Variable Input Constant Output Voltage Regulator

Final Project Proposal

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Date:

December 16, 2013

I. Project Summary

The need to create a more efficient form of transportation while also considering the ecosystem has led to the development and use of electric vehicles. The primary goal of the "Variable Input Constant Output Voltage Regulator" (VICOVR) project is to redesign the power electronics developed by a 2012-13 capstone project group to significantly increase output current capacity.

A secondary goal will be to design a simple closed loop control system capable of maintaining a constant output voltage over a wide range of input voltages. Although not included in the goals for this senior capstone project, the VICOVR is ultimately intended to provide a controlled DC voltage to charge the battery bank in an electric vehicle during regenerative braking.

II. High Level System Block Diagram

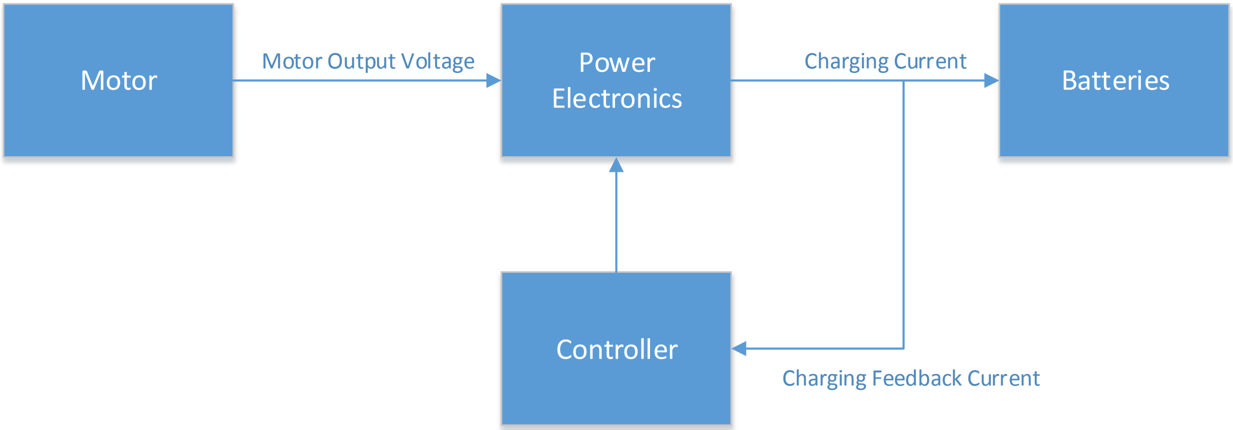

Figure 1: High Level Block Diagram

Figure 1 represents a high-level block diagram of the Variable Input Constant Output Voltage Regulator. The power electronics will convert the widely varying generator (or source) output voltage to a narrow voltage range capable of recharging the battery as the available power decreases with input voltage. The controller will change the duty cycle of a switch in the power electronics (depending on the measured output current) to maintain a charging current during the braking cycle of up to about 50 ampere.

III. Design

Calculations to estimate the energy available for recovery during regenerative braking while completing a stop in a 10 second interval are shown below.

- $P_{motor}= (V_c)(I_{Rth})$, where:
    - Pmotor is the power of the motor
    - V_c is the Capacitor voltage
    - I_{Rth} is the current into the battery banks.

Calculations for a four battery bank configuration yields the following motor power and maximum available energy recovery for V_c =36Volts and I=50 Ampere.

- Pmotor= (50 [A] * 36 [V]) = 1800 [W]
- Energy= (P_{motor})(10seconds), Energy=18,000[J].

Calculations for Go Kart Energy at 30 miles per hour:

- $E=\frac{1}{2}MV^2$, where:
    - M is the mass of the vehicle in [Kg]
    - V is the velocity of the vehicle [M/Sec]
    - E is the kinetic energy of the vehicle in motion in [J]

[The following section should be inserted before the above calculations since the reason for for 4 battery banks of 3 batteries per bank is explained below and should occur before the first mention of four battery banks above.]

The speed of 30mph will be used for the kinetic energy calculations since that is the maximum speed maintainable at the rated power and speed of the motor with a maximum vehicle load of 600 [lbs]. The total available kinetic energy at 30 [mph] with a load of 600[lbs] is therefore approximately 25,000[J].

To capture an adequate amount of the available energy, the design will be for 4 battery banks of 3 batteries per bank. The batteries have a maximum continuous charge current rating of 12 ampere. With 4 battery banks, that allows for 48 ampere (or about 50 ampere intermittently) and a voltage of 36 volts as stated previously.

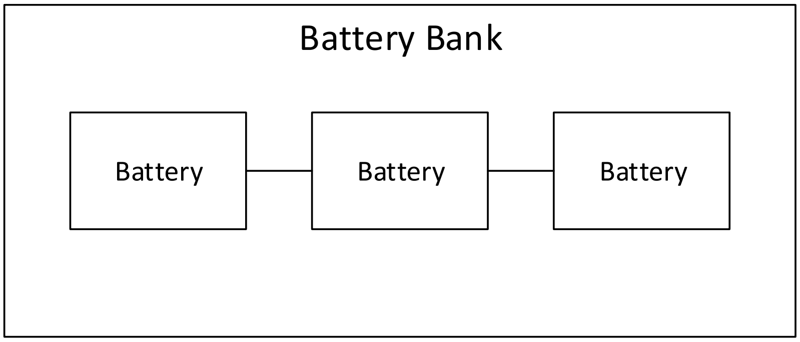

Figure 2: One Battery Bank

Figure 2 shows one battery bank, with each battery bank containing three batteries in series. Figure 3 represents the basic power electronics circuitry.

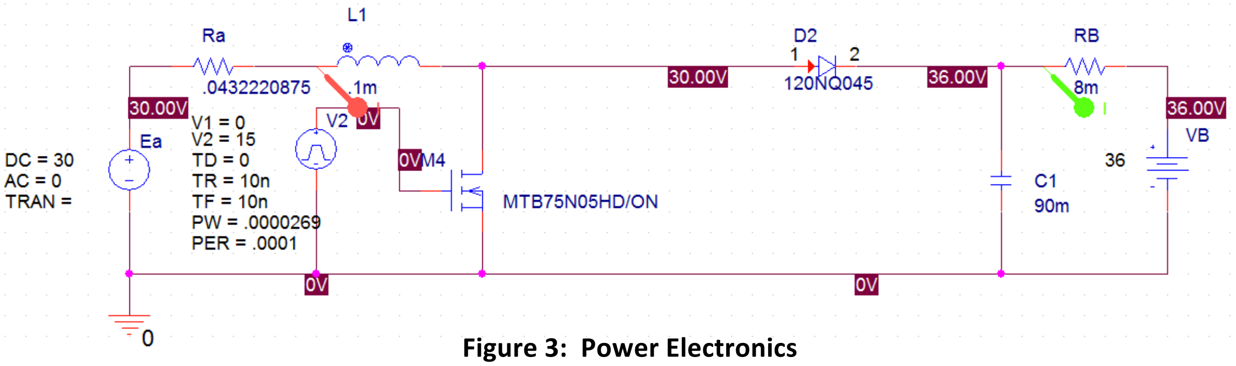

Figure 3: Power Electronics

The circuit shown in figure 3 uses the median value of armature resistance (Ra) found to be approximately 0.04 [Ohms] by a previous senior project group, a calculated inductor value of 100 [uH], and a capacitor value of 90 [mF]. The time constant of the battery resistance, RB, and the filter capacitor needed to be much greater than that of the switching frequency.

Using the following Equations, the values shown in Figure 3 were computed. The results of the Simulation of the circuit shown in figure 3 are shown in figure 4. It can be seen from figure 4 that the steady state current through RB (the Thevenin equivalent battery resistance) is about 50 ampere, which corresponds to the output current goal mentioned earlier.

- L= inductor component
- Ea= back Emf
- Δi_L= Change in inductor current
- D= Duty cycle
- Ts= Switching time
- C= capacitor component
- Vc= output voltage in the capacitor
- Rth= thevenin Resistor value in the battery

Equations are as follows:

- $L = \frac{E_a}{\Delta i_L} D T_s$
- $C = 10 \frac{T_s}{R_{Th}}$
- $\frac{Vc}{Ea} = \frac{1}{1-D} \quad , (Vc > Ea)$

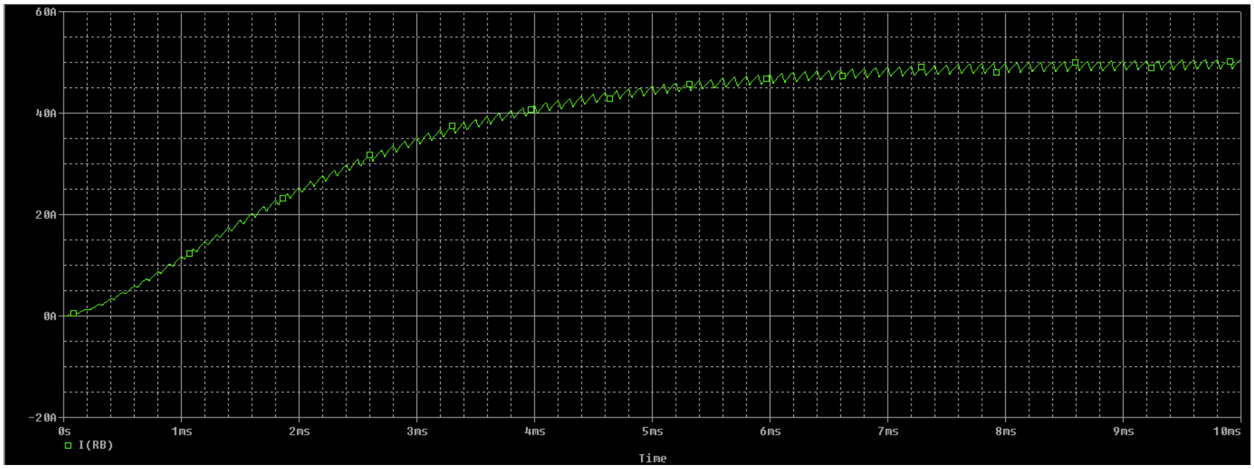

Figure 4: Simulation output for Figure 3

The controller will function as indicated in the flow chart shown in figure 5 below. The controller will only be active, while the braking system is activated. During braking, it will read the current sensor and determine the level of the battery current compared to the desired current level specified for this project. It will adjust the duty cycle as necessary to maintain the maximum possible charging current, and then repeat the process as the charging current level decreases as the braking process reduces the motor speed.

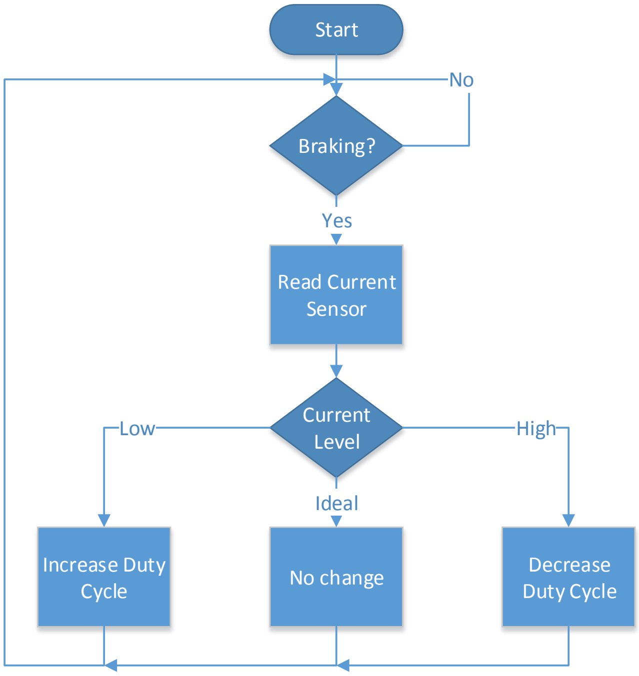

Figure 5: Controller Flowchart

IV. Equipment List

MOSFET – FF900R12IP4D
Control Board – ATMega128
Motor – D&D ES-10E-33
Batteries – SLA1161
Current Sensor – L08P050D15
Diode – 120NQ045
Inductor – 100 microHenry
Capacitor – 90 milliFarads

V. Schedule

January 22 - 28:	Build a Physical Power Electronics Circuit Based on the Simulation Model
January 28 - February 10:	Work on the controller code
February 11 - 24:	Test the Controller Code
February 24 - March 3:	Merge the controller with the Power Electronics
March 4 - 24:	Run Test to ensure they work well together
March 25 – April 7:	Apply both the controller and the power electronics to the Electric Vehicle
April 7 - 22:	Test the Electric Vehicle with the Controller and the Power Electronics
April 23 - May 2:	Prepare final report and presentation documents

VI. References

[1] Jaris, Kevin, and Nathan Golick. "Micro Electric Urban Vehicle - PHASE III." Electrical and Computer Engineering Department Bradley University, n.d. Web. 2013.

[2] Kuhn, Brian, Steven Komperda, and Matthew Leuschke. "Micro Electric Urban Vehicle - PHASE II." Electrical and Computer Engineering Department Bradley University, n.d. Web.

[3] Mrsolar.com. Interstatebatteries.com, n.d. Web. 2013. <http://www.mrsolar.com/pdf/Interstate/Interstate SLA1161.pdf>.

[4] "D&D ES-10E-33 Motor." *Www.evdrives.com*. N.p., n.d. Web. 2013. <http://www.evdrives.com/product_p/mot-es-10e-33.htm>.