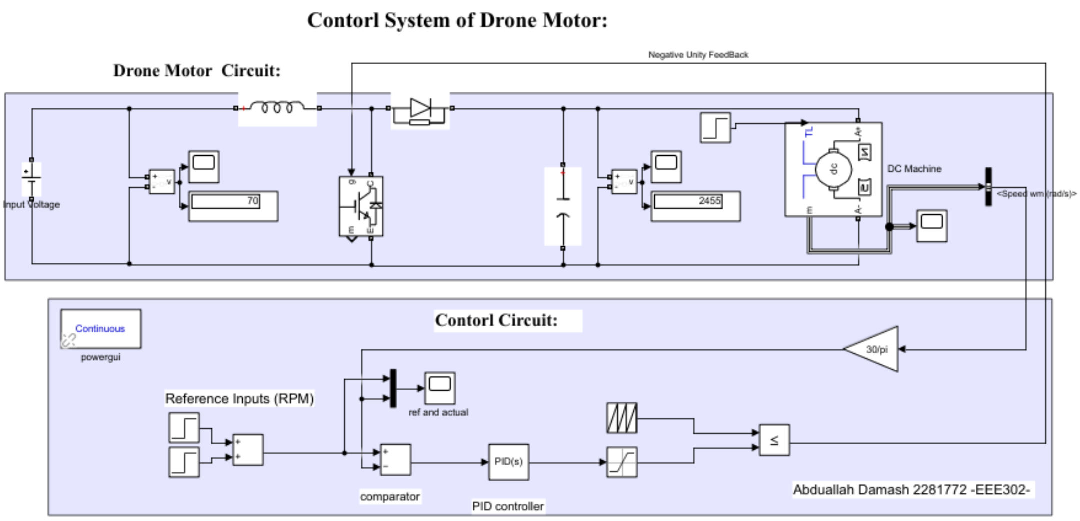

Figure 2. Complete Control System of Drone Wing Motor.

Simulation Results:

Now, in order to generate 3 different speeds, there are two step inputs that start at 4000 rpm, and then increased to 7500 rpm ending at 10000 rpm at each 10 second, so total simulation time is 30 seconds. Running the simulation with the values found in Table.1, it will be as following:

PID Controller Simulation Output:

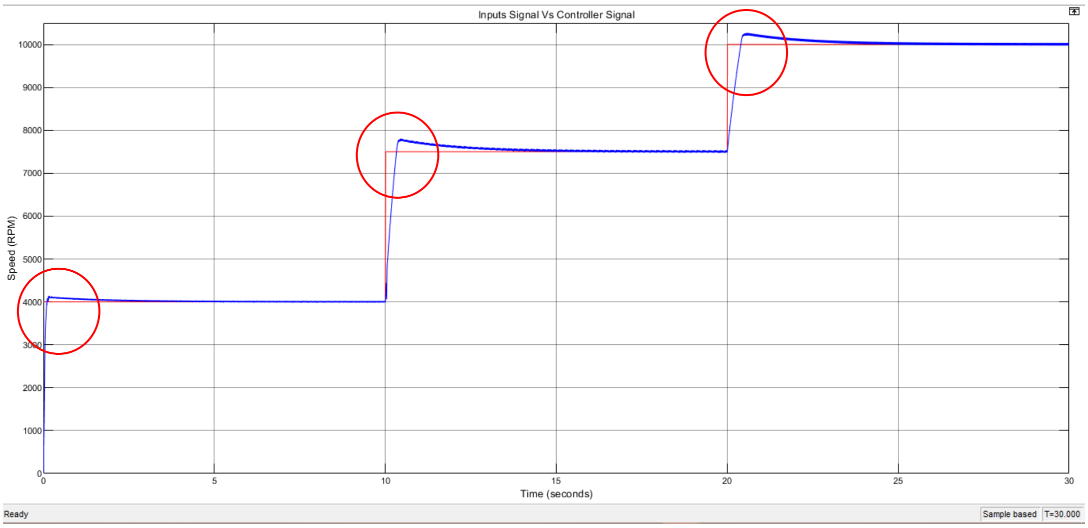

Figure 3. PID Controller Simulation Output.

Notice the settling time is around 3s for all speeds, and the overshot is around 11% < 15%.

PI Controller Simulation Output:

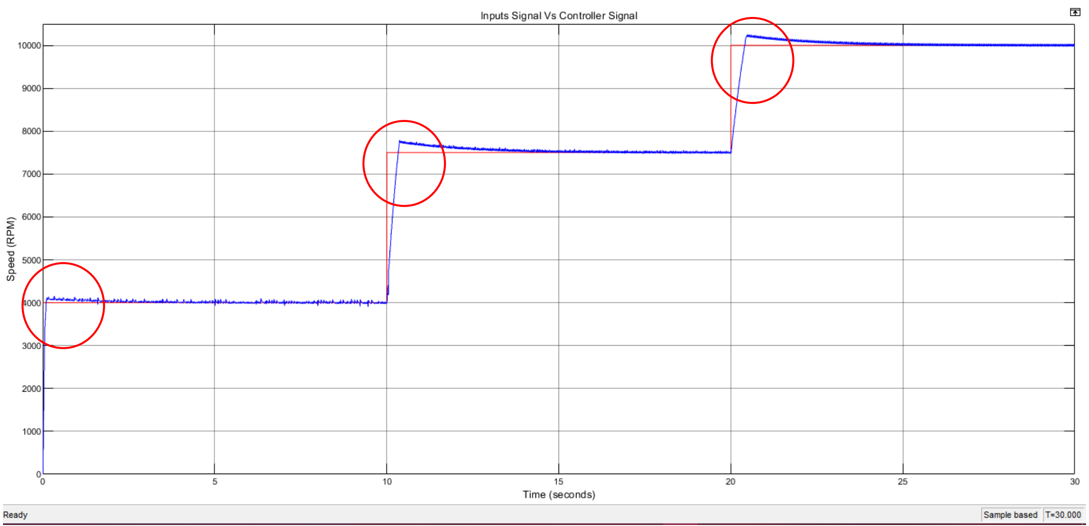

Figure 4. PI Controller Simulation Output.

Notice that the overshot is almost the same as the PID controller, but the settling time is increased to be more than 3 seconds. Also, notice that the raising time is increased compering to PID controller.

PD Controller Simulation Output:

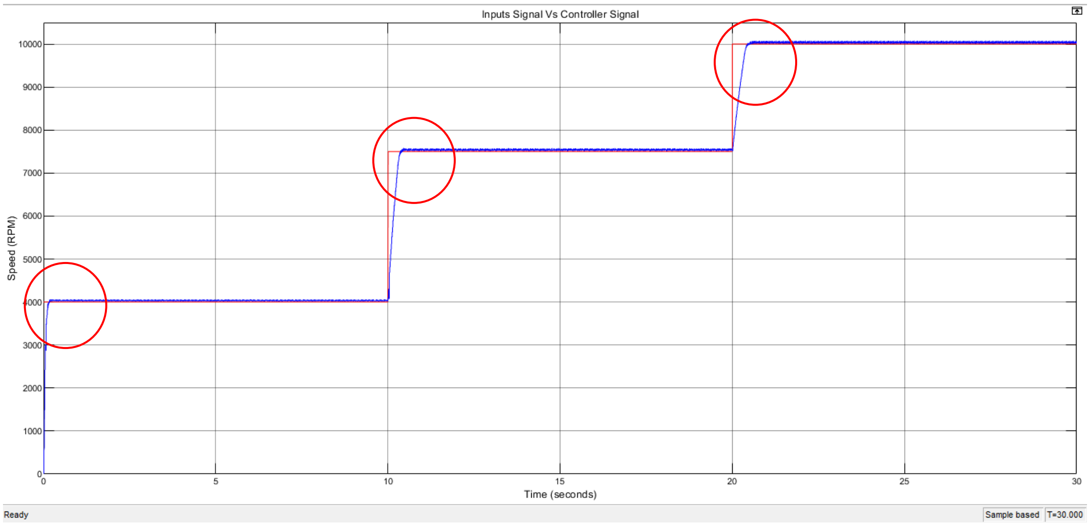

Figure 5. PD Controller Simulation Output.

Notice that the overshot is decreased to be almost zero comparing to PID and PI controllers. Also, the settling time become faster compering to previous controllers. However, it can be seen from the graph that raising time higher than the one in PID and PI controllers.

Conclusion:

In this project, we went over three types of controllers to control the speed of the drone wing motor that we modeled using a brushless DC motor and DC-DC Boost Converter.

After running the simulation for PD, PI, and PID controllers, the result can be summarized in the following graph.

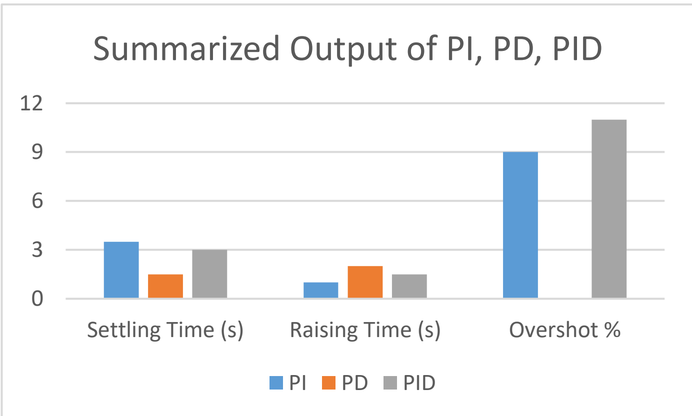

Figure 6. Summarized Output of PI, PD, and PID

In the end, we can conclude that the best approach for designing an effective control system for the drone motor that is using PID controller because it meets the parameter of the overshot and settling time. However, using PD will be better in systems where we need to minimize the overshot of the system as shown in the graph. Also, PI optimizes the raising time compering to other ones so it can be used in systems where raising time is a critical parameter.

Each type of controller has its advantage and disadvantage and choosing which one is better depends on the different parameter in the system such as settling time, overshot, raising time. etc. That come from experience and observing different control systems in different application.