Lab A: Modeling Robot Batteries

Introduction

Single Sentence Overview

We will model how battery voltage changes due to instantaneous loading, as well as loading history.

Overview

Anyone who has used a cell phone is acutely aware that batteries are finite resources. How we use the phone affects how long we can use it for. Likewise, roboticists are concerned with how the use of electrical power affects the performance outcomes of robots. Mobile robots are even more dependant on theses characteristics than cell phones are, largely due to the energy drawn from the battery and into the motors.

Here, you will simulate how to combine a high-voltage (~30 volts) and high-current (10+ amperes) battery pack with a large DC motor (30 volts / 90 watts) suitable for mobile robots.

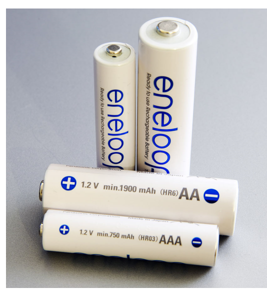

Figure 1 Typical rechargeable batteries (source: https://en.wikipedia.org/wiki/Nickel–metal_hydride_battery)

Learning Outcomes

The student will understand

1. How to obtain battery characteristics suitable for modelling
2. How to implement the internal resistance of battery model in Simulink
3. How to feed the discharge history of a battery in the load back into the battery to modulate its internal voltage.

Success Criteria

Review the grading rubric and evaluate how it relates to achieving these criteria:

1. Model a resistive battery on an inductive-resistive load
2. Model a resistive battery with varying voltage on an inductive-resistive load
3. Relate the voltage variance to the discharge history of the battery

Grading Rubric

During class make sure to conduct all the required demonstrations to the lab instructor.

- *Part 1 demo:*
  - *0 pts: no difference shown between internal battery voltage and terminal voltage*
  - *5 pts: difference b/w two voltage shown but it's not correct*
  - *10 pts: correct battery voltages shown in simulation*
- *Part 2 demo:*
  - *0 pts: no curve shown of voltage changing during discharge*
  - *5 pts: curve shown, but is not correct*
  - *10 pts: curve shown and is correct*

Prerequisites

You are expected to have done the following before attending the class:

- Review this document
- Identify a suitable C-cell NiMH battery type, record its relevant characteristics.
- Create a plan for developing the model.
  a. Pay special attention to modeling the internal resistance of the battery and measuring the discharge history of the battery model.
  b. What specific Simulink components do you think may help you model the battery?

More Resources and Information

Search engine terms include:

c. *"Maxon RE35" (the 90 watt motor that will act as the load)*
   i. "DC motor model" or "brushed DC motor model" are related search terms
d. "Discharge characteristic" (this is how energy leaves the battery)
   i. Amp-hours, discharge curve, discharge time, midpoint of discharge, knee of discharge, midpoint voltage are all related search terms
e. "NiMH" or "Nickel Metal Hydride" (the specific chemistry of the battery in question)
f. "Panasonic", "Energizer" and "Sanyo" (all major vendors of NiMH batteries)
g. "C-Cell" or "C cell" is a good sized battery for medium-sized mobile robots. These where the types of batteries used in the battery packs of the RHex mobile robot.

The exercise

The goal of this exercise is to model a NiMH battery pack that will be used to power your simulated mobile robot. You will need to simulate two main characteristics of this battery pack:

1. That the terminal voltage is a function of current drawn from the battery.
2. That the battery's voltage decreases with usage.

Regarding the first point, the battery has an internal resistance. Any external load (like a motor) that is connected to the battery's terminals will experience a lower voltage than that which is produced internally within the battery.

Regarding the second point, the battery, once fully charged, has a voltage above the nominal value. As we draw current from the battery, its voltage will drop and remain at its nominal level for some time. Then, near the end of its useful life, the voltage will quickly drop below the nominal value. The battery discharge curve is specified for all batteries. Assume that the discharge characteristic is for 10 ampere constant current draw.

Assume that you will be using motors rated at 30 volts and that you will have to draw 10 amperes of current continuously to these motors. Create a "battery pack" from multiple NiMH C-cells using specifications from a manufacturer like Sanyo, Panasonic or Energizer. The nominal voltage of this battery pack should be just over 30 volts.

Implement the following model and update it to include the two main characteristics described above.

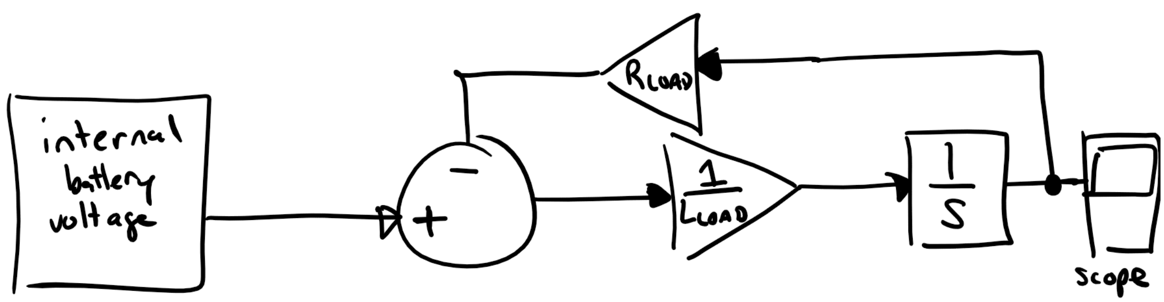

Figure 2 The battery is connected to a resistive-inductive load similar to a DC motor. Complete the model with two additional characteristics discussed in this document.

For the sake of implementation, you will need to create an amp-hour-drawn versus voltage discharge curve. This will be a modified version of typical time versus voltage discharge curve. Convert the x-axis, in units of time, to be in units of amp-seconds discharged. The conversion factor is the amperes that the original curve was determined at; some datasheets provide the curve for 1 ampere continuous discharge, others for 2, 5 or 10 amperes. 10 amperes is considered high discharge and typical of high performance mobile robots. The curve is likely to be best described by a 3^{rd}, 4^{th} or 5^{th} order polynomial, but you may be able to find a different function to approximate it.

To drive a robot's motors we modulate the battery voltage via a motor amplifier. While the motor amplifier typically uses pulse-width modulation to accomplish this, for the sake of your model, simply pretend that the battery can provide a proportional fraction of the maximum battery voltage. For instance, if you want to drive the motors at 20% of the peak battery voltage (36 volts), then assume that you are running the battery at 7.2 volts.

Demonstrate how this combined model behaves for

1. Desired 20% of internal **peak** voltage (20% of 36 v), driving for **1,000** seconds (about 16 minutes).
2. Desired 50% of internal **peak** voltage (50% of 36 v), driving for **1,000** seconds (about 16 minutes).
3. Desired 80% of internal **peak** voltage (80% of 36 v), driving for **1,000** seconds (about 16 minutes).
4. Desired 100% of internal **peak** voltage (100% if 36 v), driving for **1,000** seconds (about 16 minutes).

Show both the initial voltage as well as the curve that shows the decreasing value of the battery voltage over time. There should be **one graph per scenario**. Label the voltages at beginning and end. Label the axes of the graphs.

Create and submit a report with four graphs, one per scenario.