LABORATORY EXPERIMENT II

IMPLEMENTATION OF A SPEED CONTROLLER

MTRN3020

Modelling and Control of Mechatronic Systems

I verify that the contents of this report are my own work.

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1. INTRODUCTION

This experiment refers to the design and operation of a speed governing controller of a motor existing under a variable load. The task was to be approached by following a systematic design procedure, namely the Ragazzini method, and employing the multidomain dynamical system analysis software Simulink in formulating a consistent block diagram. Implementing the design output with a real life apparatus allowed a comparison of said experimental controller design data against predicted controller performance, to give students feedback on how successfully their controllers performed.

Students were obligated to derive their personalised speed controller from given time constant/sample times before attending a laboratory session. The controller was inserted into software to calibrate and direct a generator rig/electric motor system by way of exploiting a 15 resistor bank to adjust the motor loading. After performing the experiment twice (once with disturbance rejection, once without), two data sets were logged and distributed for simulation in Simulink to help analyse any theoretical consistencies by applying specific/unique loading patterns.

1. AIM

The aim of this experiment is to verify whether an analytically formulated speed controller functions correctly in handling and rejecting disturbances resulting from a variable motor/generator load on a real life rig implementation, and to compare these results to a theoretically based performance.

1. THE EXPERIMENTAL PROCEDURE

Following the derivation of a unique speed controller transfer function from given time constant/sample times, the coefficients acquired from forming the corresponding final difference equation can be input into the control computers UI to calibrate and drive the motor/generator system.

The procedure can be abstracted into a series of two sections. The first of which (A) is performed to ensure the validity of the design procedure, namely under inspection if a 1st order response (FOR) produces a time constant aligning with the given unique time constant design-parameter and a zero steady state error (SSE) is produced by the actual response, then the controller design can be considered valid. After confirming validity and to produce a plot, the initial run was performed with the system running at 1000rpm, and modulated to 2000rpm by inducing a step of 1000rpm. As noted, a result of using a correct controller, the step shift from 1-2krpm will produce a FOR that is consistent with design parameters. The zero SSE will be detectable at both rotational velocities (1-2krpm). The data will then be plotted and the accuracy of the design can be verified by inspection

The second section (B) refers to disturbance handling in response to loading. The quantity of active resistors connected to the generator affects the loading placed on the motor. When performing this section, eight run’s with 200 successive values are recorded with runs 1 and 8 having zero active resistor loadings, whilst the remaining six runs run take varying active resistor values determined from student numbers. As mentioned, the controllers design success can be validated by inspecting how it responds to variations in velocity; if the controller bounces back to a chosen definite speed, the controller can be deemed correct.

1. CONTROLLER DESIGN CALCULATIONS

We begin our calculations by obtaining a first order approximation to our no load open loop data, ie of the form:

We can use lsqcurvefit to fit a curve to our data and simultaneously obtain our *A* and . These values can then be plugged into our transfer function that relates the applied voltage to the speed in counts/second:

Including an integrator to obtain a transfer function that relates voltage to counts is:

By combining all of the block in our block diagram for the system, excluding *Gc(z)* the transfer function for the plant is:

Using Matlab’s c2dm function to find us a discrete version of our continuous transfer function helps us find *Gp(z)*.

The next step is to form our *F(z)*. Using our unique time constant and the fact that we need zero steady state error, that is unity DC gain ie . Because our zero could cause ringing, it must be absorbed by the numerator of By knowing that a time constant of corresponds to in the *s*-domain, its location is therefore . So keeping in mind that

Now that we know we can plug it into the following expression to obtain :

Using my sampling time of 4ms and my time constant of 45ms, my resulting controller is:

1. SIMULINK BLOCK DIAGRAM

In order to create a simulation to compare to our experimental data, we use Matlab’s Simulink to easily construct a block diagram of our system. By referring to the appendix included in the guidelines, the following block diagram as seen in Figure 1 was made:

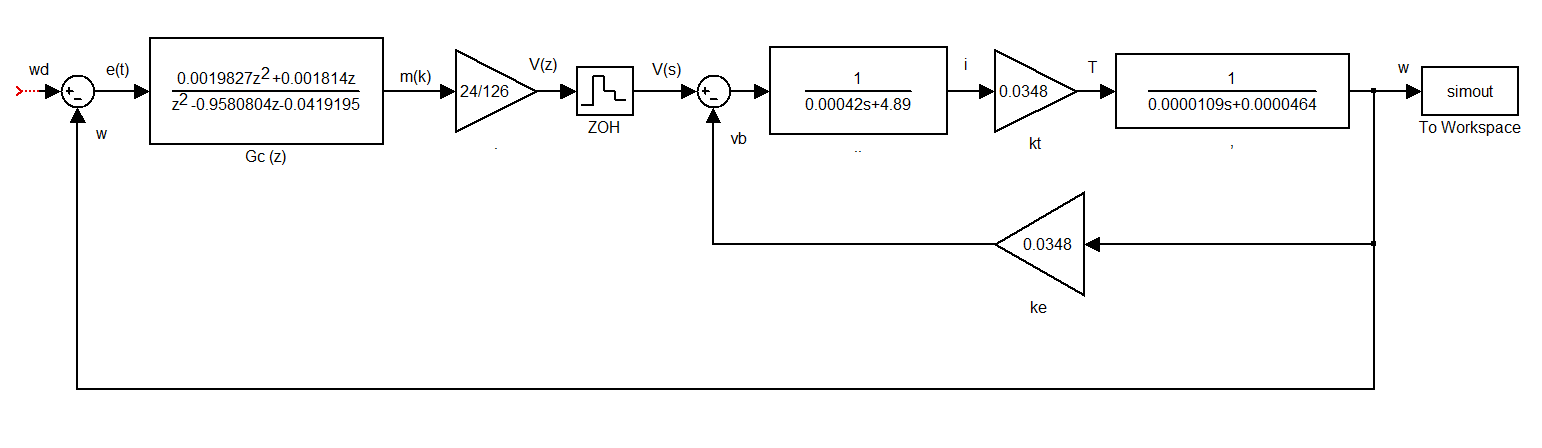


Figure 1: Simulink block diagram of the experiment.

1. PART A – 1000RPM TO 2000RPM

Now that we have our block diagram constructed, we can input step functions to simulate our experiment. Just like the second run in the lab, we will include an initial step to 1000rpm and then another 1000rpm step to bring the total rpm to 2000. We will then superimpose the simulated data with the experimental data to verify the design. Figure 2 shows the step function blocks as they appear in Simulink.

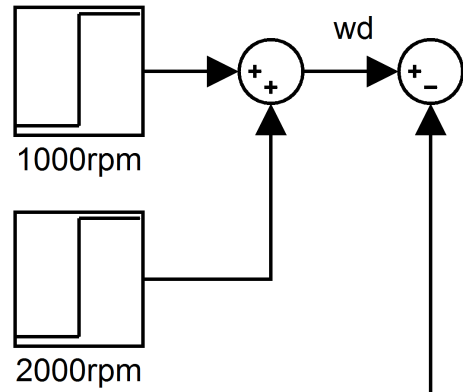


Figure 2: Simulink step function.

There are two step function blocks. The top most block is activated at t = 0 and the second one, whilst labeled as 2000rpm, only adds 1000rpm to the input, begins at the same time as the experimental results step up to 2000rpm. Once these two blocks are added, we run the simulation and the output block returns an array of data. Obviously, this data is not of the same length as our experimental result’s data, so we use Matlab’s interp1 function to interpolate the simulated data to correspond to the length of the time vector of the experimental data. Now we can superimpose the plots of both sets of data to compare the block controller design as shown in Figure 3.

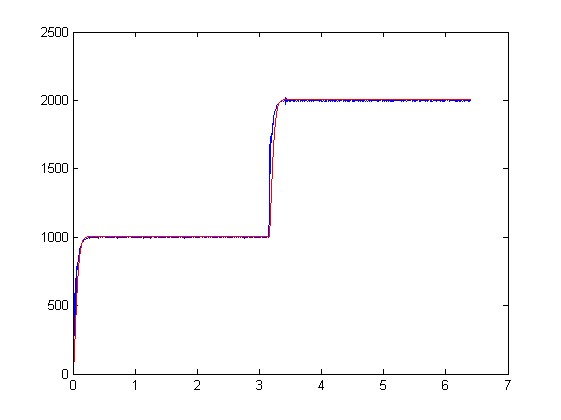


Figure 3: Superimposition of experimental and simulated theta vs time plots. Experimental is show in blue, whilst simulated is represented by red.

1. PART B – LOAD CHANGES

We can now adjust the same Simulink block diagram this time to represent the load changes discussed in section 3. To determine our load pattern we convert our 7 digit decimal student number into a 6 digit hexadecimal number. Each of the 6 digits in this number represents a corresponding number of resistors that are to be active at each 200 sample period. For my student number, 3331804, we get 32D6DC. We can see the effects of the resistors in our first experimental data file:

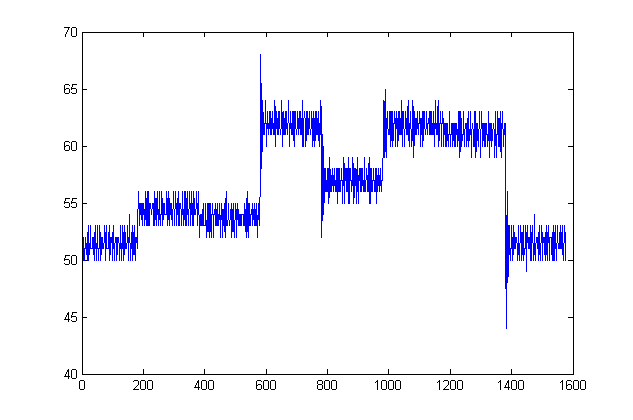


Figure 4: Resister loads in the pattern: 0-3-2-D-6-D-C-0

In order to simulate the load from the resistors, we use the “LoadSim” block that is made available to us. It will handle the complexities of the resistors themselves for us and enable us to only be concerned with feeding in our omega and the number of resistors currently active, and feed out the resulting load torque to be differenced with our motor torque to give us the torque available to accelerate inertia.

In order to manage the number of resistors that are to be active, we create a series of step functions that are all summated and fed into the LoadSim block. The way this work is when the number of resistors is to go up or down, another step function occurs that will add or subtract the required amount of resistors. The LoadSim and resistor blocks can be observed in Figure 5.

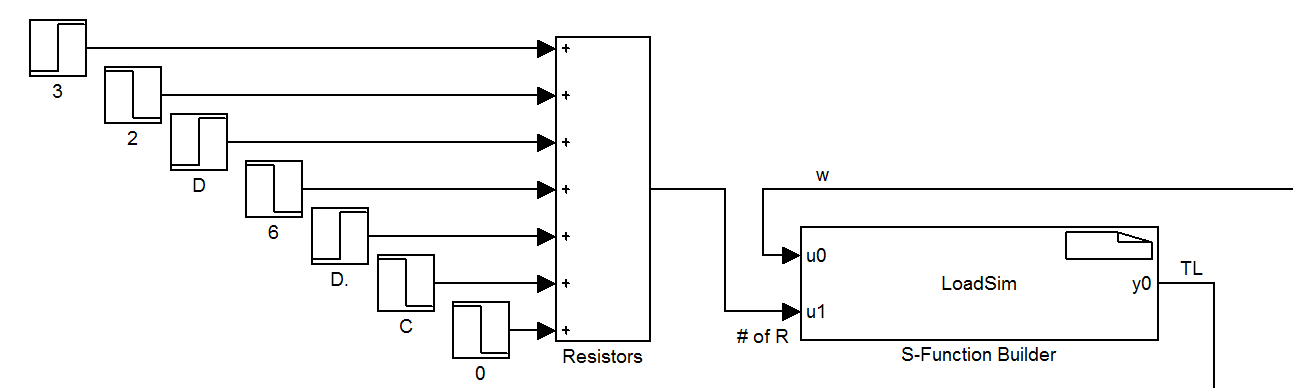


Figure 5: The summated resistor step files being fed into the LoadSim block.

Now that the load feature has been added we can go ahead and run the simulation at 2000rpm. The comparison of both plots, experimental and simulated is shown in Figure 6.

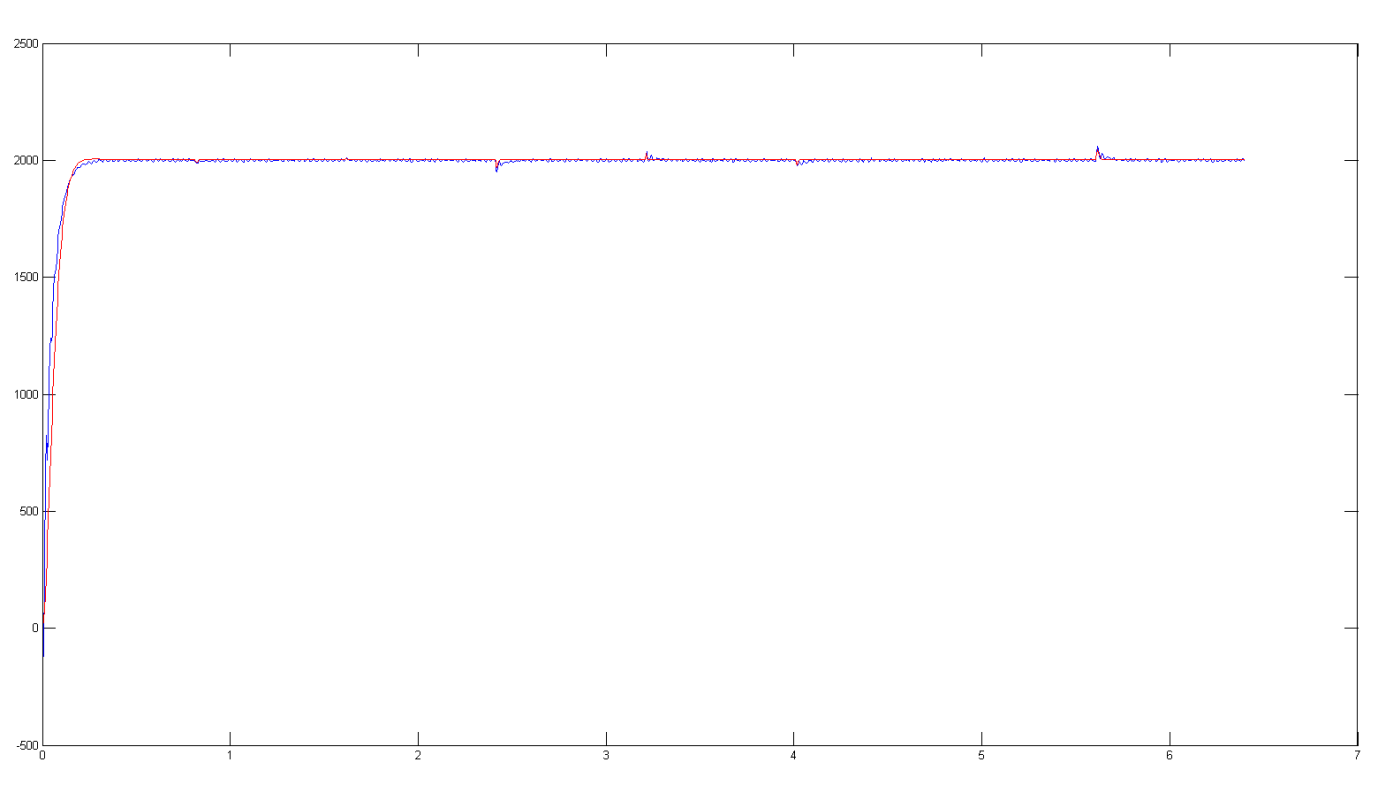


Figure 6: Experimental (blue) and simulated (red) load affected data superimposed.

A closer, more detailed view of two of the load shift points can be observed in Figure 7.

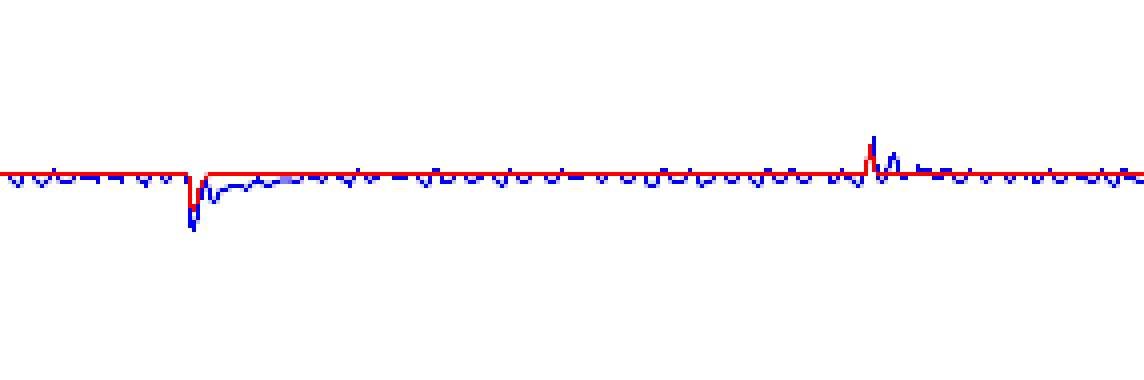


Figure 7: Zoomed in view of the resistor number changing from 2 to 13 and back down to 6.

It is clear that the simulation is compatible with the experimental data, as both plots respond to the changes in the loads accordingly.

1. CONCLUSION

In conclusion, it is apparent that the experiment functioned quite well compared to the simulation. By observing figures 3, 6 and 7, we can identify that there is not too much discrepancies, especially after both plots reach the steady state of 1000rpm or 2000rpm.

However, there is quite some discrepancy in the initial rise period of the controllers. By looking at Figure 6, we can see that the simulated plot rises quicker than the experimental plot. This is most likely due to the presence of friction in the system, and at such high rotational velocities, this is expected.

As well as this, there is very obvious ringing in the experimental plot at the steady state, as a zoomed in image of a section of one of the experimental plot shows in Figure 8.

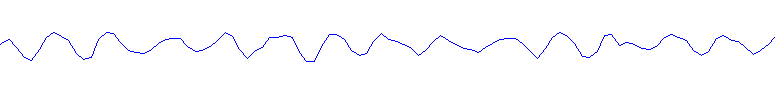


Figure 8: Ringing present in experimental plot.

This ringing is relatively small, peaking at +/- 0.5% deviation from the desired rotational velocity, which does not increase as time goes on. This ringing is most likely due to the lack of accuracy in the speed sensor.

Additionally, it is clear that not only has the simulated model manages to outperform the experimental rig controller as seen by the lower deviation from the steady state line, and the shorter recovery times in Figure 7. This could be due to friction in the system again, or even inaccuracies with the resistor system. The very non-uniform effects of the resistors can be observed in Figure 4.