Laboratory Experiment II : Implementation of a Speed Controller

MTRN3020 Modelling and Control of Mechatronic Systems

Abstract

This document is complementary to the pre-experiment document you may have used to design the speed controller. The experimental set up is described in more detail and the required content of your report is explained.

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.

The control input to the system is the voltage to be applied to the motor. To generate the applied voltage, a pulse width modulation (PWM) amplifier is used. Hence, we can consider the controller output as the input to the PWM amplifier. Therefore the units of the output of the controller you would design is "PWM Units". The controller makes its decision based on the error in speed. The speed is measured in counts/second and hence the units of the input to your controller is "counts/sec".

The motor drives a DC generator with identical parameters as the motor. The output of the generator is connected to a bank of 15 resistors connected in parallel, each with a resistance of 150Ω. If none of the resistors are connected, then the motor generator system runs on "no load". If a certain number of resistors are connected, then their will be a current in the generator circuit and as a result there will be a load torque on the motor that drives the generator. When the load changes, the speed will be affected. The purpose of the controller you design is to maintain the speed at the specified value regardless of the load changes.

2 The Experiment

The following two parts form the experiment.

2.1 Part A - Design Verification

This part is designed to verify if you have carried out the speed controller design correctly. The design is correct, if the actual response shows zero steady state error and a first order response that shows a time constant of τ_d that was mentioned against your name as one of the design parameters. In order to generate a plot, first the experiment was run as 1000 rpm and then a step change of 1000 rpm was applied bringing the speed to 2000 rpm. The transition from 1000 rpm to 2000 rpm must show a first order response that corresponds to your time constant τ_d. The zero steady state error can be detected at both speeds, first at 1000 rpm and then at 2000 rpm. This performance graph will verify the veracity of your design.

2.2 Part B - Disturbance Rejection

As mentioned earlier a load (a means of drawing a current - in this case through a resistor) can be connected to the generator. Depending on the number of resistors connected, the load on the generator, and hence on the motor, changes. The experiment is design in such a manner that the entire disturbance rejection part of the experiment lasts 1600 data samples consisting of 8 sets of 200 consecutive data samples. The first and the last of these sets do not connect any load resistors. The remaining 6 sets take a varying number of resistors as the experiment progresses. The resistor pattern to be connected is determined using your student number and hence is unique to each student.

If the controller is designed correctly, as the resistors get connected, the speed will momentarily drop, however, the controller will make the system get back to the specified speed. In a similar manner, when the resistors are removed, the speed will momentarily increase and the controller will force it back to the specified speed. The data gathered during your experiment can be used to generate this plot.

3 Report Content

The report must have the following. **If items 1. and 2. below are not adhered to, your report will not be marked. If a report is late by more than a week, a penalty of 1 mark per week applies. The formal deadline for the submission of reports is 22 September 2012, 5pm. All reports must be submitted electronically to Blackboard.**

1. A cover page containing title of the experiment (16pt font size centred), the course code and course name(14pt centred) and the statement "I verify that the contents of this report are my own work" in 12 pt font centred. Your electronic submission will be taken as your signature to this statement. Then mention your name(12pt), student number(12pt) and date(12pt) at the bottom right hand corner of the cover page on three separate lines.
2. All sections, pages, figures and tables must be numbered. Equations may be numbered as necessary.
3. Introduction - briefly describe what the experiment is about (1 mark).
4. Aim - the purpose of the experiment (1 mark).
5. Brief description of the experimental procedure (1 mark).
6. Controller design calculation (2 marks).
7. Simulink block diagram of the experiment. This is the core task. See the appendix for guidance (3 marks).
8. Part A - adjust the Simulink block diagram to have no load and generate a plot that shows the speed changing from 1000 rpm to 2000 rpm. Superimpose the experimental plot and show that the design is correct (3 marks).
9. Part B - adjust the same Simulink block diagram this time to represent the load changes. You need to use the "LoadSim" block that is made available to you. The LoadSim block needs to be connected to the motor speed and the number of resistors connected at any given time. It will give you the load torque. Generate a plot for the same load pattern used during the experimentation. You can obtain your load pattern by using the following command in MATLAB.

```
>> dec2hex(<student number>)
```

Superimpose the experimental plot on the plot generated by Simulink model and show the compatibility of your results (3 marks).

10. In a conclusion discuss the success or otherwise of the experiment and address the discrepancies between the simulated and experimental plots (1 mark).

Appendix - Building Simulink Block Diagram

Use the following data in your Simulink model.

Item	Symbol	Value	Units
Armature Resistance	R_a	4.89	Ω
Armature Inductance	L	0.00042	H
Motor Inertia	J	0.0000109	kg/m^2
Viscous Damping	B	0.0000464	Nm/(rad/s)
Torque Constant	k_t	0.0348	Nm/A
Back EMF Constant	k_e	0.0348	V/(rad/s)

Use the following equations to build your Simulink model.

Let the required variables be,

ω_d	Desired speed in counts/s.
$\omega(t)$	Calculated speed in counts/s.
$e(t)$	Error in speed counts/s.
$m(t)$	Control effort in PWM Units
$v(t)$	Applied voltage (output of the PWM amp) in volts
$i(t)$	Motor current in Amperes
$v_b(t)$	Back emf in volts
R_a	Armature resistance in ohms
L	Inductance in H
T_m	Motor torque in Nm
T_L	Load torque in Nm
T	Torque available to accelerate inertia in Nm
J	Inertia of the entire system in kg m^2
B	Damping constant of the entire system Nm/(rad/sec).
$v_g(t)$	Generated voltage in volts
$i_L(t)$	Load current in A
R_l	Load resistance in ohms
k_t	Torque constant Nm/A
k_e	Back EMF constant Volts/(rad/sec)

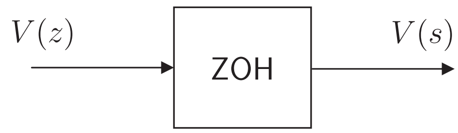

Figure 1: From discrete to continuous

$$
\begin{aligned}
e(t) &= \omega_d - \omega(t) && (1)\\
M(z) &= G_c(z)E(z) && (2)\\
V(z) &= \frac{24}{126}M(z) && (3)\\
v(t) &= v_b(t) + L\frac{di}{dt} + iR && (4)\\
T_m &= k_t i && (5)\\
v_b &= k_e\omega && (6)\\
v_g &= k_e\omega && (7)\\
v_g &= L\frac{di_L}{dt} + i_L(R + R_L) && (8)\\
T_L &= k_t i_L && (9)\\
T &= T_m - T_L && (10)\\
T &= J\dot{\omega} + B\omega && (11)
\end{aligned}
$$

Use the block shown in Fig. 1 to go from $V(z)$ to $V(s)$. Equations (7), (8) and (9) are implemented in LoadSim block which is readily available to you.

