Laboratory Experiment II : Design of a Speed Controller

MTRN3020 Modelling and Control of Mechatronic Systems

Abstract

This laboratory exercise is to design a speed controller to be implemented in a motor-generator system. The direct analytical design method or the so-called Ragazzini's method is to be used to design the controller. The controller design involves only a small amount of calculations leading to a difference equation. This document only lists the steps to be followed to obtain the values that will be used in the experiment. In your final report, follow this step by step procedure to obtain the difference equation of your controller. See Post-SpeedControlExperiment.pdf file to find out the required report content.

1 Experimental Setup

The experimental set up consists of a motor that is connected to a generator. In practice, the generators are driven by some form of a prime mover powered by a gasoline or steam engine/turbine. For the purpose of clean experimentation, in this case, the generator is driven by an electric motor.

2 Controller Design

The block diagram to be used is shown in Fig. 1.

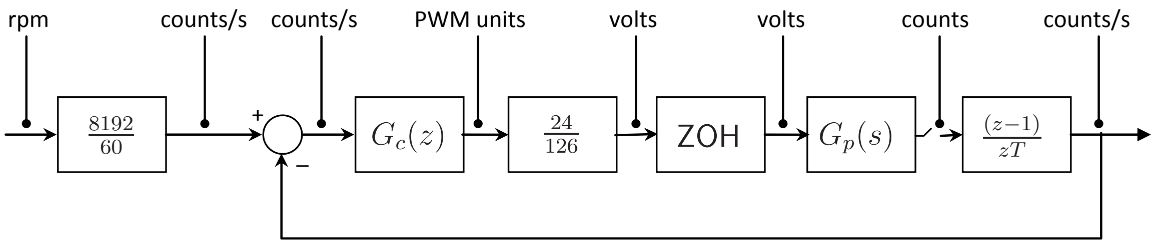

Figure 1: Speed control block diagram

2.1 Step 1

Download the file `noload.m` from Moodle. This file shows the response of the motor when a voltage of 24 volts is applied. Plot a graph of time (column 1) as x-axis and motor speed (column 3) as y-axis. Time is in milliseconds and hence need to be converted to seconds. The speed is in counts/second. As shown in Fig. 1, the controller $G_c(z)$ relates the error in counts/second to PWM Units. Hence the motor speed need not be converted to any other units. Through first order response fitting to the motor response data, obtain a transfer function that relates the applied voltage to the speed in counts/second. Let this be,

$$G_{p_1}(s) = \frac{A}{1+\tau s}. \tag{1}$$

Note that by this time you should have the numerical values for A and τ.

In this experiment, we cannot sample the speed. We only sample the counts using an encoder. The speeds are calculated. Hence the experimental situation is such that we should form the transfer function that relates voltage to counts. This can be obtained by including an integrator and is,

$$G_p(s) = \frac{A}{s(1+\tau s)}. \tag{2}$$

2.2 Step 2

By combining all blocks in the block diagram, except $G_c(z)$, the plant transfer function can be obtained as follows.

$$G_p(z) = \mathcal{Z}\left[\frac{24}{126}\frac{(1-e^{-sT})}{s}\frac{A}{s(1+\tau s)}\frac{(z-1)}{zT}\right]. \tag{3}$$

Break this into two parts,

$$G_p(z) = A(z)\frac{(z-1)}{zT}. \tag{4}$$

Use the following commands in Matlab to find the $A(z)$ part. T to be used right throughout can be found against your name in a file in Blackboard.

```
>> num = [24*A];
>> den = 126*[tau 1 0];
>> [numd, dend] = c2dm(num,den,T,'zoh');
>> roots(numd)
>> roots(dend)
```

The `c2dm` function automatically takes into account the ZOH as we have mentioned so with '`zoh`' in the `c2dm` function. Now, using the above found roots, $A(z)$ part can be written in the form,

$$A(z) = \frac{C(z-z_1)}{(z-1)(z-p_1)}, \tag{5}$$

where the constant C is also known. Substituting (5) in (4), $G_p(z)$ is now,

$$G_p(z) = \frac{C(z-z_1)}{Tz(z-p_1)} \tag{6}$$

Note that all numerical values of the parameters of $G_p(z)$ are now known.

2.3 Step 3

We now need to form our $F(z)$. Use the design specifications given to you to obtain the $F(z)$. Your controller must also have zero steady state error.

Note: if your $G_p(z)$ has a ringing zero, it MUST be eliminated!

2.4 Step 4

Knowing $G_p(z)$ and $F(z)$, use

$$G_c(z) = \frac{1}{G_p(z)} \frac{F(z)}{(1 - F(z))} \tag{7}$$

to obtain the controller transfer function. This transfer function can be put into a difference equation form. The coefficients of this difference equation are the ones you will use in the experiment. On the day of the experiment they will be calculated using a demonstrator supplied function. In your final report, you must provide the numerical calculations to show how these coefficients are obtained.

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